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Methodologies for Integration of Energy Performance and Life-Cycle Costing Indicators into Property Valuation Practice

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II. Glossary

AAP	Average Adjustment Parameter
ABGR	Australian Building Greenhouse Rating
AI	Appraisal Institute
AMM	Additive Mixed Regression Model
ANEVAR	Asociatia Nationala A Evaluatorilor Din Romania
API	Australian Property Institute
ASB	Appraisal Standards Board
ARE	Austrian Real Estate Experts
Betr.KV	Betriebskostenverordnung
BIIS	"Bundesverband der Immobilien-Investment-Sachverständigen e.V."
BIM	Building Information System
BLUE	Best linear unibiased estimator
BREEAM	Building Research Establishment Environmental Assessment Method
CAPM	Capital Asset Pricing Model
CASBEE	Comprehensive Assessment System of Building Environmental Efficiency
CBRE	CB Richard Ellis
CCRS	Center for Corporate Responsibility and Sustainability
CPD	Continued Professional Development
CREIS	Neumann & Partner CREIS Real Estate Solutions
CSR	Corporate Social Responsibility
DCF	Discounted-Cash-Flow
DGNB	"Deutsche Gesellschaft für Nachhaltiges Bauen"
DIN	Deutsches Institute für Normung e.V.
EEA	European Environment Agency
ECSD	Energy Cost Saving Potential
EPBD	European Energy Performance of Building Directive
EPC	Energy Performance Certificate
ERV	Estimated Rental Value
ESD	Ecological Sustainable Development

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ESI	Economic Sustainability Indicator
EVS	European Valuation Standards
FCA	Full-Cost Accounting
GBCA	Green Building Council of Australia
GCV	Gross Calorific Value
GDV	Gross Development Value
Gif	Gesellschaft für immobilienwirtschaftliche Forschung e.V.
GWR	Geographically Weighted Regression
HWB	“Heizwärmeenergiebedarf”
IMT	Institute for Market Transformation
ImmoWertV	“Immobilienwertermittlungsverordnung”
IPCC	International Panel on Climate Changes
IRR	Internal Rate of Return
IVS	International Valuation Standards
IVSC	International Valuation Standards Committee
KVP	Key Valuation Parameter
LBG	“Liegenschaftsbewertungsgesetz”
LCC	Life-Cycle Costing
LCCA	Life-Cycle Cost Analysis
LEED	Leadership in Energy and Environmental Design
MLF	Mortgage Lending Value
NABERS	National Australian Built Environment Rating System
NIY	Net Initial Yield
NOI	Net Operating Income
NTF	Norges Takseringsforbund
NYSERDA	New York State Energy Research and Development Authority
MAR	Market Adjustment Rate
OIB	Österreichisches Institut für Bautechnik
OLS	Ordinary least squares
ÖII	Österreichisches Institute für Immobilienbewertung und Bewertungsstandards
PINZ	Property Insitute of New ZealandRAF
RAF	Rent Adjustment Factor

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RICS	Royal Institution of Chartered Surveyors
ROI	Return on Investment
RPI	Responsible Property Investment
SAP	SAP Aktiengesellschaft
TBL	Triple-Bottom-Line
TEGoVA	The European Group of Valuers' Associations
TIAVSC	The International Assets Valuation Standards Committee
UK	United Kingdom
US/USA	United States of Amerika
USGBC	U.S. Green Building Council
USP	Unique Selling Proposition
USPAP	Uniform Standard of Professional Appraisal Practice
V	"Vervielfältiger" / Multiplier
VAT	Value Added Tax
VEA	Valuation Estimation Adjustment
VPA	Valuation Parameter Adjustment
WAF	Weighted Adjustment Factor
WAPEC	Weighted Adjustment for valuation Parameter Effecting Characteristics
WBCSD	World Business Council on Sustainability Development
Y	Yield
YP	Year's Purchase / Multiplier

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1 Introduction

In 2002 the member state of the European Union started an integration of the European Energy Performance of Buildings Directive (EPBD) into national legislation. According to the directive, "Energy Performance Certificates" (EPC) shall be available for new and existing buildings all over Europe.

Building sector accounts for 30 % of energy use

One of the main reasons why the European Union established the EPBD is the fact that buildings account for 30-40 %[1] of the world's energy consumption and for a significant amount of the overall carbon emission. If the real estate industry were to reduce the use of energy there would be a significant contribution to the stabilisation of the global energy demand and greenhouse gas pollution. This effort will be a significant contribution to the international targets according to the Intergovernmental Panel on Climate Change (IPCC) or the Kyoto-Protocol could be achieved.[2]

Awareness is growing

Investors, developers and tenants are key actors in assessing the energy efficiency of a building and the reduction of energy costs. They have also started paying attention to various issues like corporate social responsibility (CSR)[3], responsible property investment (RPI)[4], or ecological sustainable development (ESD). In addition, during the last few years several specialised sustainable asset funds have been initiated, such as iii-investment, IVG AG, Cordea Savills or the Bowfonds Asset Management Fund. All of them take sustainability and energy-efficient building performance into account as factors in their investment or rental decision processes as well as the fund set up process. The awareness and understanding has become more and more evident. This change in practise has also been driven by the growing

[1] WBCSD (2009), p.6

[2] Cf. WBCSD (2009)

[3] „Corporate social responsibility" (Waddock and Graves, 1997) describes companies voluntary choice to integrate social and environmental issues into corporations daily business to behave ethical and improve social conditions by considerations about input (e.g. raw material sources), internal process (e.g. environmentally friendly production), and publicity (e.g. community relations) aspects.

[4] „Responsible property investment" (RPI) defines investors choice to "maximize the positive effects and minimizing the negative effect of property ownership, management and development on society and natural environment" (Pivo and McNamara, 2005).

awareness for Climate Changes, high oil prices and rising energy costs, documented in various studies.

Property valuation is behind

As a consequence, real estate valuation experts already agree that these changes will have an impact on the real estate industry and market structures as well as the methods and tools used to analyse real estate. Nevertheless one cannot give a quick and easy answer to these challenges due to lack of practical experience and valid data.

Yet, real estate professionals are aware of challenges confirmed in discussions between professionals and some research projects are already trying to identify, quantify and measure the market impact of green and energy-efficient building features (see also Chapter 5.1).

Development of guidance for property valuation

Due to the lack of relevant studies and information regarding the link between green buildings' energy performance and property valuation, the independent-trans-European project "IMMOVALUE" has been initiated in 2008. The project aims to determine and define common and accepted approaches and methodologies on how new developments such as EPC/EPBD as well as life-cycle costing (LCC) and analysis (LCCA) could be integrated in today's and future practice of property valuation.

2 Background

To ensure the aims and objectives of the IMMOVALUE project remain independent, investigations on existing valuation methodologies, energy performance and certificates and life-cycle cost analysis were carried out before starting to derive methodologies which integrate green building features to property valuation.

Existing studies for Anglo-American markets

To begin, the report summarizes the main results of existing studies. They serve as a starting point for the results presented in this report. Existing studies on linkages between international, European and national valuation practice and EPC and LCC assessment refer mostly to countries such as Australia[5], the US[6] and the UK[7].Yet so far no specific methodology for an integration of green building features into property valuation practice is available. There is, however, a common understanding of which factors (e.g. rents, yields, etc.) that green attributes might influence and therefore have to be adjusted if building performance features related to sustainability will be considered explicitly in property valuation practice. Furthermore, a few valuation institutions such as e.g. the Royal Institution of Chartered Surveyors (RICS) in the UK have already started to hand out general valuation guidance with reference to green building aspects in general, in order to stimulate and boost the recognition and awareness of the importance of the integration of building performance aspects into the property valuation practice.

Energy certificates as an ambiguous source of information

A second field of preparatory analysis on energy performance certificates shows that, due to various existing and differing national EPCs and the assessment used for generating illustrated indicators, there is no or just limited directly comparable EPC-data available. The information and data received from the EPC therefore needs to be transferred and adjusted in order to assure useful, valid and reliable information that can be integrated into property

[5] Cf. Bowman, R., Wills, J. (2008); Boyd, T. (2005)

[6] Cf. Kats, G. et al. (2003); Miller, N., Spivey, J. and A. Florance (2008); Eichholtz, P., Kok, N. and J.M. Quigley (2008); Miller, N. (2010); Pivo, G. and Fisher, J.D. (2010)

[7] Cf. Sayce, S., Ellison, L. (2003); RICS (2005); Fuerst, F., McAllister, P. (2008); Fuerst, F. and McAllister, P. (2010); Fuerst, F., et al (2010); Chegut, A., et al. (2010)

valuation. Therefore the proper integration of energy data into property valuation practice may rely on two challenges:

(1) experts for energy performance certificates have to participate, and

(2) a certain standardized process or format has to be established to implement information out of the EPC or other energy performance results to fit for property valuation calculation schemes.

Integration of energy efficiency and LCC is no easy task

Results of the third preparatory analysis provided an overview of different LCC methodologies for buildings and how LCC essentially can be used within property valuation. As part of the survey, different LCC-tools were reviewed and examined to address the general applicability and linkages between LCC and property valuation practices. Furthermore, suggestions have been made to quantify in which way LCC can be used to affect the different valuation approaches.

Comprehensive feed-process

The modified methodology for property valuation set out in this report has been tested on a group of pilot projects to ensure the applicability and practicality of the developed modifications[8]. Additionally, the outcome of this report is the resulted from an extensive review process involving well-known international and national property valuation associations and experts such as RICS, US Appraisal Institute (AI), TEGoVA (The European Group of Valuers' Associaton), German BIIS (Bundesverband der Immobilien-Investment-Sachverständigen e.V.), Norwegian NTF (Norges Takseringsforbund), the Romanian ANEVAR (Asociatia Nationala A Evaluatorilor Din Romania), or the Austrian ÖII (Österreichisches Institute für Immobilienbewertung und Bewertungsstandards), ARE (Austrian Real Estate Experts) etc. to ensure a widespread acknowledgement and acceptance of the property valuation society. The comments of these experts have been integrated in this present report at hand.

Legal framework supports awareness

[8] Bienert, Sven et. al.: IMMOVALUE Report on the Pilot-Project and Survey Results, Vienna, July 2010, www.immovalue.org

From another perspective, since EPCs are mandatory in the European Union and therefore must be available for new as well as already existing buildings, the accessibility of energy-efficient building performance indicators will increase and lead to a higher transparency as well as provoke property investors and occupiers to start to compare these measures of building performances. This will consequently lead investors, developers and tenants to further consider buildings' energy performance and other related aspects in their decision making process. Thus, the property markets' behaviour will change in the mid and long run and will most likely justify a premium for the market values of green buildings, or possibly a discount for conventional buildings. Especially in an economic downturn, it might be useful to increase energy efficiency in order to reposition the property and increase values.

Different publications in different countries stress the current absence of valid and reliable evidence regarding value and sustainability issues.[9] Investors and users will not respond to sustainability features and issues effectively without reliable benchmarks and hard facts.[10]

[9] Cf. Warren-Meyers, G., Reed, R. (2009); Madew, R. (2006); Lorenz, D., Lützkendorf, T. (2008a)

[10] Cf. Sayce, S., Ellison, L. (2003) ; Sayce, S. (2010)

3 Aims and Targets of the Report

Based on the results and findings of the preceding investigations, the authors of this report will find ways to modify approaches and give guidance to ensure the appropriate integration of a buildings' energy performance and energy-efficiency indicators derived from EPC, LCC or LCCA within property valuation. The project partners of IMMOVALUE will focus mainly on direct rather than indirect impacts and differences within the three basic and internationally used property valuation methodologies – the cost approach, the sales comparison approach, and the income related approach.

To assure the quality of these overall target intensive investigations concerning the potential gaps and pitfalls between property valuation, EPC and LCCA have been carried out.

The report also suggests ways in which property valuers can handle energy efficiency and performance issues in general and derive the key indicators required from EPC and LCC/LCCA and estimate their value impact even if non-transparent market circumstances with only limited market information and evidence, etc. exist. Furthermore this report reveals not only ways to calculate the quantitative impact of sustainable features but also points out qualitative aspects which one must describe within the valuation report to assure a transparent and comprehensible examination, integration and estimation of the properties' market value.

To sum up the outlined main objectives, this report answers the following questions:

(1) What is a „Green Value"? How can sustainable buildings be differentiated from their non-Green-Peers? (see Chapter 4)

(2) What are the must-knows of a value dealing with energy efficiency and LCC? (see Chapter 5)

(3) Is it possible to get feasible and meaningful figures out of EPCs and LCCA and if so, will the market demonstrate representative and significant evidence?

(4) What are the gaps and pitfalls between EPC or LCCA and property valuation, and how valuers can overcome these obstacles? (see Chapter 5.4.2)

(5) What is the general background a valuer must have in mind to avoid wrong calculations/interpretations when dealing with the topic? (see Chapter 6)

(6) What are in general the main key information derived from EPC or LCCA and which are in general suitable for the integration into property valuation practice? (see Chapter 5.2)

(7) Ways in which valuers can integrate and link information related to buildings energy performance and efficiency within the main property valuation approaches (sales

comparison, cost related and income related approach) in manner? (see Chapter 6.4.4 and 6.4.3)

(8) How can one implement the findings within the legislative framework? (see Chapter 7)

(9) What can be done to consider buildings' energy performance within property valuation practice even if implementation-inhibitive circumstances (e.g. lack of market evidence, etc.) exist? (see Chapter 6.3 and 6.4.3.2.2).

(10) What are the future challenges and task to stimulate and strengthen the importance of buildings' energy performance within property valuation? (see Chapter 6.1 and 6.2).

4 Definition and Explanation of the "Green Value" Terminology

Key Facts and Findings

- The sustainability agenda is a wide-spread approach which one must examine using sophisticated methods. Whereas ***"energy-efficient"*** just refers to using less energy resources to provide the same level of service, ***"green"*** or ***"sustainability"*** encompasses further aspects such as building quality, thermal quality (e.g. indoor air quality, etc.), energy performance (e.g. energy consumption), carbon dioxide (CO2) emission, reusability of building materials, connection to local public transportation, social impacts (e.g. extended productivity), etc.
- Green buildings always include a life-cycle perspective.
- Sustainability in a broader sense focus on social, economic and environmental aspects, including intergenerational justice and internalization of negative external effects.
- Regarding the "Green Value", which one can defined as: "the net additional value obtainable by a green building in the market compared to conventional or non-green properties", the formerly debated "**Null-Hypothesis**" (no impact of green building features on property values) can be already proven as being wrong due to various accepted scientific studies.
- The core of the following report mainly refers to possibilities of integrating energy performance and efficiency aspects derived from EPC and LCCA and therefore the report only represents a part of the total green value of a green building.
- Two aspects need to be highlighted to avoid misunderstanding: First values do not make the market, the rather use market evidence. And second cost is not necessarily value.

To file IMMOVALUE and especially this report into the overall context of recent international discussion and publication regarding sustainability issues in the real estate industry, an introductory analysis by factoring the buildings' energy performance aspects into

the broader “framework” of sustainability and green building aspects is given under this chapter.

4.1 “Sustainability” in a broader sense

Climate change, the increasing numbers of environmental hazards and ecological disasters as well as rising oil prices have driven the sustainability movement forward. Consequently, a paradigm change on a broad scale throughout all industries has evolved and public attention is continuously rising.

Due to these developments the sustainability topic (also called green issues) has also found its way into the real estate industry and has inspired real estate academics and professionals to intensively carry out scientific studies and surveys. As a result, one can see the rising momentum and importance of “green building” or “sustainable building.”

To understand the consequences and impacts that the rising importance of sustainability might provoke within the real estate industry, the report provides a short explanation the general concept of sustainability.

Triple Bottom Line (TBL) to describe sustainability

While the terminology of sustainability has existed for decades, the debates concerning the wide-ranging term of sustainability remain open. Most of the interpretation of sustainability encompasses and refers to the widely recognised and consensual accepted three main dimension of sustainability[11]: namely ecological, social and economical characteristics and aspects (also known as the “Triple Bottom Line”), which has to be seen as a permanently evolving approach. This Triple Bottom Line approach is based on the origin and widely accepted Brundtland’s definition of sustainability developments, which will be described later. The following timeline illustrates the major steps within the TBL framework:

[11] Eklington, J. (1994), pp.90-100

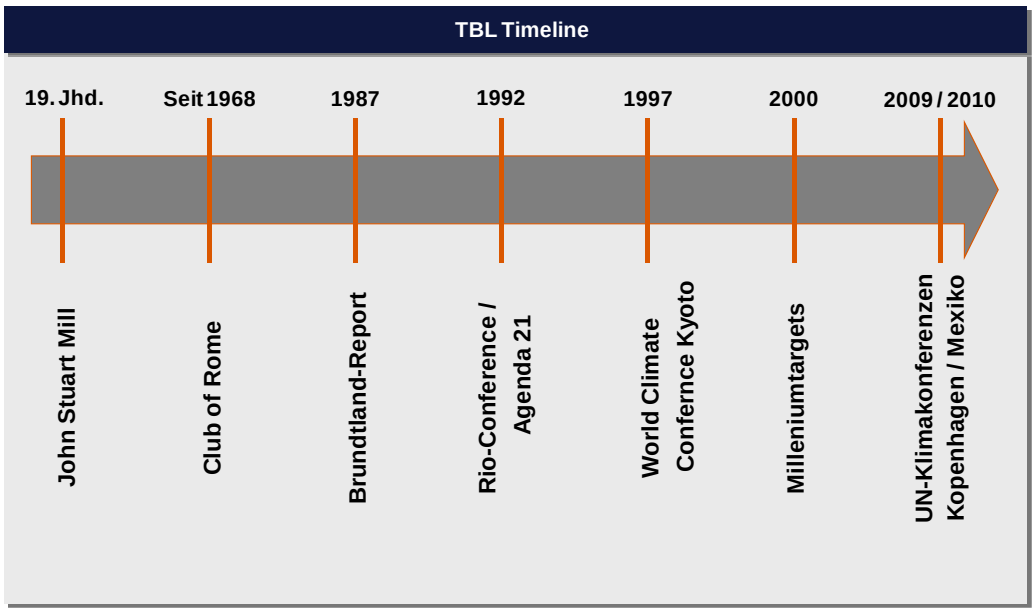

Figure 1: TBL Timeline – major steps forward

4.2 Definition of "Green Building"

To understand the widespread facets which define green buildings, one must establish a sense and sensitization for the meaning of what describes a green building. The recent number of existing definitions for green buildings shows the current uncertainty about the characteristics of a green or sustainable building.

Efficient use of resources

For example according to Kats (2003) a "green" or "sustainable building" "uses key resources like energy, water, materials and land much more efficiently than buildings that are simply built to code, …are cost effective and reduces operations as well as maintenance cost, …creates healthier work, learning and living environments, …contribute comfort and productivity".[12]

In contrast, the report also discusses the significance of green or sustainable buildings in the light of broader aspects such as RPI or ESD, which go back to the widely accepted general definition of sustainability by Brundtland. In the late 80s, Brundtland[13] defined sustainability

[12] Kats, E., et al. (2003), p. V

[13] Brundtland Commision (1978)

as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[14,15]

Broader definition includes external effects

This means that the concept of green buildings also takes into account social, ecological and environmental issues and effects caused either by the property itself or the surrounding environment. Therefore a broader definition relates more to potentially negative external effects and aspects of intergenerational justice that might arise.

For the purpose of this report the definition of the Royal Institution of Chartered Surveyors (RICS) fits best. RICS defines a green building as a property that “displays characteristics that minimise environmental impact through all parts of the buildings life-cycle and focuses on improved health for its occupiers, optimise utility for their owners and occupiers and the wider public, whilst minimising the use of natural resources and environmental impact”.[16] A good illustration of sustainability within the property industry might be the following graph:

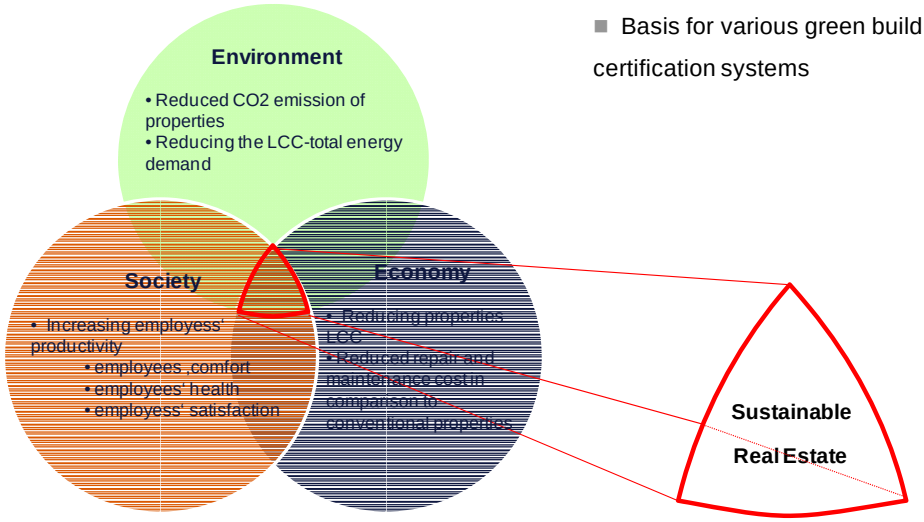

Figure 2: Illustration of “Sustainable Real Estate”

[14] Digital report of Brundtland, G.H. (1987) available on http://www.un-documents.net/wced-ocf.htm

[15] Brundtland’s definition contains two concepts – “the concept of ‚needs‘, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs”

[16] RICS Valuation Standards Board (2008), p.5

4.3 Terminology of "Energy-Efficient Buildings"

Beside these green buildings definitions, the term "energy-efficient building" is often used misleadingly as a synonym for green or sustainable buildings. While energy-efficiency only refers to using less energy resources to provide the same level of service, green or sustainability encompasses further aspects such as building quality, thermal quality (e.g. indoor air quality, etc.), energy performance (e.g. energy consumption), carbon dioxide (CO_2) emission, reusability of building materials, connection to local public transportation, social impacts (e.g. extended productivity), etc.

Energy-Efficiency as part of a Green Building

Therefore it is necessary to clearly differentiate between a building which is "just" energy-efficient and a green building. Even if there is no common definition for "green" or "sustainable" buildings, there is a consensus in the building and real estate industry that green buildings minimise primary energy demand and consumption (conservation of energy) and therefore use resources such as energy more efficiently, which also leads to lower CO_2 emission. Consequently, energy-efficiency is an essential feature of a green building.

4.4 "Green Value" terminology

In line with the ongoing debate related to the sustainability movement within the real estate industry, market participants questioned whether all aspects surrounding "sustainable" buildings could be properly reflected in the properties market value.

Therefore the impact of green property features on property value is now the center of attention. Even though research on this topic is just emerging, one can already rule out the statement that there is no correlation between properties' market value and its green building features also called the so called "Null-Hypothesis.". The awareness for a market-proven added value of green buildings is growing due to a number of recent scientific papers and survey. In this context the fundamental results e.g. by U.S.-American University of San Diego in cooperation with the CoStar Group[17], or the University of California[18], as well as by the Australian Green Building Council[19] (GBCA) or the University of Melbourne[20] and few

[17] Cf. Miller, N., Spivey, J. and Florance, A. (2008)

[18] Cf. Eichholtz, P., Kok, N. and Quigley, J.M. (2008)

[19] Cf. Bowman, R., Wills, J. (2008)

European institutions such as the RICS in the UK, the Center for Corporate Responsibility and Sustainability[21] (CCRS) in Switzerland or the German Institute for housing and environment (IWU) in cooperation with the department of housing in Darmstadt[22] (Germany) – which constitute some market evidence for the impact of energy efficiency and green building features on property rents and values are of particular interest.

Studies reveal added value for green buildings

Some results e.g. by Jones Lang LaSalle[23], Parker[24], or Fuerst and McAllister[25] already conclude that there is a growing consensus of the need for a discount on conventional buildings' value rather than a value-premium for green properties, since green buildings will become the market standard requirement and therefore a "must have" in the mid to long run.

Discount or premium - a question of time?

Similar to the idea that there are various green building definitions, there is no commonly accepted *"Green Value"* terminology. After taking into account the findings from preceding explanations, the definition of RICS which describes the Green Value as the *"net additional value obtainable by a green building in the market"*[26] compared to conventional or non-green properties, seems to be the most accurate one. This definition of green value is also in line with the terminology of the market value according to the IVSC (International Valuation Standards Committee), which is the "estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm's length transaction after a proper marketing wherein parties had each acted knowledgeably, prudently, and without compulsion."[27]

Green Value as part of the Market Value

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[20] Cf. Robinson, J. (2005), p.6

[21] Cf. Meins, E., et al. (2008); and Meins, E., et al. (2007)

[22] Cf. Amt für Wohnungswesen Darmstadt (2008)

[23] Cf. Jones Lang LaSalle (2006), p.6

[24] Cf. Parker, D. (2008)

[25] Cf. Fuerst, F., McAllister, P. (2008), p.10,

[26] RICS (2005), p. 2

[27] IVSC (2007), p.27

Thus, the Green Value represents an integral part of the overall market value. However, one can only both aspects theoretically – as in the case of building and land values which both make up the overall market value and can also not be separated. Furthermore, it is essential to understand two fundamental principles before discussing Green Values:

(1) ***"Valuers do not make the market"*** – Valuers do not "make" the market; they are look for market evidence to use for a specific valuation. Therefore speculating what might happen in the future and attempting to price in something that has yet to occur is not useful. Some professionals think it might be appropriate to add a premium to a properties market value just because the EPC, or other green building assessment tools and labels such as LEED[28], BREEAM[29] or Energy Star are in place. This of course has nothing to do with proper property valuation. Valuers cannot add premiums if the market does not support this premium with significant evidence.

(2) ***"Cost is not Value"*** – The costs for constructing a green building or upgrading existing conventional properties to e.g. energy-efficient buildings do not necessarily lead to a Green Value and vice versa. This means that a green or sustainable property with identical costs of construction (and land) and identical certification (e.g. LEED, BREEAM, EPC), etc. can still have a totally different added value in different locations, just because the willingness to pay revealed by consumers in different markets might vary substantially. Therefore one need to keep in mind that evidence from other markets concerning price variations for green features might not be relevant.

On order to remain consistent with the previously stated definition of green buildings and the green value terminology, one must explicitly state that the core of this report mainly refers to the possibilities for integration of energy performance especially the energy-efficiency aspects of a property and therefore only represents a part of the total green value. This is achieved through the use of EPC- and LCCA-data as well as other elements (e.g. investments for energy performance improvements, etc.) to acquire suitable indicators and input variables for property valuation while remaining flexible enough to leave room for the implementation of further green building features.

In this context, one must mention that the rising concept of *"Green Lease"* arrangements is not studied within this report, even if such issues might have an impact on property valuation.

[28] *"Leadership in Energy and Environmental Design"* established by the U.S. Green Building Council.

[29] *„Building Research Establishment Environmental Assessment Method"* established by the UK-based Building Research Establishment Ltd.

In general, a green lease refers to an emerging concept that integrates ESD, CSR issues, etc. in the lease contract between owner and tenant of a sustainable/energy-efficient property. Green lease arrangements regulate various aspects mainly related to green or energy-efficient building standards, operational controlling and audit procedures related to energy performance measurements. It also relates to incentive and penalty clauses etc. due to agreed upon service and energy performance levels.

5 Overview on valuation approaches, energy performance certificates and LCCA approaches (Deliverable D5.1)

5.1 Analysis of Valuation Approaches

Key Facts and Findings

Valuation Process

- Even thought different valuation methods exit in each country, European Valuation Standards (EVS) form the basis for a generally accepted and harmonized European procedure.
- Three main internationally accepted valuation approaches are always part of the entire process: sales comparison approach, cost approach, income related approaches (direct capitalization or DCF).
- No matter which approach forms the basis for the calculation: market data and market evidence are always needed to calculate the value.

Empirical Studies

- Non-European studies (Australia & USA): some evidence for certified sustainable buildings (LEED, Energy Star, Green Star) isolates effects for income producing commercial properties. They focus exclusively on the income approach.
- European studies (Switzerland & Germany): Swiss Economic Sustainability Indicator (ESI) valuation considers sustainable characteristics and their future development within the exit cap rate of the DCF-approach. German ecologic rent tables for specific cities illustrate possible rental premiums or discounts for the characteristic of energy-efficiency of a building. Whereas the Swiss approach is mainly a scoring model, the German is based on empirical data.
- Comparability and Significance for other sub-markets of the research results have to be critically remarked. Most studies focus mainly on premiums (rather than discounts).

Linkages for property valuation

- Some possible linkages within the existing valuation approaches could be identified for the implementation of different aspects of energy-efficient building characteristics.

- Quantification depends on empirical market evidence, which is often the missing element.

Conclusion

- Currently sustainability features/aspects as well as EPC or LCC and investigations on such topics are not reflected, considered or even mentioned in the property valuation reports; –such aspects have to be taken into consideration in the future.
- Research is still in an early stage focusing on empirical analysis and on the integration of environmental aspects into the income approach.

5.1.1 Valuation Approaches

In general, property valuation is associated with the three main approaches: the sales comparison approach, the cost related approach and the income related approach all over the world.[30] In Europe the European Valuation Standards (EVS) as well as the methods RICS professionals (so called "Red Book") use, form the basis for a harmonized and generally accepted procedure to value a property. With the exception of some national particularities and different notations, all valuers use the same basic approaches. Further, one can differentiate the income related approach into the methods of direct capitalization and discounted cash flow (DCF).

Worldwide valuers use variations of the three basic valuation methods

The direct capitalization approach uses the estimated achievable market rents less outgoings divided by a cap rate/yield to derive the market value.[31] The DCF approach in contrast analyses the first 10 years of revenues and costs in detail on a yearly basis and assumes that the property will be sold after this holding period for a so called "Terminal Value". The cash flows are calculated in detail for every single year of the holding period. Therefore, the valuer must estimate rental growth rates, inflation rates, occupancy rates etc. on a yearly basis.[32] The essential advantage of the more complex DCF-Approach is that the assumptions are more transparent and detailed.

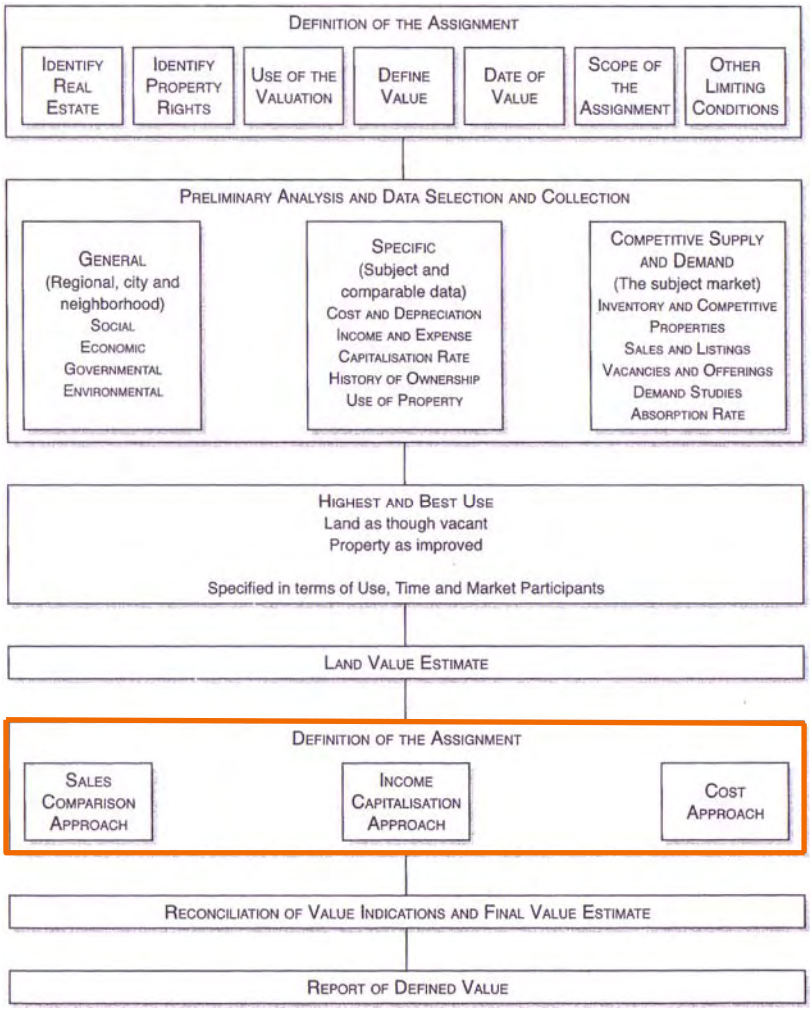
[30] Cf. Gelbtuch (1997): p. ix.

[31] Cf. Appraisal Institute (2008b), p. 377 seqq.

[32] Cf. Hungria-Garcia (2004): p. 19 et seqq.

In contrast to the above shortly explained income approaches the sales comparison approach uses sales data/transaction prices, which are comparable to the subject property being valued. In most cases the difficulty in applying this approach is the lack of existing comparable data.[33] The cost approach is deriving the (depreciated) replacement costs of the property being valued taking into account the quality of fittings, the cost level of the region, the age etc.[34]

Figure 3 illustrates the entire valuation process. One should select the appropriate valuation method after a detailed preliminary analysis, data selection and collection.[35] The calculation itself is therefore only one part of the whole process, which is documented in the valuation report. The valuation report communicates the different steps of the valuation process from the research and data collection to conclusion and final estimate of the market value.[36]



[33] Cf. Appraisal Institute (2008b), p. 300.

[34] Cf. ibid p. 377.

[35] Cf. IVSC (2007), p. 170.

[36] Cf. ibid.

Figure 3: The Valuation Process[37]

All applicable valuation approaches use data and information sources that feature market evidence to estimate the market value.[38] Market evidence is essential for all approaches.
The valuer is also dependant on market evidence to consider and quantify added values within property valuation due to enhanced energy-efficient features of a property. The following section will point out the most prominent published research results regarding the investigation of the terminology of an "added value" due to energy efficiency, respectively sustainability of real estate.

5.1.2 International Research - "Green/energy-efficient achieves an added Value"

5.1.2.1 Non-European research results

Some organizations such as the Green Building Council of Australia (GBCA)[39], the Royal Institution of Chartered Surveyors (RICS)[40], the New York State Energy Research and Development Authority (NYSERDA)[41] and economic scientists all over the world[42] have produced a wide range of case studies to verify the effect sustainable features on property values. Most studies and scientific papers deal with the different available sustainability certification systems like the American LEED, the British BREEAM or the Australian Green Star and their impact on values, which may be achieved due to a certain rating level. These international well-known sustainability labels are going beyond the aspect of energy-efficiency and therefore beyond what the IMMOVALUE project is primary looking at.
Still these international publications identify key variables as the main drivers leading to an added value, the so-called "Green Value" of a property in comparison to a non-sustainable respectively non-green peer group.
Table 1 illustrates the different published potential key variables and the quantitative results of the empirical studies.[43]

[37] Cf. IVSC (2007), p. 171.

[38] Cf. ibid p. 170.

[39] Cf. Bowman, R., Wills, J. (2008).

[40] Cf. RICS Valuation Standards Board (2008), Corps, C. (2005).

[41] Cf. Institute for Market Transformation (2003).

[42] Cf. e.g. Warren-Myers, G., Reed, R. (2009), Sayce, S., Ellison, L. (2003), Miller, N., Spivey, J., Florance, A. (2008), Lorenz, D., Lützkendorf, T. (2003 - 2008), Pitts, J., Jackson, T. (2008).

[43] Cf. Pitts, J., Jackson, T. (2008), p. 117.

Variable \ Country	USA (Mc Graw, Hill Construction 2005)	USA (Mc Graw, Hill Construction 2008)	USA (Miller et al. 2008, using CoStar Database)	USA (Fürst, McAllister. 2008, using CoStar	USA (Eichholtz et al. 2009, using CoStar Database)	Australia (Bowman, Wills 2008)
Rental Growth for non-Green	-	-	-	-	-	-1.50%
Rent Premium for Green	3.00%	6.10%	-	-	3.00%	
Energy Star	-	-	2.80%	-	-	
LEED	-	-	0.30%	-	-	
Energy Star/LEED	-	-	-	11.80%	-	
Effective Rent	-	-	-	-	6.00%	-
Decrease Operating Expenses	8.00-9.00%	13.60%	-	-	-	-
Reduction cap rate	-	-	-	-	-	25-50 BP
Improved ROI	6.60%	9.90%	-	-	-	-
Increase occupancy ratio	3.50%	6.40%	-	-	-	-
Market value	7.50%	10.90%	-	-	-	-
Selling price	-	-	-	-	16.00%	
Energy Star	-	-	5.76%	10.00%	-	
LEED	-	-	9.94%	31.00%	-	
Energy Star/LEED	-	-	-	11.40%	-	

Table 1: Results of published empirical non-European case studies

Three of the illustrated case studies used the same dataset, the CoStar's national dataset, which includes 2 million properties with around 42.9 billion square feet (around 4 billion square meter) of commercial space. The difference between them is the usage of the data, the used sample sizes, and the application of variables and therefore the complexity of the analysis. Miller et al. for example included control variables as location, size and age into the hedonic regression model. The positive results were tested and the results show that they are not significant at the 10 % level.[44]

Eichholtz et al. choose a similar hedonic framework for analyzing the effect of certification on contractual rents. They found some rent premium (see Table 1). This increases as they reflect lower vacancy rates with adjusted rents. But especially the premium for LEED-certified buildings has to be used cautious while they also fail to be significant at the 10 % level.[45]

Non-European research focused on income approach

Fürst and McAllister were analyzing the effect of LEED- and Energy Star certification with two different hedonic models: the rent model and the transaction price model. The price

[44] Cf. Fürst, F., McAllister, P. (2008), p. 16.

[45] Cf. Fürst, F., McAllister, P. (2008), p. 16.; Fürst, F., McAllister P. (2010)

premium of about 31 % for LEED-certified buildings seems to be extraordinary. The authors themselves stated that the results seem to be "[…] indicative of a 'hot' market […]".[46]

In summary, all existing empirical studies tried to find hard evidence that the green features of a building reflected a higher market value. They all used commercial market data sets, in most cases focusing on the office market; therefore the studies only analyze the impact of different potential parameters within the income approach.

Only few European research initiatives

All above mentioned research results illustrate specific property markets outside the European continent. Therefore the following section describes a methodology that was established in Switzerland along with the consideration of energy efficiency within the German qualified rent tables. These rental tables were established as the legal basis for landlords to raise net rents for residential floor area. The results are based on empirical data of the local rental markets, which were updated over the years.

5.1.2.2 European research results

5.1.2.2.1 Swiss Valuation Model - ESI Valuation

Instead of the in section 5.1.2 mentioned American and Australian research results the Swiss Center of Corporate Responsibility and Sustainability (CCRS) established a so called Economic Sustainability Indicator (ESI).[47] ESI measures the properties risk to achieve an increase respectively a decrease of value on the basis of long-term future developments.[48] CCRS uses the DCF-approach to include specific long-term risks as seen in a sustainability perspective. ESI identfies risks, which may occur between the date of sale (e.g. end of year 10) and the end of the economic lifetime of the building (e.g. year 35 or 40).[49] So it isolates and values the uncertainty, which is not automatically included explicitly in the cash flow calculation of the so-called holding period of the property.[50] Five groups of sustainability features were identified to quantify ESI:

(1) Flexibility and applicability

[46] Cf. ibid p. 23.

[47] Meins, E., Burkhard, H.-P. (2007); Holthausen, N., Christen, P. (2009).

[48] Meins, E., Burkhard, H.-P. (2009): p. 4, p. 12.

[49] Cf. p. 4, p.13.

[50] Cf. p. 13.

(2) Dependency of energy and water

(3) Accessibility and mobility

(3) Security and

(4) Healthiness and Comfort.[51]

The results of the sub criteria must then be aggregated to ESI and quantified through a risk-based weighting model that implicates three main elements: scenarios, probabilities of occurrence and dimension.[52] Hence the ESI reflects the property's future risk, which one should consider within the estimation the exit cap rate of the DCF-approach.[53] ESI was specified for multi-family houses, office and retail spaces.[54]

DCF Model and Risk adjustment in Swiss Approach

Researchers published three practical examples with corrections of value for different property types. Thereby the calculation of ESI are dependent on the classification of the different characteristics within the five sustainability groups as sustainable (1), average new construction (0) and non-sustainable (-1).[55] With the aid of sensitivity analysis CCRS calculated the maximum change in value for sustainable respectively non-sustainable buildings. The analyses resulted in a maximum added value of 6.60 % and a maximum discount of value up to 14.90 %. Via multiplication of the estimated ESI and the maximum change of value the correction factor can be quoted.[56]

Type of Porperty	Market Value	ESI	peek Change	correction factor	ESI Market Value
Multi-Family House	28 190 000 CHF	0.5	6.60%	3.30%	29 120 270 CHF
Multi-Family House	10 227 000 CHF	-0.2	14.90%	-2.98%	9 922 235 CHF
Shopping Center	85 660 000 CHF	0.1	6.60%	0.66%	86 225 356 CHF

Table 2: Practical Example ESI Market Valuation

CCRS tested the use of ESI within the property valuation during the past one and a half years with the aid of independent property valuers. The pilot projects certify the applicability and

[51] Cf. ibid p.4, p. 9.

[52] Cf. ibid. p. 14 et seqq.

[53] Cf. ibid p. 13.

[54] Cf. ibid.

[55] Cf. ibid.

[56] Cf. ibid. p. 18.

the practicability in the daily business of a property valuer. The time needed to calculate ESI during the pilot projects ranged from a half to three hours dependent on the starting position of the valuer.[57] CCRS will investigate if the method is also applicable for the certified LEED- and BREEAM-properties. Researchers established the the method specifically for the Swiss property market. If one were to apply the the ESI property valuation method to other markets, the specific characteristics and framework conditions should be revised accordingly.[58]

5.1.2.2.2 German Ecologic Rent Tables

In Germany, landlords use rent tables (so called "Mietspiegel"*)* as the legal basis to increase net rents for residential floor area. Real empirical data updated over the years by surveys forms the basis.

In 2003 the City of Darmstadt established the first ecologic rent table for the estimation of local comparable residential rented floor area.[59] In 2008 the City of Darmstadt published a revised rent table and adjusted the impact of energy-efficient characteristics of buildings.[60]

In cooperation with the Institute of Living and Environment ("Institut für Wohnen und Umwelt") in Darmstadt the first result of the research project was the statistical proof that buildings that featured good thermal performance ("gute wärmetechnische Beschaffenheit") were able to achieve a rental-premium compared to energy inefficient buildings of up to 0.37 €/m²/pm.[61] The aim of the cooperation between the City of Darmstadt and the Institute of Living and Environment was to investigate the impact of the thermo technical quality of residential buildings. The research was carried out during the preparation of the rent table for Darmstadt. The analyses resulted in a practicable and useful way of integrating the energetic characteristics into the qualified rent table with the aid of information out of the EPC.[62]

Rental-premium of up to 0.37 or 0.49 €/m²/pm

If a building is able to fulfil the conditions required to achieve the designation of "average/upgraded thermo technical quality" net rent compared to non energy-efficient buildings goes up about 0.37 €/m² or even 0.49 €/m² for living space in Darmstadt due to the

[57] Cf. ibid p. 18.

[58] Cf. idid p. 19.

[59] Amt für Wohnungswesen Darmstadt (2003), p. 3.

[60] Amt für Wohnungswesen Darmstadt (2008), p. 3.

[61] Knispel, J., Alles, R. (2003), p. 1.

[62] Amt für Wohnungswesen Darmstadt (2003) and (2008).

rent table published in 2008.[63] According to the results the premium is dependent on the base rent.

Darmstadt and Berlin as early-adapters

Recently (July 2009) the city of Berlin published a new qualified rent table, which also includes the aspect of energy-efficiency.[64] The table described different rental ranges dependent on the year of construction, location and rental space. To include the aspect of energy efficiency the authors developed a guidance note in order to calculate the rent for a specific property. The characteristic of energy efficiency is part of the overall building characteristics. Therefore the valuer can use the tabular templates that are integrated within the rent table. The following characteristics are only part of the rating scheme for building characteristics, which potentially result in an increase or decrease in value (Table 3).

Decrease in Value	Increase in Value
☐ insufficient insulation or heating system with less favourable efficiency (installation before 1984)	☐ insulation additional to existing building stock or installation of a modern heating system after 1 July 1994
OR	
☐ energy consumption exceeds 190 kWh/(m²a)	☐ energy consumption less than 120 kWh/(m²a)
☐ energy consumption exceeds 230 kWh/(m²a)	☐ energy consumption less than 100 kWh/(m²a)
☐ energy consumption exceeds 270 kWh/(m²a)	☐ energy consumption less than 80 kWh/(m²a)

Table 3Every matched characteristic stands for a decrease or an increase in value.[65] Thus the valuer must carry out an auxiliary calculation. In the end a maximum 20 % increase or decrease can occur due to specific building characteristics.

Decrease in Value	Increase in Value
☐ insufficient insulation or heating system with less favourable efficiency (installation before 1984)	☐ insulation additional to existing building stock or installation of a modern heating system after 1 July 1994
OR	
☐ energy consumption exceeds 190 kWh/(m²a)	☐ energy consumption less than 120 kWh/(m²a)
☐ energy consumption exceeds 230 kWh/(m²a)	☐ energy consumption less than 100 kWh/(m²a)
☐ energy consumption exceeds 270 kWh/(m²a)	☐ energy consumption less than 80 kWh/(m²a)

[63] Amt für Wohnungswesen Darmstadt (2008), p. 11.

[64] Senatsverwaltung für Stadtentwicklung Kommunikation Berlin (2009), p. 14.

[65] Cf. ibid p. 15.

Table 3: Energetic characteristics considered in the rent table of Berlin[66]

So if you have an average rent of 6.57 €/m² per month in the range between 5.85 €/m² and 7.80 €/m² and the insulation of the building is insufficient, the rent would decrease about 20 % in the range of 6.57 €/m² and 5.85 €/m². This means that the rent would decrease by about 0.14 €/m² and would achieve 6.43 €/m². Vice versa the rent would increase about 20 % in the range of 6.57 €/m² and 7.80 €/m² up to 6.82 €/m² if the energy consumption of the building was less than 80 kWh/(m²a). On one hand, these two examples describe a decrease of 2.13 % and on the other an increase of 3.81 % of the net rental income per m² per month. For a better understanding see the structured calculation example in Figure 4.

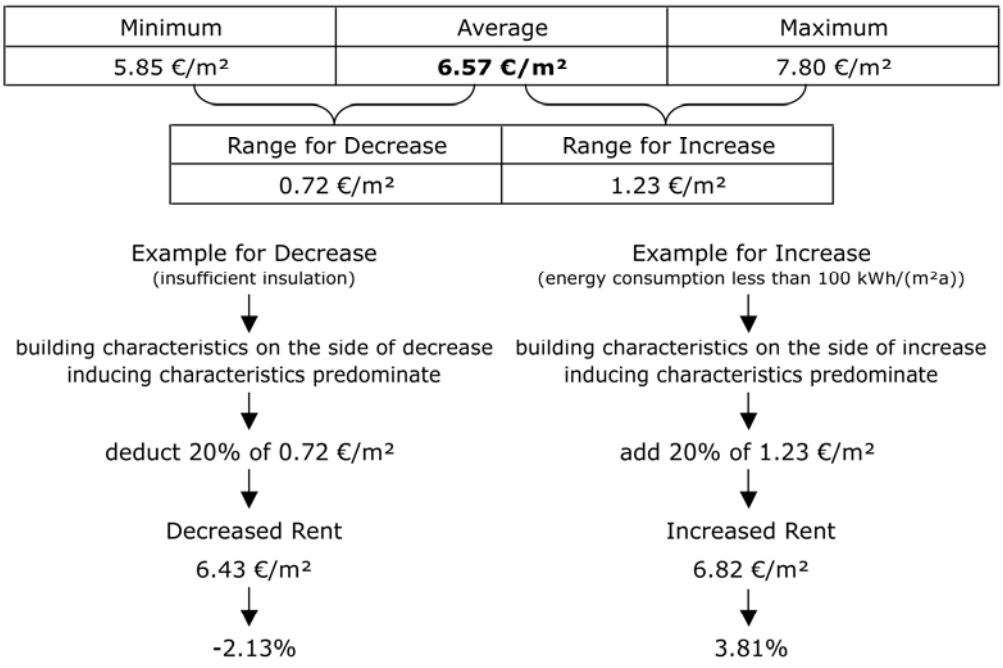


Figure 4: Calculation Example Rent Table Berlin[67]

Finally, these qualified residential rent tables are based on empirical regional real data. The premium of energy-efficient or the discount of non-efficient buildings depends on the base rent in Darmstadt and additionally, in Berlin, on the range between the minimum and the average as well as between the average and the maximum.

Empirical Data as basis for adjustments

[66] Cf. ibid p. 18.

[67] Senatsverwaltung für Stadtentwicklung Kommunikation (2009), p. 12 et seq.

Finally Table 4 summarizes the results of the Swiss research results and the German ecologic rent tables.

Variable \ Country	Germany (Ecologic Rent Table Darmstadt 2003)	Germany (Ecologic Rent Table Darmstadt 2008)	Germany (Ecologic Rent Table Berlin 2009)	Switzerland (Meins, Burkhard 2009)
Rental Premium	-	-	-	
Minimum	4.71%	3.97%	0.41%	
Maximum	13.60%	15.17%	5.87%	
Rental Discount			-	
Minimum			1.25%	
Maximum			6.79%	
Market value				-
Maximum Increase				6.60%
Maximum Discount				14.90%

Table 4: Results of published empirical European case studies

Respectively further German cities like Wiesbaden and Hamburg will publish qualified ecologic rent tables that consider the characteristics of energy-efficient and non-efficient buildings. In the future, German ecologic rent tables that rely on market evidence might be broadly available so that valuers can consider the energetic quality of residential rental properties automatically. But what is about the other types of properties in Germany and Europe? Is it possible to apply the non-European research results (see 5.1.2.1) and what about the significance and the comparability of the previous research results? One can conclude that there are results regarding specific markets and research questions revealing the link between sustainability/energy efficiency and value but a consistent framework how to integrate these aspects within property valuation is still missing.

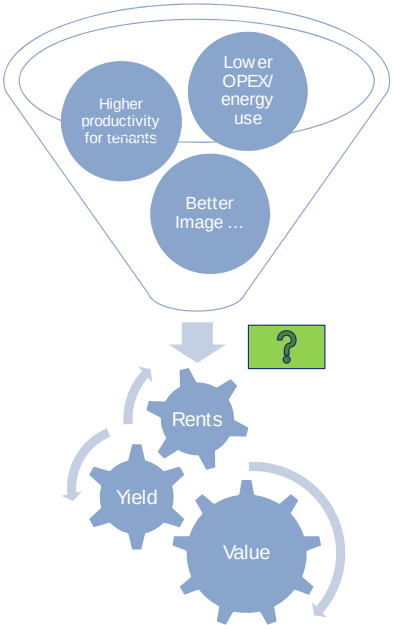


Figure 5: Linkage between sustainability features and value

5.1.2.3 Survey of Roland Berger

In an online survey (dated April 2010) among 40 big real estate companies in Germany, Switzerland and Austria the strategy consultant Roland Berger evaluated (among other issues) the willingness to pay for environmental/sustainability features of assets[68]. 70 % of real estate investors answered that they are willing to accept higher average investment cost of 8.9 % for sustainable buildings resp. refurbishment. On the tenants side the answers reveal that 86 % are willing to accept higher rents by average 4.5 % if the object is "sustainable". Altogether the survey shows an increasing awareness and weight of energy efficiency and sustainability issues among real estate companies. However, one must stress that the results show only intentions and not realised transactions. Nevertheless one can conclude that during the duration of the IMMOVALUE project the awareness of consumers and their willing to pay for sustainability rose significantly. This latest study by Roland Berger illustrates therefore this development of a gradually but steadily changing market sentiment.

[68] Roland Berger Strategy Consultants, Nachhaltigkeit im Immobilienmanagement, Kurzfassung, April 2010, http://www.rolandberger.at/media/pdf/Roland_Berger_Nachhaltigkeit_im_Immobilienmanagement_20100413.pdf

5.1.2.4 Critical remarks - The applicability of the recent research results

Although researchers were able to find some empirical evidence, all of the mentioned (non-European) results are not quite significant because of the small sample sizes in comparison to the national and internationally reviewed markets.[69] Muldavin for example states that the results of the above-mentioned studies must be handled critically regarding their applicability for other sub markets, in particular the ones that rely on the CoStar data set. He states that analysis must be more detailed and on a property specific level

The established Swiss valuation methodology which uses the ESI was tested within real pilot projects. The results certify the credibility and practicability of the methodology.[70] However it remains to be seen whether this approach is applicable due to specific adaptations for certain European indeed for international property markets. Thus, the process may require further testing. Moreover the valuation method used to include the issue of sustainability was only the DCF-approach. It might be more interesting if the ESI valuation is applicable for the other valuation approaches. Furthermore, the scoring is only empirical to a certain extent, and therefore market based.

With the exception of the Swiss methodology, a review of existing research papers didn't give a hint as to how valuation could include sustainable and energy efficiency characteristics. Qualitative surveys and analysis demonstrate that experts and market participants expect a premium or a discount based on the degree of sustainability/energy efficiency and the respective certifications of the properties. However, due to the lack of data and comparable information, no one is able to give a clear indication about the quantitative mid- and long term impacts of sustainability on a national or international level. Further national research projects like the one by University of Stuttgart have just been initiated in 2010.[71]

Nevertheless, one can identify some of the linkages within the several valuation methods where property valuers and the market participants from all over the world expect the effects which may arise in the near future due to the sustainability and energy efficiency discussion. Linkages are always related to the benefits of owners and occupiers:

[69] Warren, C. (2009), p. 8; Muldavin, S. (2008), p. 4 et seqq.

[70] Meins, E., Burkhard, H.-P. (2009), p. 18.

[71] Cf. Schäfer, H., et al (2010)

BENEFITS	
OWNERS	OCCUPIERS
▪ Reduced operating costs ▪ Enhanced brand ▪ Mitigation of future regulatory impacts ▪ Reporting to stakeholders ▪ Tenant retention ▪ Increased rents ▪ Differentiated position of asset ▪ Shorter letting up periods ▪ Increased market share ▪ Higher net revenue return	▪ Reduced operating costs ▪ Enhanced brand ▪ Mitigation of future regulatory impacts ▪ Reporting to stakeholders ▪ Employer of choice, employee retention ▪ Enhanced building environment ▪ Improved productivity ▪ Decrease their footprint on the planet ▪ Stronger tenant/owner/manager relationship

Figure 6: Advantages to owners and occupiers

5.1.3 Possible Linkages to property valuation

Figure 3 summarizes all imaginable linkages within the existing valuation approaches to include the aspects of energy efficiency of buildings:

Valuation Approach	Possible Linkage	Possible Effects
Sales Comparison Approach	• Sales Prices of Comparable Properties	• Energy-efficient buildings may achieve higher sales prices. • Non-efficient buildings may achieve lower sales prices.
Cost related Approach	• Replacement Costs of a building • Adjustments (due to Specific Building Components) • Depreciation • Adjustments	• Replacement Costs may be higher for energy-efficient buildings (e.g. special materials). • Consideration of special features concerning e.g. renewable energy sources (photovoltaics) within the building. • Longer remaining economic lifetime and therefore less depreceation than for non-efficient buildings. • Non-efficient buildings may reduce the remaining economic lifetime due to economic inefficiency. • Upgrade of energy-efficient building due to the tight market and the better marketability.
Direct Capitalization	• Annual Potential Gross Income • Annual Operating Expenses • Yield/ Cap Rate • Adjustments	• Rents may increase due to good thermal quality standards of a building while non-energy efficient decrease. • Operating Expenses may decrease, while tenants and landlords may benefit. • Yield will decrease due to higher marketability, lower vacancy rates and therefore the lower risk in comparison to non-efficient buildings. • Direct consideration of enhenced thermal quality, longer remaining economic lifetime and upgraded marketability of energy-efficient buildings.
Discounted Cash Flow	• Annual Operating Gross Income (holding period e.g. 10 years) • Annual Operating and Capital Expenses • Discount Rate/ Terminal Cap Rate • Discounted Cash Flow from Sales	• Rents may increase (adjusted growth rates), lease terms will elongate due to the better marketability and the narrow markets. • Operating Expenses may decrease, e.g. because of special capital expenditures to improve energy efficiency during the investment period. • Discount Rates may decrease due to declined risks of energy-efficient buildings. • Better expected marketability due to an improved energy efficiency level will be reflected in an adjusted exit yield/cap rate.

Figure 7: Possible Linkages within the Valuation Approaches

As stated above, some differences may already exist between energy-efficient and non-efficient buildings respectively sustainable and non-sustainable. The questions that arise in this context are:

(1) Is it possible to get some feasible and meaningful figures out of the pan-European liable EPC's and realized LCCA of energy-efficient buildings and if so will the market demonstrate representative and significant evidence?

(2) And if so could they be included within existing property valuation methods in day-to-day business?

The following chapters 5.2 and 5.3 try to answer the first part of the question and illustrate what data one might extracted from EPC's and LCCA to support the valuation professionals with reliable and suitable figures for the consideration of energy-efficiency aspects within the valuation process.

5.2 Analysis of Energy Performance Certificates

Key Facts and Findings

- In contrast to property valuation, Energy Performance Certificates (EPC) do not follow a generally accepted and to a large extend identical procedure throughout Europe.
- Hence the information available in the EPC cannot be used directly for valuation purposes due to the existence of large differences between EPC methodologies and thus the included information throughout Europe.
- One can, however, process the "row material" delivered by the EPC further so that it might be useful for property valuation. In this case it improves the data quality for property valuation mainly in the following areas: (1) energy consumption level for the operation of the building (transferable to energy cost level), (2) technical equipment of the building (described in detail in most data sets for EPC), (3) modernisation needs of the building (transferable into modernisation costs), and (4) overall energy quality compared to other buildings (label schemes of the EPC).

5.2.1 Basics for Valuers

Two principal types of energy ratings for buildings have to be differentiated:

(1) The calculated energy use,

(2) The measured energy use.

The calculated energy rating can be either

(1) Standard: based on conventional climate, use, surroundings and occupant-related input data, defined at national level and given in a national annex.

(2) Tailored: calculated with specific climate, occupancy, and surroundings data adapted to the purpose of the calculation. It can be either calculated for planned buildings (design rating) or for existing (already built) buildings.

National bodies determine under what conditions the design energy rating can be considered as or converted to a calculated energy rating for the actually realised building.

5.2.1.1 Calculated energy use

The calculation direction goes from the demand to the source (e.g. from the building energy needs to the primary energy). For the assessment of the energy performance of buildings there are several energy performance indicators:

Energy performance indicator	System boundary	Explanation
Heat transfer coefficient (U-Value)	Building element level	Energy loss through building element
Net energy demand (heat demand, cooling demand, hot water demand)	Used rooms in the conditioned floor area	Heat to be delivered to or extracted from a conditioned space by a heating or cooling system to maintain the intended temperature during a given period of time, not taking into account the technical building systems
Final energy demand	The whole building	Total energy, supplied to the building through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.), taken into account the technical building systems
Primary energy demand	Building and energy production	Primary resource energy divided by delivered energy, where the resource energy is that required to supply of delivered energy, taking account of the resource energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operations necessary for delivery to the building in which the delivered energy will be used.
CO_2 Emissions	Building and energy production	Quantity of CO_2 emitted to the atmosphere for the delivered energy

Table 5: Explanation of energy performance indicators

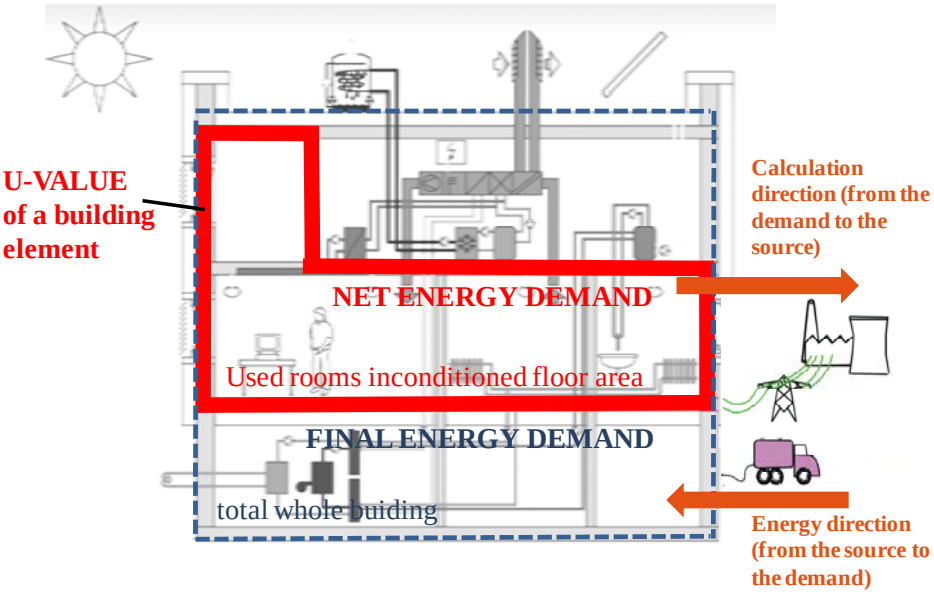


Figure 8: System boundaries for different energy performance indicators[72]

5.2.1.2 Measured energy use

The measured energy use is based on real energy consumption of the building. To calculate the measured energy use fte amount of all energy "carriers" must be summed up as accurately as reasonably practicable, from recorded data, energy bills, or other measurements.

If the measured energy rating is not based on the actual energy use recorded over at least three full years, a correction of the measured energy is necessary. This correction must ensure that the energy consumed during the period of measurement is representative for the average local weather condition.[73] Furthermore, one must adjust the results of the measured data if the building is not used completely. There should not be a benefit for the energy performance due to occupancy levels in the building.

To compare the results of measured data with the calculated data,system boundaries of the measurement have to be the same as the ones in the calculation. One must separate energy uses other than those for building conditioning.

[72] DIN 18599

[73] To achieve this, the measured energy use for heating and cooling shall be adjusted to the average weather for the building location.

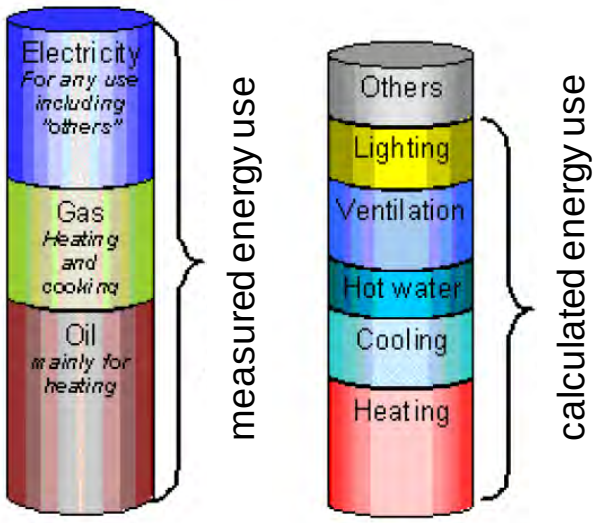


Figure 9: Different system boundaries of measured and calculated energy use

5.2.2 Starting points for an integration of EPC into property valuation

5.2.2.1 No direct use of EPC due to large differences throughout Europe

One cannot directly use the information available in the energy performance certificates (EPC) as input parameters for property valuation purposes due to the following reasons:

(1) The **types of indicators vary considerably** in the EU countries. In the frame of the project, a comprehensive analysis of the indicators and other information available in the EPC for Romania, Austria, Germany and England has been made. The **heterogeneity of EPC** in these countries is visible in Table 6 below.

(2) Even in cases where energy performance indicators used in the EPC are denominated by the same term, the content is not the same. The differences arise from **different calculation methodologies** applied. Although a set of European standards for the calculation of energy performance exists, it leaves enough room for national flexibility. The national embodiment of the European standards causes a huge heterogeneity in important details that have considerable influence on the final result. In order to foster a kind of “harmonisation” the IEE-project ASIEPI, among other topics, carries out a comprehensive analysis comparing the differences in the calculation methodologies. An example of preliminary analysis results for different energy performance indicators is given in table 6). In addition, the IEE-project DATAMINE

has examined the differences in input and output data for the energy performance calculations and has developed a harmonised data set. In any case, researchers have not developed these approaches far enough for a direct application in property valuation. The description of the energy performance of a building in different countries and regions is still far from harmonisation.

(3) If indicators for (measured) energy consumption are used a direct use for property valuation seems easier. It is important, however, that one be aware that **consumption figures are strongly influenced by the quantity and quality of use** in a certain building and by the climate conditions. To get a "neutral" picture of the thermal-energy quality of the building for property valuation purposes it is important to know about the usage and climate parameters behind the measured energy consumption value and to be able to "normalise" the effect of usage and climate.

Question	Answer	AT		EN		GE			RO	
		res	non	res	non	res	res	non	non	
						dem	con		con	
Indicator basis	calculated energy rating	o	o	o	o	o		o		
	measured energy rating						o		o	
	both									o
Energy certificate format	Classification (A to G)	o	o	o	o					o
	No Classification					o	o	o	o	
Number of labels (representing all energy uses)	One label	o	o		o	o	o	o		
	Two labels			o					o	
	more labels									o
Type of indicator for the energy efficiency label	net heat demand	o	o							
	net cooling demand									
	final energy demand					o	o	o	o	o
	primary energy demand					o		o		
	CO_2 emissions			o	o					
	Energy costs			o						
	Other:									
Other global energy demand indicator	energy demand for space heating	o	o	o	o	o	o	o	o	o
	energy demand for space cooling		o		o			o		o
	energy demand for mechan. ventilation	o	o		o	o		o		o
	energy demand for domestic hot water	o	o	o	o	o	o	o	o	o
	energy demand for lighting		o	o	o			o		o
	energy production, in part. by RES				o					o
	Other:			o					o	
Improvements measurements	standardisation for improvement measures			o	o	o	o	o	o	o
	individual formul. of improvmt. measures	o	o							o
Energy costs	energy costs included			o						
	energy costs NOT included	o	o		o	o	o	o	o	o

	res… residential non… non residential

Table 6: List of indicators in energy performance certificates

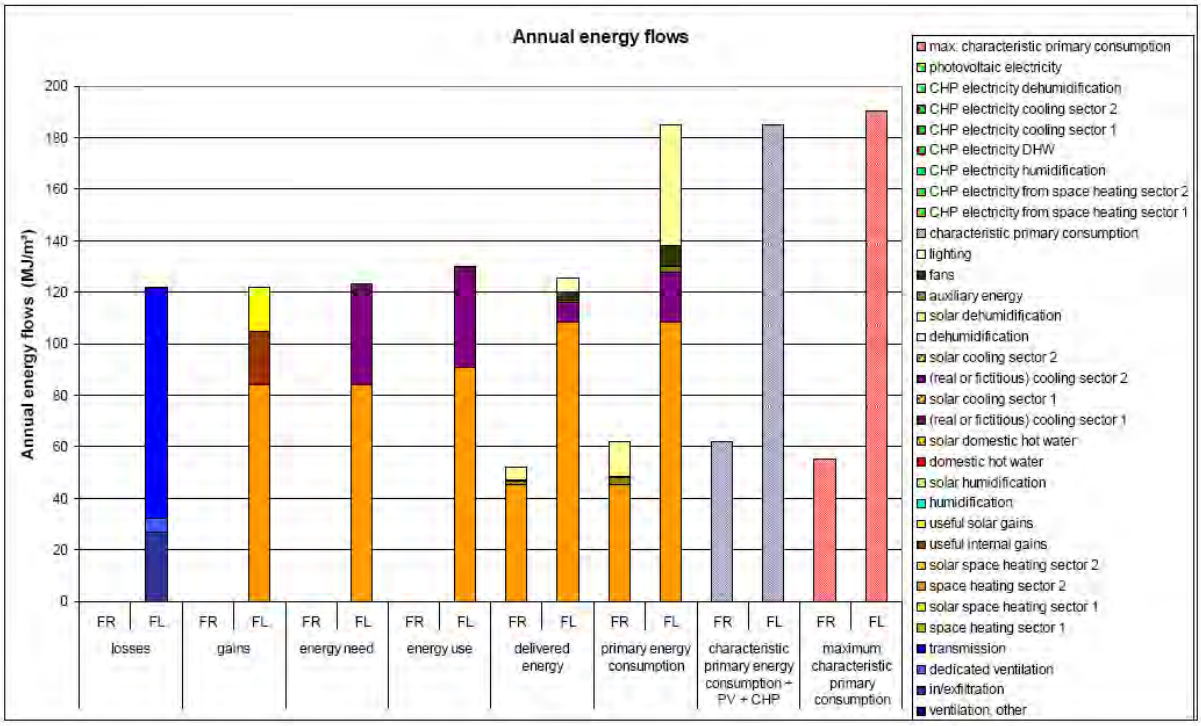


Figure 10: Detailed comparison of the calculation method for the energy performance of buildings between France and Flandern[74].

Figure 10 illustrates the enormous difference between delivered energy as well as primary energy demand between France and Flanders. The data of this figure is based on the calculation of one reference building in different countries using the national calculation method for the energy performance certificate. The delivered energy for the building in France is around 50 MJ/m², in Flanders around 125 MJ/m². That means in France the delivered energy is only around 40 % of the value in Flanders for the same reference building. Therefore, one cannot use the results of the calculations regarding energy performance certificates directly to calculate the energy costs of a building because certain input parameters (e.g. usage patterns, comfort levels) and fixed values (e.g. factor for shading from surroundings etc.) are defined differently for the calculation on national level. Thus a direct comparison with the actual energy consumption of the building requires careful interpretation.

[74] D'Herdt, P., Van Orshoven, D., Wouters, P. (2008)

5.2.2.2 Link between EPC and the information needed for property valuation

Figure 11 illustrates the link between the information needed for property valuation and the information contained in the EPC.

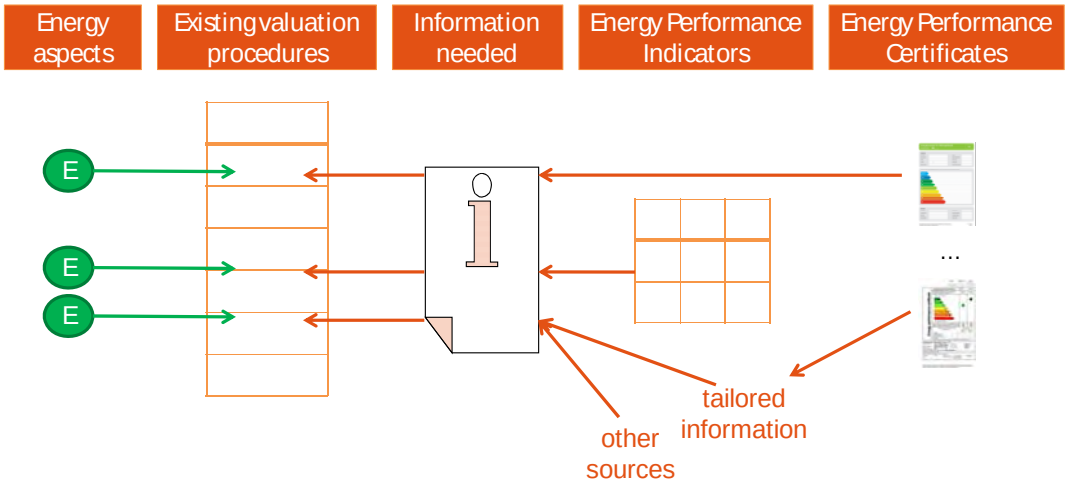


Figure 11: Link between energy performance from an EPC and property valuation perspective.

Table 7 presents a structure of the information needed from the point of view of different property valuation approaches.

valuation approach	method	relevant information needed / link to EPC
Income related approaches	Adjustment of the potential gross and net income / non-recoverable operating expenses	Operation cost (including energy cost, maintenance cost etc.) and energy consumption
	Adjustment of the all risk yield	Thermal-energy quality (expressed in the label category of the energy certificate and in other calculation results) as influence factor for the interest rate applied
	Appreciation/depreciation for value influencing characteristics	Factors with link to energy certification: • need for modernisation / maintenance • thermal-energy quality (expressed in the label category of the energy certificate and in other calculation results) as potential factor for appreciation/depreciation
	Adjustment of the maintenance costs	Maintenance cost differentiated in • running maintenance • repair works In addition required modernisation to reach a given quality level (e.g. B-category

		in energy certificate)
	Adjustment of the residual life-time of the building	Construction year of the building and of its equipment
Cost related approaches	Adjustment of construction costs	Construction cost
	Adjustment of the age of the building (accrued depreciation)	Construction year of the building resp. of the technical equipment
	Appreciations/depreciations for value affecting characteristics	Factors with link to energy certification: • need for modernisation / maintenance • thermal-energy quality (expressed in the label category of the energy certificate and in other calculation results) as potential factor for appreciation/depreciation
	Appreciations/depreciations for adjustment to the market value	
Value comparison approaches	Draw comparison by using building of the same energy efficiency level	Labels and other calculation results, that describe the thermal-energy quality of buildings (in order to select comparable buildings)
	Appreciations/depreciations derived from the energy efficiency levels	Factors with link to energy certification: • need for modernisation / maintenance • thermal-energy quality (expressed in the label category of the energy certificate and in other calculation results) as potential factor for appreciation/depreciation
	Adjustment of the value influencing characteristics	

Table 7: Information needed to integrate energy efficiency indicators in property valuation

The prevailing part of the information available in the EPC requires additional process steps to make them usable for property valuation. Taking into account the necessity of additional processing, the analysis of the EPC from Romania, Austria, Germany and England shows that in general the energy performance certificates are able to provide information such as:

(1) General data on the **energy quality of the building** (energy use indicator, energy label, energy mark) that positions the building within a certain range where the existing building stock lies currently; for example: on a scale A to G, a building with label B is above the average, close to the highest standards, while a building with label F is clearly a poor quality one in the stock. The building value could be influenced accordingly.

(2) **Energy cost level** for the operation of the building, expressed as a label that ranks the building within the existing stock, or in present monetary values that are readily included in any valuation calculation (at least for total occupancy cost of the user).

(3) **Difference in energy uses between a real building and a similar one that complies with the current national energy standards**. This indicates either how old the building is (having high operating costs) or how modern and efficient the minimum requirements are (having low operating costs).

(4) **Year of construction and age of technical equipment** from the history of energy standards, plus depreciation, gives a hint about the building energy quality (operating, maintenance and repairs costs) relative to the existing stock as well as the building's remaining lifetime.

(5) **Modernisation costs** to bring the building at least to the current minimum requirements; such information is valuable in assessing the investment needed to be made sooner or later in order to diminish the risk of over-depreciation on the market.

5.2.2.3 EPC improves data quality for property valuation purposes

The comprehensive analysis on potential links between EPC and property valuation that have been carried out in the frame of the IMMOVALUE-project make clear that

(1) EPC delivers the "row material" for the property valuation process,

(2) Information related to the energy efficiency of a property is relevant for valuation,

(3) Additional information and analysis is needed to process the results.

Therefore EPC´s are the basis for an improvement in the quality of data used in property valuation.

Due to the heterogeneity of EPC in the different countries and regions of Europe, quality assurance in this context implies to make use of

(1) a preferably harmonised set of data from EPC used as input data for property valuation purposes. The results of the DATAMINE project offer a good starting point in that respect;

(2) a standardised methodology how to transfer technical data regarding the energy performance of the building into monetary values. In this context, life cycle cost assessment is a useful approach.

With respect to the "work flow" of transferring "raw material" from EPC to useful input data for property valuation two approaches seem possible:

(1) One can involve specific energy performance experts (and potentially LCCA) directly in processing the data regarding the energy performance of the buildings from

the EPC, however, this method is costly and therefore should be reserved for large-scale/big valuation projects;

(2) One could establish a certain standardised process or format to transpose information from the EPC into useable input data for property valuation calculation schemes. This approach seems feasible mainly for the more direct links between EPC information and valuation. One example is the link between final energy demand / measured energy consumption and the energy costs in Euro. Since all valuations are currency based figures, a purely non-currency based method doesn´t seem helpful.

Finally, one must understand that further information on the building's energy quality apart from that gathered through the EPC is available from the reports delivered as a result of obligatory inspections of heating and ventilation systems. Such reports are more detailed in relation to the installation performance of the building compared to the energy performance certificates (including extensions and/or annexes).

5.3 Analysis of Life-Cycle Costing

Key Facts and Findings

- The basic idea behind Life Cycle Costing (LCC) is that one should not only consider the economic costs relating to the construction and initial purchasing. Rather, is also important to take into account the costs occurring in the whole remaining life time of a building such as operating costs, maintenance costs and replacements costs.
- LCC can be done for a whole building, or for a relevant subset of building components.
- It should, however, be made clear which cost elements are paid by the building owner resp. investor (non-recoverable costs) and which cost elements are paid by the tenant (recoverable costs).
- As important element within the LCC approach Service Life Planning (SLP) can be used to estimate the maintenance intervals and the Residual Service Life (RSL) of a building component. Using the “Factor method” one can adjust the standardized life time of a building component depending of the internal and external factors it is exposed to.
- LCC is relevant for valuation since it provides additional and more precise information about the expected future costs related to a building. With its focus on operating cost, one can almost directly plug LCC in the income related approaches if costs between tenant and landlord were split correctly.
- Furthermore, using scenario analysis it is possible to use LCC as a tool to analyze uncertainty and risk.
- In practice, however, there are several barriers to the integration of LCC, such as a need for software-tools that support the management of complex data structures inherent to LCC analysis of buildings and of course data-transparency itself.
- The LCC Approach fits within the income method framework but doesn´t work well with the cost approach or direct comparison.
- Little information exists regarding LCC/LCCA and the benefits that these tools might have for valuation.

5.3.1 Basics for valuers

In the following section general issue relating to LCCA, which are important from a valuer's perspective will be shortly described.

5.3.1.1 Cost data classifications in LCCA

LCCA (Life Cycle Cost Analysis) consists of calculating the present value of all costs for the whole remaining life of a building (LCC, Life Cycle Cost).
These costs include not only the initial investment in the building, but also the running costs (maintenance, replacement, energy, cleaning etc.) as well as the residual costs when the building has reached the end of its economic life (residual cost, can be negative if demolition is necessary and/or cleaning up the site for substances potentially dangerous to the environment is required). In some European countries there exist national standards and guidelines for carrying out a LCCA. At the international level the ISO 15686-5 Buildings and constructed assets - Service life planning - Part 5: Maintenance and life cycle costing sets the frame. The ISO 15686-5, however, does not include a normative setting for an economic data structure which means that different approaches are in use in practice. Table 8 shows an example for a possible structure of cost/income elements which are relevant for an LCCA analysis.

TC 350 life cycle stage	**Cost/Income Category**	**Cost/Income item**	**Example of costs**
Before Use Phase	Construction Costs	Land costs	Cost of the land on which the building stands
		Professional Services	Costs for project management, architecture, structural/civil/environmental engineering, cost and value management
		Site clearance, temporary works	Costs of the activities to prepare the building site for construction
		Construction of asset	Costs for infrastructure within the surrounding of the building, structure, envelope, services, fitting out, commissioning, handover
		Landscaping, external works on the surrounding	Costs for external works such as lawn, trees on the land within the surrounding of the building
		Taxes and other costs related to permission to build	Costs for taxes and fees for land and construction of the building

	Construction Income	Subsidies and incentives	Income related to sustainability measures such as renewable energy and energy efficiency, including loans
Use Phase	Operational Costs	Building related facility management costs	Costs for regular and routine activities such as cleaning, inspections, caretaking, management of planned service contract, products or materials used for mentioned activities
		Building related insurance costs	Costs for insurance for building owner and/or occupier
		Regulatory costs	Costs for activities such as fire inspections, access inspections, declarations relating to energy performance
		Utilities - energy, water, sewage	Costs for energy such as fuel for heating, cooling, power, lighting as well as water and sewage costs
		Ground operations	Operational costs on the land within the surroundings of the building such as cutting trees, mowing lawn
		Taxes and other costs related to building operation	Costs such as local charges and environmental taxes
	Operational Income	Subsidies and incentives	Income related to sustainability measures such as renewable energy and energy efficiency, including loans
		Sale of assets or elements	Income from disposal of interest in building or salvaged materials
	Maintenance Costs	Repairs and replacement of minor components	Regularly maintenance costs defined by value size of area, contract term
		Replacement of major system and components	Costs to keep the performance of building elements including design and project management such as exchange roof or facade
		Redecoration	Costs to keep the performance of the building including design and project management such as renewal of façade
		Refurbishment	Costs to improve the performance of a building including design and project management such as new chillers or boilers with higher energy efficiency
		Ground maintenance	Maintenance costs on the land within the surroundings of the building
		Taxes and other costs related to maintenance	Costs for taxes on maintenance goods and services
	Maintenance Income	*(no cost element yet)*	
End of Life Phase	End of Life Costs	Final condition inspection	Cost for inspection after use of the building

		Disposal and demolition	Costs for disposal and demolition including pre-demolition inspection, decommissioning, disposal of materials and site clean-up
		Reinstatement	Costs for reinstatement of site to meet contractual requirements
		Taxes and other costs related to end of life of a building	Costs for taxes on goods and services
	End of Life Income	disposal and recycling goods	Income from disposal of materials of the building
		Asset or elements	Income from disposal of interest in land, building or salvaged materials

Table 8: Classification of economic data for an economic performance assessment of buildings[75]

LCCA needs a vast amount of input data

The table shows that a large amount of information is necessary to carry out a full LCCA. For all the cost elements mentioned above, LCCA needs additional information concerning the lifetime perspective (ref. Service Life Planning, SLP, see below), i.e. in which time period which kind of cost may be expected. And finally LCCA needs to reflect the complexity of the building itself consisting of a huge amount of building elements and of important systemic connections between these building elements. Only a comprehensive assessment of all these constitutes a full LCCA

LCCA is not harmonized

At the moment there exist hardly any standards for LCCA. Pelzeter (2/2007) has shown that because of this reason relevant differences exist between the calculation methods in use which lead to considerable differences in the results[76]. The main differences include the following:

- structuring of data (i.e. the impact-cause model of building characteristics and the produced cost)
- pricing (i.e. the level of prices and cost for the different categories of construction and operation cost)
- calculation method itself (e.g. static versus dynamic approaches)

[75] Hofer, G., Leutgöb, K. : Input Paper for CEN TC 350 WG 4 Economic Performance Assessment of Buildings, May 2009 (confidential)

[76] Pelzeter, A.: Life cycle cost of real estate - comparison of possible calculation methods, German Journal of Prooerty Research, 2/2007

Therefore one should always interpret LCCA results against the background of the model used. Good LCCA always communicate their main assumptions such as discount rate used, the length of study period and the general structure used in the model.

5.3.1.2 Deflator in LCCA

One needs a deflator to calculate the present value of all these expenses at different points in time. To determine this deflator (almost always a constant number, but it could also be a variable number) one must use a risk-adjusted interest rate. The interest rate or better "yield" used can be different for different companies, but when carrying out a valuation the yield chosen should reflect the market perception of potential owners and resp. buyers of the property considered.

Yield for present value of costs calculation

The risk that is partly reflected in the deflator also depends on the sensitivity of the investment. For example: Taking into account that sensitivity for changes in operational cost (e.g. energy prices) would influence the deflator because one can assume that an energy-efficient building is, by definition, less sensitive to changes in energy prices.[77] This approach is therefore in line with income related valuations.

5.3.1.3 LCCA reflects only internalised costs

LCCA usually does not take external effects into account (positive or negative) instead it only "internalized" costs. If the construction, running or demolition of a building leads to negative consequences for the environment it is only included if the owner has to pay the full cost (or a part of it). It is possible, however, to include external cost if one can expect such as cost to be "internalised" due to changes in the (legislative) framework conditions. If there is a significant probability of such changes one should take such a change into account.[78] Since externalities are also irrelevant for valuation, this aspect harmonizes.

5.3.1.4 Simplifications of LCCA in practice

It is obvious that doing a full LCCA requires a large amount of input data, but in practice simplifications can be made. Focussing on the most important elements that influence cost

[77] RICS, p.19, 6.15

[78] RICS, p.17, 6.4.12

("cost drivers") provides an opportunity for one to greatly simplify the task. Software can also help a great deal. Further, if a rich BIM (Building Information Model) is available for the building ("as-built" and "as-maintained") the task can be even simpler and faster.

5.3.1.5 Use of LCCA at present

To a certain degree, LCC is taken into account in the planning phase of a building. However, the major focus for decision making is still on the initial cost for the developer. The developer wants to maximize the Residual Value (here: his profit) by subtracting investment costs from the Gross Development Value (GDV). Therefore: If the LCC approach is not considered relevant for GDV calculation, this might lead to a decision making process that just minimises the initial investments costs for a given concept without any reference to the operating costs the project might have later on.
As refers the use of LCCA in property valuation, based on interviews with several valuation professionals, we can assume that in valuation practice LCCA is hardly used today.

Knowledge and usage of LCC is poor amongst valuers
Not using LCC leads – from a macro-economic point of view – to sub-optimal decisions in the design and purchase phase respectively. In a sense, one might call this a "market failure," meaning that full information about important aspects of an economic good (the building) is not available when decisions are made. In the short term this can lead to incorrect price signals for the buildings being sold and in the long term it could lead to the construction of "wrong" buildings.
In the future LCC will probably be increasingly used in connection with advanced software tools for forecasting and risk analysis when it comes to the total (initial, running and final) cost. One can carry out this kind of analysis for both new and existing buildings. Further, LCC can not only help developers but also investors to enhance information needed to make a decision. Not using LCC means a lack of transparency and information.

5.3.1.6 Service Life Planning

Service Life Planning (ISO 15686[79]) is a method used to determine a reasonable expectation for the remaining life span ("Residual Service Life", RSL) of a building or its components to exceed specific performance. To obtain an estimated service life (ESL) one uses the factor

[79] More information about ISO 15686 can be found on Wikipedia: http://en.wikipedia.org/wiki/ISO_15686

method used in ISO 15686-1 to modify an RSL. One must take a number of variables into account when using the factor method as described in ISO 15686. This is shown in Equation (1):

$$ESL = RSL * A * B * C * D * E * F * G \quad (1)$$

Where:

A = Quality of the component

B = Design level

C = Work execution level

D = Indoor environment

E = Outdoor environment

F = In-use condition

G = Maintenance level.

In principle one may also use other methods ("the probabilistic method" or "the engineering method") but they require more information. One the other hand, some have criticized the factor method for oversimplifying what is inherently a complex problem.

Service Life Planning is relevant for the question at hand because it estimates the residual service life of a building or its components as well as their respective maintenance frequency. This is relevant in a LCC perspective since it provides information required to calculate maintenance and replacement costs (it does not provide cost information directly, but estimations of RSL and maintenance intervals are necessary to do LCC with high precision).

If a component (or a group of components), based on a LCC/SLP analysis, has a significantly higher present value of its (partial) LCC cost, one should take it into account. This may be especially relevant in cases where a building has a very high energy performance, but this performance is a result of components which in present value are expensive to maintain and/or replace. If the valuer only addresses the positive sides of these high cost components (energy performance) and not the negative ones (high replacement/maintenance costs) the result could be biased.

One practical suggestion may be to use software and key numbers that make it simple for the valuers to pick items from a list (for instance an A/C system or high performance windows) when he considers these to be of significant importance for the outcome of the valuation.

5.3.2 Starting points for integration of LCCA into property valuation

LCCA has a special fit for the income related approach in property valuation (see chapters 5.1.1 and 6.4.3), since it is based on discounted cash flow and therefore one can "plug it in"

almost directly. From the point of view of property valuation the following issues are crucial for an integration of LCCA into property valuation in practice:

(1) The full LCCA approach needs to be downsized to a simplified one which focuses on running cost of existing buildings, because the vast majority of valuations refer to existing buildings on the one hand. On the other hand, operating costs are already explicitly taken into account in the income related approach; therefore LCCA only improves the data quality on this side. This linkage is further worked out under 6.4.3.

(2) The LCCA needs to be differentiated into one part relating to the costs which the owner pays for and another part which the tenants pay for (non-recoverable versus recoverable cost), since this is a crucial issue in property valuation;

(3) LCCA can be increasingly used as a standard tool for sensitivity analysis and therefore for identifying the risk inherent to potential changes in important cost parameters.

(4) LCCA must be addressed with a user-friendly software-tool which is able to manage the vast amount of data that is necessary for such an integrated analysis but at the same time is flexible enough to be able to handle the different properties a valuer deals with.

Although the LCCA approach has a special link to the income-related valuation approach, in principle one can also use the information from the LCCA with other valuation approaches. In the sales comparison approach one can use a LCC (full or simplified) as an adjustment factor. Further, if one uses the LCC to do a risk/sensitivity analysis then one can use this information to adjust the yield (because of different risk).

In the following describes some of the abovementioned crucial apects of an integration of LCCA in property valuation..

5.3.2.1 Integrating risk analysis into the LCC

The valuer can use LCC as a tool to analyze uncertainty by applying scenario analysis. For example, one might run the LCC calculation with different values for important parameters. That method provides the valuer with the possibility to calculate how the LCC will change if energy prices increase by 50 %. It is also possible to use a computer to do a “Monte Carlo” analysis if one inputs a statistical distribution for important parameters. One can integrate this type of analysis into valuation as part of the risk.

Increase transparency by LCC Tools

One starting point for integrating risk into LCC might be to look at the willingness-to-pay (WTP) of an economically rational individual or firm:

One scenario: If the energy prices increases significantly, the WTP for a tenant (the rent) can increase if the building is highly energy-efficient – while the owner of a highly energy inefficient building might have to reduce his net rents to keep the occupation rate high. In a transparent and efficient market a tenant would care about the total amount he pays, not how the total costs is split between different cost categories.[80] If for instance one can show that an office is 20.000 Euros cheaper than other offices when it comes to the energy costs (paid by the tenant), an economically rational tenant would be willing to pay approximately 20.000 Euros more in rent (ceteris paribus).

5.3.2.2 Possible simplifications

As mentioned above, a full LCCA requires quite a lot of data and work. However, there might be some approaches to simplify this while still using the "LCC approach of thinking" as a basis:

(1) Using "cost drivers" based on standardized LCC-calculations with information from the energy certificate and a simple estimation of the consequence for other costs: The idea here is that the valuer can (possibly using software) select alternatives from a list, and based on this get an acceptable estimate of the total cost of various alternatives. In addition a direct estimate of the energy costs (based on information from the energy certificate) and some basic information about the technical installations in a building can be used to calculate the other costs. For instance: One could use the type and age of the ventilation system to estimate costs related to the Service Life of this part of a building's installations. Based on age and type it is possible to estimate maintenance and replacement costs (and when they will happen in time). In this way, it might be possible to **get a fairly good estimate of the most important LCC elements** of a building.

(2) Only looking at the cost differences: For the purpose of property valuation a LCC analysis (simplified or complete) of a few selected aspects of a building might be enough to get figures with acceptable accuracy. For instance: Two buildings (or the subject property vs. the comparables) are mostly identical, but they differ in the fact that

[80] RICS, p. 15, 5.8.10

one of them has a more advanced ventilation system (with heat recovery) and this building also has windows with better thermal values. In this case the LCCA can focus on the cost differences of these two building parts including the following aspects: What is the residual service life of these two types of components (using the Service Life Planning approach addressing under 5.3.1)? When do we estimate that they have to be changed at which cost? What are the maintenance costs? Does the usage of these two components imply other costs? In addition the valuer can use the information on calculated energy use (resp. consumption) from the energy certificates. Based on this approach it is possible to get an **estimate of the *difference* in LCC costs** – based on a comprehensive assessment differing components and building parts and their total implications for overall costs (energy and other costs).

5.3.2.3 LCCA supporting software tools

In the future valuers will be able to gather a lot more information and computations will be simplified if well-structures Building Information Models (BIM) are used more frequently. If this were the case, simplifications might not be necessary and a full LCC may be much easier to do. With sound data-basis of building related costs and coherent tools for assessment a lot of the “heavy lifting” connected with LCCA can be done automatically, but of course competent valuers will still be important – it just simplifies the job and makes LCC much more accessible for valuation. One might also use the BIM to create the energy certificates using energy simulation software so that in the future relevant information will be available in an “as-built” or “as-maintained” BIM.

BIM are helpful for all three major property valuation approaches:

(1) If one uses a BIM based LCC/valuation tool for the Cost Approach then the identification of plausible replacement costs will be easier. Under certain assumptions one can do most of the calculations automatically by looking up the relevant values in a database – and adjustments for cost based valuation taking into account that high energy performance can imply low depreciation can also be calculated more easily.

(2) If a BIM is available for the Sales Comparison Approach it will be possible to use software to semi-automatically calculate (a) the value of a property based on key aspects of other properties that are considered comparable by the software, and (b) how large the adjustments due to differences in energy performance/LCC aspects should be.

(3) Since the Income Related Approach is closely related to the discounted cash flow approach used in LCC, this approach is the easiest to integrate with LCC/Energy performance in. Based on BIM and LCC/SLP software one can estimate the operating/maintenance/replacements costs and include this information in the DCF using information from LCC/SLP databases. This approach is described in more detail under chapter 6.4.3.2.2.

5.3.3 Will valuers more frequently use LCC in the future?

Whether valuers will use LCC in the future depends partly on the demand for this kind of information in the market place, and also on possible changes in the requirements. Most likely the adoption of LCC in valuation will depend on the following factors:

The importance of LCC information in **estimating the market value of a building**: This depends partly on impact of LCCA on the total estimated value of a building and partly on the fact that only a well-structured LCCA makes transparent cost differences which at the moment are not really available for the valuation process.

Normative regulation in the future: Here the question is, if the law or standards will require this type of information (see chapter 7 on a “road map” for the transfer of the approaches developed in this report into the normative and standardisation process at different levels.

How **time-consuming and difficult will it be to do a LCCA**? This depends on development of software, the availability of cost drivers (derived from a serious a previous analyses), and availability of coherent and comprehensive Building Information Models for new and existing buildings.

The level of energy prices and other operating cost elements in the future, and also the uncertainty of these cost elements.

Training: Will the professionals doing valuation have knowledge and competence to do a LCCA effectively?

In any case there is a need for **easy applicable LCCA tools**. Examples of LCCA models for the calculation of operational cost of buildings are included in Appendix A.

5.4 Gap between current valuation approaches and EPC resp. LCCA (deliverable 5.1)

Key Facts and Findings

- So far there are no specific concrete approaches available that describe how one could value the energy efficiency and the overall "green" performance of a property. No detailed guidance exists how theses aspects could be taken into account in the course of property valuation.
- RICS Valuation Information Paper No. 13 provides a good basis for qualitative integration.
- Various research projects are underway but clear guidance for daily business is still missing.

Major current gaps for an integration of EPC and LCC into property valuation are as follows:

- The energy performance indicators presented in the EPC need interpretation and cannot be used directly for property valuation purposes.
- Although in principle there is a quite direct link between LCC and valuation (mainly income related approach), LCC needs simplifications (focus on operating costs) and support by a well-structured software-tool in order to become applicable in the property valuation process.
- For valuers it is unclear which part of information from the EPC or from an LCCA is the important one from the perspective of valuation.
- There exists a general knowledge gap between valuers, energy experts and LCC experts; therefore knowledge transfer and training are required.

5.4.1 State of the art in valuing energy-efficient resp. green buildings

To summarise the previouse chapters in general: there are no detailed investigations that exist thus far, which describe and illustrate in an appropriate manner how existing property

valuation methodologies can be applied with regard to the energy performance and efficiency of a building.

So far, alternative approaches such as the Triple Bottom Line[81], which tries to measure green features on a more holistic level by taking social, ecological/environmental and community performance factors (adjacent to economic performance of an asset) into account, is generally not recognised by the real estate protagonist at the present.

Results like the latest RICS report are in line with the findings of this study. However RICS guidance is a more general/verbal support for valuers to address the "right thing" but operational methods for calculations are still not given.

LCC or LCCA itself does not identify further energy performance indicators such as the EPC which directly influences the property's value, but can be used as an analysis tool that supports the valuers in estimating of future benefits due to energy efficiency and other building related improvements. This might be useful especially within valuation approaches where an adequate modelling of future cash flows is required (e.g. DCF-approach). Even though LCCA follows the same structure as the DCF-approach and provides valuable information one should state explicitly first that carrying out LCCA is not mandatory and therefore will not be available from every property. Second it is not advisable that LCCA be especially applied just for valuation purposes since it might be too costly.

"New" valuation methods are not needed

Due to findings of preliminary investigations, it seems to be very likely that the general valuation methodology will remain unchanged and just few input variables and parameters need to be modified – or in other words: need to be derived in a new way – to account for energy-efficiency or sustainability in general. The scope and range of these modifications will differ:

(1) in **time**: where we expect a premium for energy-efficient buildings in short to midterm, we see a discount for non efficient buildings in the long-time perspective.

(2) in **location**: because the structure of EPC and the property markets differ from country to country, the modifications of the parameter will also differ. There is no such thing as a static "European Correction Factor" to the energy-efficient property. Further on the level of "energy efficiency" of the non-efficient buildings (peer group) differs also county by country (even old Swedish buildings might have better insulation than

[81] Cf. Eklington, J. (1994), p.90-100

those in Italy). Beside the aforementioned, national legal incentives or punishments as well as consumer sentiment might influence the markets' perception in different ways.

(3) in relation to society's **expectation**: even if the modifications reflect a change in value, the overall changes might not be as high as politicians and society expect. Other factors potentially still overlap the influence of energy efficiency and sustainability in general – like e.g. partly bad economic climate.

Interestingly, the UK government invited RICS to explore the extent to which energy performance is reflected in the value of a property as a result of the installation of different energy efficiency and renewable heat and energy technologies. This underlines the rising importance of incorporating and implementing buildings' energy performance and efficiency respectively EPCs and LCCA into property valuation practice.

Clear guidance for daily business is still missing

So far there are no concrete and specific approaches available that describe how energy efficiency and performance of a property could be valued and taken into account in the course of property valuation. While a few theoretical elaborations exist, they mostly do not explain practical implementation and application possibilities. Other more general guidance notes, like the RICS Valuation Information Paper No. 13,[82] are also lacking a well-structured practical approach.

Even though the LCCA follows the same structure as e.g. the DCF-approach, such aspects are unconsidered so far.

Instead, it is usual in common valuation practice to use general benchmarks derived from general sources or just apply a differentiated extrapolation of operating expenses and other value-relevant life-cycle-costs including energy cost.

5.4.2 Gap and required investigations

When discussing the issue of green or energy-efficient property valuation, one must always keep the fundamental guiding principal that **"valuers just reflect and do not make the market"** in mind as well as taken into account whether or not one has considered modifications to property valuation approaches due to energy efficiency and performance.

Valuers reflect the market

[82] RICS, (2009), p.11ff

The idea of applying a reference building to quantify the extent of which a specific building achieves a specific green building or energy-efficiency performance standard, as it is often used in EPCs, seems to be as well an adequate method for application within property valuation on the first site. However, one must mention that the method of reference building applied in EPCs refers to a general mean value or energy performance standards, whereas **for valuation purposes the "reference" always refers to a mean of comparable properties**. Comparable property in this case means properties that are in all characteristics completely like the property being valued (e.g. construction age, use, location, etc.) and just differ with respect to their energy performance and efficiency aspects or few other aspects that the valuer may consider for adjustments.

"Reference" building for EPC is not automatically a "Comp" for valuation

The suitability of sustainability issues, LCC and EPC for property valuation still require the following:

(1) Support the awareness and increase the general understanding of property valuers regarding sustainability issues, LCC and EPC information that could be used for property valuation,

(2) Further investigations on the quantitative effect of sustainable and green property features, etc. are required,

(3) Reveal concrete and hands' on linkages between LCC and running operating and maintenance costs, and

(4) The development of a common ("easy to handle") structure for direct integration of EPCs in standard valuation processes.

5.4.2.1 Gap between valuation and energy performance certificates

The current major gaps are as follows:

(1) There is no direct link between valuation and EPC, i.e. the energy performance indicators presented in the EPC need interpretation;

(2) There is no coherent information resp. approach on which parts of the EC should to be integrated into property valuation;

(3) The quantification of cost indicators for specific energy-efficient building improvements, etc. is not a valuers' task but rather that of building construction engineers and energy experts;

(4) There is a general knowledge gap between valuers and energy experts (valuers don't have a clue about energy efficiency and energy experts do not know what valuers need – therefore some knowledge transfer is required).

5.4.2.2 Gap between valuation and LCC

The current major gaps with regard to the application of LCCA in property valuation are as follows:

(1) Although in principle there is a quite direct link between LCC and valuation (mainly income related approach), LCC needs simplifications (focus on operating costs) and support by a well-structured software-tool in order to become applicable in the property valuation process;

(2) For valuers it is unclear what information aggregated in usual LCCA tools is important from the perspective of valuation;

(3) There is a general knowledge gap between valuer and LCC experts (valuers do not have any experience with LCC and therefore need training in that field).

5.4.2.3 Required future tasks

One must further increase the awareness of the real estate markets in general and its protagonists (especially the property valuers) towards the increasing relevance of sustainability issues and green building features in order to derive evidence describing the relationship and interdependences between property valuation and green building.,

Further, appraisers should use the services of professional education and as well share their gathered experiences regarding energy efficiency and sustainability in a transparent way with other experts such as investors, energy experts and other green building protagonists to derive a common understanding and clear sense for sustainability and green buildings' principles. Also, green labels and sustainability rating systems must more clearly address the language of the appraisal community in order to be better understood.

Additionally, appraisers and all other real estate professionals should collect and share comparable data and collaborate to push more research work regarding the isolation of value drivers of green features in order to tear down the existing barriers that "sustainable" or "green" still face in the real estate industry. If professionals can collect and share comparable data and compensate for the present lack of information, then reliable and profound

investigations on the relationship between energy-efficient sustainable properties' worth and value will be obtained and impartial market evidence found.

Moreover, valuation standards need to address the "new" topic of sustainable building issues directly in order to help appraisers correctly process the information gathered and show how the green value contribution of a subject property should be discussed in a specific section within the valuation reporting. This aspect is deepened with concrete proposals and approaches in the following chapter 6.

Also regulators and policy makers must help to improve the awareness of a market in transition and support internalisation of external effects to reach a "fair" market value from a social perspective. With this respect, the valuation process must more clearly reflect the increasing importance of CO_2 (carbon) emissions. However, the emission is not directly linked to the energy performance and thus consumption because the CO_2 emission also depends on the energy source used.

6 Integration of LCC and EPC into property valuation approaches (Deliverable D5.2)

Key Facts and Findings

- This chapter presents in-depths and practical approaches for integration based on the findings from different valuation approaches, the information received from energy certificates and from life-cycle cost analyses.
- Since the quantitative calculations represent only part of the valuation report – albeit the most important one – the chapter also includes a section about the introduction of energy performance and LCC information into the qualitative description within the appraisal report.
- Thereupon the chapter presents practically applicable approaches for the integration of EPC and LCC information into the income related approach, the sales comparison approach, the cost approach as well as how can use each approach to calculate property value. For all three approaches the chapter differentiates between well-developed real estate markets and less developed markets (opaque markets). In well-developed markets information related to the property market (and therefore on comparable properties) is transparent and publicly available. In opaque market this information is only fragmentary and leading to a higher degree of uncertainty.
- Case studies demonstrate the applicability and potential results of the integration developed for all three valuation approaches.

6.1 General requirements of valuation methodologies for integration in practice

A valuation methodology must fulfil the following criteria:

(1) Encompass the property market situation in different countries,

(2) Provide objective and comprehensible evidence as well as rational constituted valuation results,

(3) Be easy to handle, fast, feasible, and

(4) Practical and efficient for daily business.

Therefore it it must also be possible to standardize input parameter and the methodical know-how. This refers mainly to the harmonization of the valuation methods, the dataset of input variables, market transparency and consistent terminology.

This means, in regards to the valuation of energy-efficient buildings, that besides including typical factors such as location (micro and macro), economic situation, qualitative building factors (architecture, technical standards, construction quality and age, current and alternative usability aspects, functionality, flexibility, etc.) and quantitative building aspects (rental income, other income producing cash flows, tenant incentives, occupancy rate and vacancy loss, non-recoverable operating expenses, etc.), one must also include energy-efficient building performance aspects explicitly within the valuation process.

Any method developed should be guided by the fundamental valuation principals

In any case; the method or process of the assessment generally needs to identify a benchmark or a sample that could be differentiated into a non-green-segment and vice versa a peer-group for green feature.[83] This is the minimum requirement for the identification of value premium or discount for green or energy-efficient buildings. Such a procedure would be in line with general valuation approaches since the use of a pool of comparables properties (so called peer group or comps) to identify key valuation parameters is a common and accepted method.

[83] Cf. Eichholts, P., Kok, N. andQuigley, J.M- (2008), p.9

6.2 Fundamental challenge when „putting an added value on green buildings“

Key Facts and Findings

- General Discussion → There are three main obstacles for the integration of green and energy performance features into property valuation: Limit of system, limit of focus and limit of evidence, methods and practice.
- **Willingness to pay** → In commercial markets, buyer's willingness to pay and accept a totally rational decision making process based on pure cost/ benefit analysis tends to be much higher than in residential housing markets. However, one must mention that due to the fact that markets do not always behave rationally, the market majority might not be willing to accept e.g. a higher rent for such properties. Consequently, valuers are forced to permanently observe the markets' behaviour and evolution to avoid misleading valuation assumptions.
- **Evolution of Green Value** → In the long run it will be more obvious that there will be a value discount for non-energy-efficient properties instead of a value premium for green or energy-efficient buildings. This is because it is most likely that green or energy-efficient building standard become the usual building code.
- **Knowledge deficit** of valuers regarding energy efficiency and green building aspects → It is essential for valuers to have a basic understanding of the principals of sustainability and energy efficiency and its evolving relationship with properties' value.
- **European-wide vs. country practice** → Due to the fact that the energy performance of a property and its building standards (e.g. EPC, mandatory regulations, etc.) is also dependent, to a certain extent, on national regulations, ecological and economical climate, etc., a European-wide value impact of green or energy-efficient buildings will not have the same impact in different countries. However, it is possible to establish a general framework and implementation guidance as to how valuers might be able to address energy performance and efficiency within property valuation.

6.2.1 General Discussion

The following chapters deal with the fundamental problems of "putting a value on green or energy-efficient properties" and with obstacles that occur when buildings are valued with an appropriate premium or discount.

Concerning the correct integration of green attributes into property valuation, we identified three major difficulties:

Limit of system – negative external effects

The first problem called (1) "Limit of System." The valuer is just focussing on the asset's value, which is reflected in the present value of future benefits for the owner of the property. Hence social welfare in general is not relevant. If, for example, a LEED-certified property has just sourced its construction material in the neighbourhood, it will get credits for this aspect since transportation and the resulting pollution were limited. For the purpose of a property valuation, it is irrelevant if the identical material came from the immediate vicinity or from other countries. Therefore a lot of features that are associated with "Sustainability" and "Green" cannot be relevant to the valuer as long as there is no internalisation of positive or negative external effects. This internalisation could be carried out by policy makers through regulations, penalties, subventions, tax structures etc. Therefore, all social intangible aspects that do not meet these needs are not (and should not be) reflected in property valuation.

Limit of focus – productivity of tenants

Second, we identified the problem called (2) "Limit of Focus," Again intangible values are at the core of this barrier. Looking at the following RICS figures, one problem might be that the green industry fails to address the most important benefits in a transparent way. In most cases landlords communicate energy cost savings instead of productivity gains to the tenant:

(1) Energy costs account for approx. 1 % of the business operating costs,

(2) All real estate costs account for approx. 10 %, and

(3) The staff costs account for approx. 85 % of all business operating costs of an office tenant.[84]

All of the benefits to the user of the property can only have a positive impact on real estate value if tenants show a higher willingness to pay (rent) which will only be the case if they

[84] RICS (2005), p.2

understand that their internal productivity or other aspects might outweigh the additional occupational costs compared to a non-green building..

So far the current awareness of the market for green or energy performance aspects depends strongly on the property market maturity and therefore differs significant between countries. For example, a study by Dr. Lübke GmbH[85] stated that in Germany only one third of the office property market addressed energy-efficiency aspects within the decision making process; whereas two thirds of the market do not reflect such aspects at all.

The first two afore mentioned aspects are not often addressed in discussions concerning the integration of green features into property valuation primarily due to the fact that they do not focus on what the valuer can or must do. While the first aspect will only affect values when policy makers take action, the second aspect regarding intangible benefits to tenants is a task the real estate industry can accomplish through better communication. However, such communications should be addressed by agents, landlords or developers and not valuers. Regardless, it is not the goal of the IMMOVALUE research task or this report to address the explained problems (1) and (2).

Limit of (enough) market evidence

The third problem we identified is called (3) "Limit of Practise/ Evidence and Methods". The question is whether the fast market shifts can still be processed within the traditional valuation methods and input figures even thought market data is still very limited and comparables are rare.

Several authors have pointed out the market evidence cannot be caught by empirical analysis because, by definition, empirical data is historical data. Therefore there exists a considerable time-lag (usually 1-2 years) which is important when we deal with new market trends such as energy efficiency or other sustainability issues. Consequently, these new market trends are underestimated due to the methodology used - and not because of missing market signals[86]

[85] Dr. Lübke GmbH (2008), p.6

[86] Meins, E., Burkhard H.-P. (2009), Der Nachhaltigkeit von Immobilien einen Wert geben: ESI Immobilienbewertung - Nachhaltigkeit inklusive, Zürich.

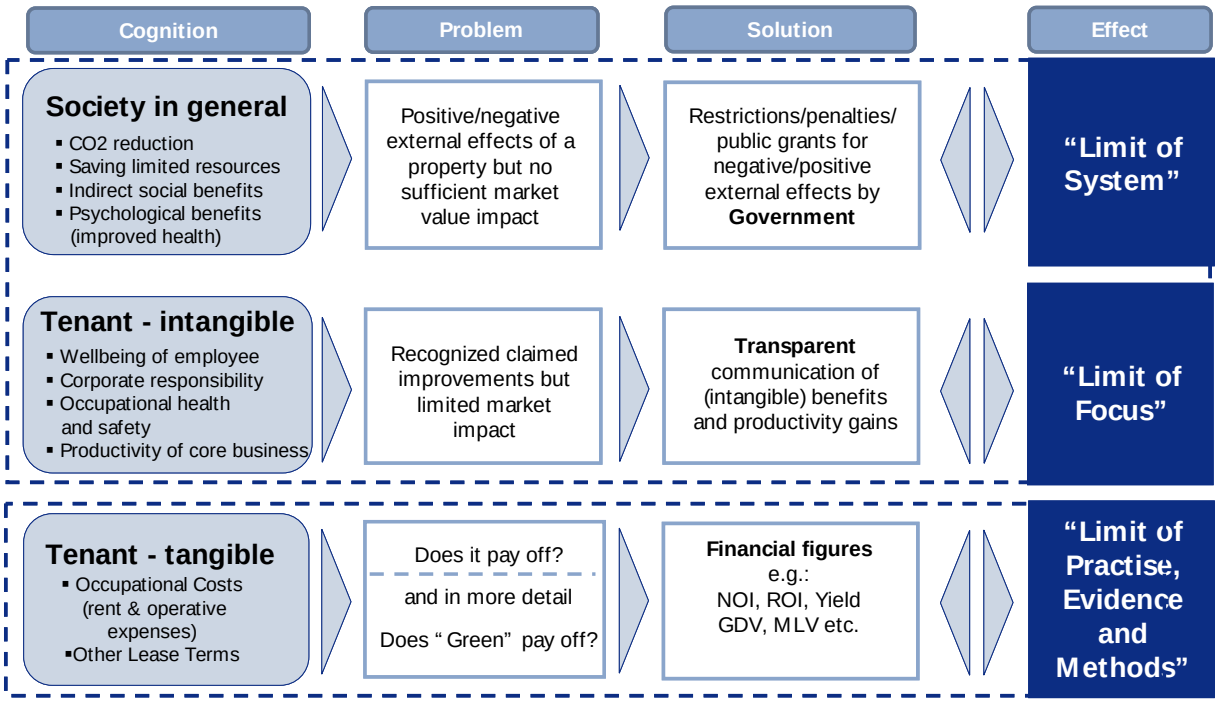


Figure 12: Obstacles for a full integration of green features

Other authors already pointed out yet other obstacles preventing the integration of energy efficiency and other green features into the property industry. The most relevant aspect is the "vicious circle," which this report will describe only briefly. Although one might think it obvious that a low energy building is more desirable than a conventional one and that it is worth paying more to build or rent a low energy building, businesses do not necessarily share this opion when investing in commercial property. Often, this scenario is caused by an underestimation of the importance of energy consumption according to a major investigation of the views of stakeholders in the property business in the UK[87]. While energy efficiency has become an important issue in real estate economy, it is still caught to some extent in a "vicious circle" (compare Figure 4).

"Vicious circle" is slowly disappearing

The introduction of EPC as well as the green discussion and sustainability initiatives gives all market participants a new impulse as it offers the chance to break this vicious circle. Further, it is the valuer's task to improve the communication and understanding of all stakeholders within this industry by providing transparent reports.[88] The authors' point of view is that there

[87] Cf. Wilberforce, R. (2006); Pett, J., et al. (2004)

[88] Cf. Myers, G., Reed, R.G., Robinson, J. (2008), p.300

has been a breakthrough in most developed countries for green-property-features and that the market already left the introductory stages of early adaptors. The benefits for all market participants are becoming more and more transparent and therefore the vicious circle will eventually disappear in the future.

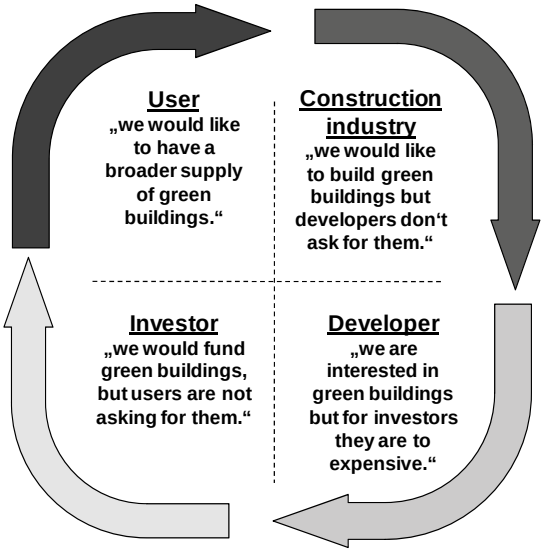


Figure 13: Former “vicious circle” of energy efficiency in real estate economy[89]

6.2.2 Willingness to pay vs. technical aspects and costs

For valuers, the challenge is to isolate and define whether aspects like energy performance, efficiency or a better green building rating (label) of green or energy-efficient buildings can be directly transformed into the (higher) market value of the subject property.

Before digging deeper, one must first understand that there might be a gap between technical aspects (e.g. investment for improving building equipment like HVAC or chillers, etc.) on the one side and the willingness to pay for such “greening” improvement by the tenant, property market, etc. on the other. It may be the case that the investments, improvement, integrated equipment, etc. are not equitable to the achievable energy efficiency levels or market premium of that property.

Cost is not value

A lot of the existing research work concentrates on the premium of certain green building labels (such as LEED or BREEAM, etc.) that might be observed in the marketplace. Future

[89] Wade, J., et al. (2003), p.12

work must also focus on the disaggregated input data that makes up the overall value premium in order to move one step further.

Premium or discounts are dependent on many factors

RICS explains that the green premium has a positive correlation coefficient with the location. Results indicate that the:

(1) Premium is higher in lower quality locations,

(2) Premium is higher in regions with more extreme weather events.[90]

Further, some differentiation must be established between:

(1) Markets for private homes/ flats and

(2) Commercial real estate markets (e.g. office or retail properties).

Differentiation between sectors is necessary

The willingness to accept a totally rational decision making process based on pure cost/ benefit analysis tends to exist primarily in commercial markets as opposed to residential housing markets. Moreover, it is likely that in net lease-orientated property markets (tenant pays in addition to rent some or all property expenses) evidence of rental changes due to energy-efficient buildings might be more rapid than in gross lease-orientated markets (tenant just pay flat rental amount, owner carries all charges incurred by the ownership) because of the direct monetary benefits for the property investor or owner. Other real estate experts such as e.g. Reed and Wilkinson[91] also share this hypothesis.

Regulated markets behave differently

Furthermore, in some markets the government controls the rent levels and defines rental caps for certain buildings. If these buildings are highly energy-efficient, tenant may enjoy lower operating expenses without higher rental income or value for the owner.

Taking the above mentioned aspect into account, one must inevitably focus on the disaggregated input data instead of having an overall premium for a certain green building label.

In extreme situations the value premium might be even higher than the green cost due to psychological effects. For example: a driver purchases an expensive car with a more efficient

[90] Cf. Eichholts, P., Kok, N., Quigley, J.M. (2009), p.23

[91] Cf. Reed, R.G., Wilkinson, S.J. (2005), p.346

diesel engine although the owner is going to drive 5,000 km per year, thus the higher up-front investment will not be outweighed by a DCF-pay-off.

In markets with an oversupply the effect will be more intensive than in markets that are rather undersupplied, since consumers will have to accept less quality to get any product. The unique economic climate following 2008 also affects consumers' willingness to pay since consumer needs in an economic crisis are much more basic.[92]

Physiological effects & the current market state influence the impact of energy-efficiency

In example, at Kennet Island the developer St. James investigated the consumers' willingness to pay for green residential development (Eddington, 2009[93]) and found out that despite the fact that there is a significant degree of goodwill towards sustainability a totally rational approach for pricing was not possible since (1) private owners do not usually perform a full DCF or LCC analysis to recognize all benefits and (2) banks (at least at that point in time) tend to not fund more money for the same size of building just because it is sustainable.

Taking the cost/value discussion into account, one must also understand that green-properties with rental premiums might nevertheless not pay off because the initial cost of the investment might be much higher than the present value of the rental premium.

To convince developers, investors and users that green premiums are a fact, such premiums must first be be identified by hard market evidence. The willingness to pay reveals the benefits. Since incurred cost of energy-efficient improvements do not necessarily translate into value premiums, one must be careful how to approach the topic

One must perform the assessment of green values in two steps:

(1) Identify if there is any premium (or discount)

(2) Quantify the delta

Further, Myers[94]revealed another reason why limited market evidence for rental or value premiums are observable despite the fact that green or energy-efficient buildings are accepted by the property market.. Myers stated that there are still inherent barriers between design and construction aspects of green or energy-efficient building that make comparison of green buildings difficult. As a result, there is little adequate or reliable evidence for value impacts.

[92] Cf. WBCSD (2009), p.7

[93] Cf. Eddington, C., Berman, D., Hitchcock, D., et al. (2009), p.10 et seqq.

[94] Cf. Myers, G., Reed, R. and Robinson, J.M. (2007)

The market does not always behave rationally and therefore it is possible that, even thought there are figures available which state a premium for green or energy-efficient buildings, the markets majority might not be willing to accept e.g. a higher rent for such properties. Consequently, valuers are forced to permanently observe the markets' behaviour and evolution to avoid misleading valuation assumptions.

6.2.3 Evolution of green value

The introduction of gradually strengthening regulation (e.g. EPCs) of new and existing building stock will eventually lead to more awareness regarding a building's energy performance and efficiency. This means that labelling and certification systems using independent information will be used more often, regulations on energy codes will become stricter and subventions and tax relief might be applied when building energy-efficient houses. Some experts already claim that the next big growth path – the next Kontratjew cycle – will be "green", which would of course further support an increasingly rapid change of market sentiment and perception of sustainability:

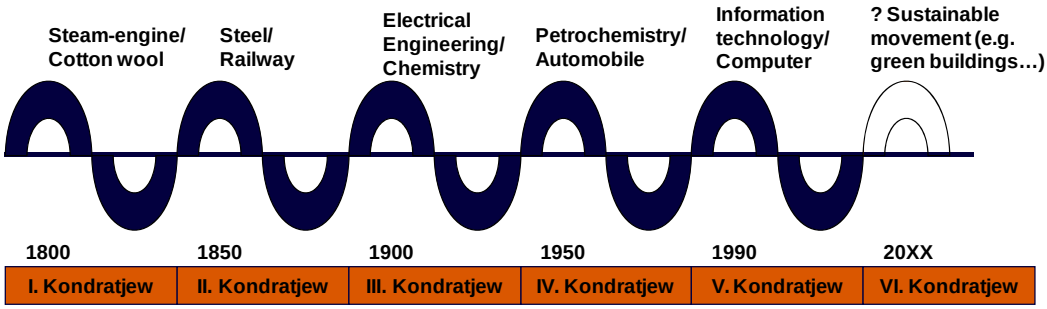


Figure 14: "Green" Kontratjew cycle?

Gradually increasing transparency might lead to bigger impact on values

Even if there are some examples of green-features that lead to a rising awareness and might lead to an added green-value as stated previously, there are still a lot of obstacles. Since markets shifted fairly quickly in some cases, market data is in most regions still limited. Even though one can see a positive exception within Australia and to some extent the United States of America, experts still claim that in these markets relevant data is rare[95] (For e.g. "Green

[95] Cf. Muldavin, S. (2008); or Bienert, S., Schützenhofer, C. and Steixner, D. (2009)

Star" in Australia was introduced in 2000 and now already accounts for approx. 30 % of newly constructed commercial buildings. In the US already 10 % of all commercial buildings are to some extent sustainable[96]).

Changing human needs affect values

In general, the development and evolution of green or energy-efficient properties and the current situation of valuation will not be a static issue but rather a more a dynamic process, which means that changes to value happen permanently over time due to changes in property market's requirements and needs. Lorenz and Lützkendorf[97]share this opinion in their statement that "the value of goods arises from their relationship to human needs, and is not inherent in the goods themselves. With changes in this relationship, value arises and disappears." Nowadays, highly energy-efficient buildings with low energy consumption or a certified green property are starting to represent a unique selling proposition and therefore are likely to achieve an added value. However, the premium is likely to decrease over time and the "product" is likely to become a standard in the future. One can compare this phenomenon to the market evolution of other high-tech products such as LCD vs. conventional TV or an integrated air conditioning system in cars.

Today's unique selling propositions (USP) might be market standard in the future

In the long run it is more likely that there will be a discount for non-energy-efficient properties instead of a premium for green or energy-efficient buildings (see Figure 15.

[96] Bowman, R., Wills, J. (2008), pp.4 et seqq.

[97] Cf. Lorenz, D., Lützkendorf, T. (2008b), p.3

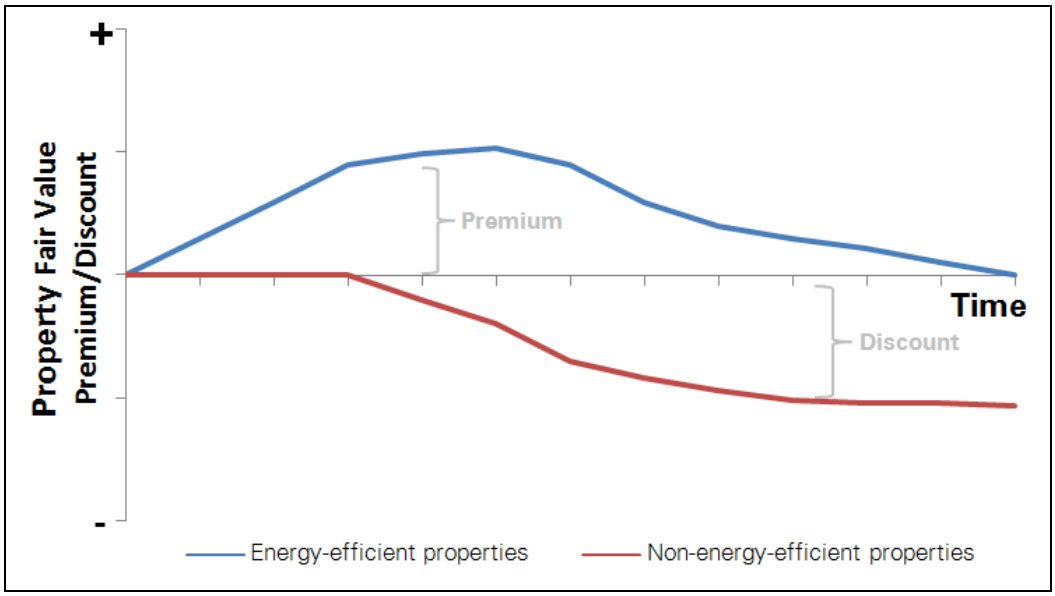


Figure 15: Possible evolution concerning premium vs. discount of energy-efficient buildings

Another aspect one must mention in this context is the fact that that all current studies and debates mainly focus on issues associated with the valuation of new green buildings, whereas the question of valuation for a non-green building might be another challenge with a much greater potential for financial impacts on the property market and capital values.[98]

Improving building and construction techniques will eventually lead to even higher "green standards"

Another difficulty regarding the inclusion of sustainable and energy efficiency aspects in property valuation will be the continuous future changes in the construction and design of green buildings. In 2005 EPC-regulations ranked most of the existing building stock in class 4 and 5..Many expect that due to tougher building codes, higher quality of the used materials and increasing energy costs new properties will possess a higher standard of energy efficiency and therefore fall into a better class such as 1 or 2(an average heating demand below 100 $kWh_{pe}/m^2.yr$).

[98] Cf. Parker, D. (2008), p.552

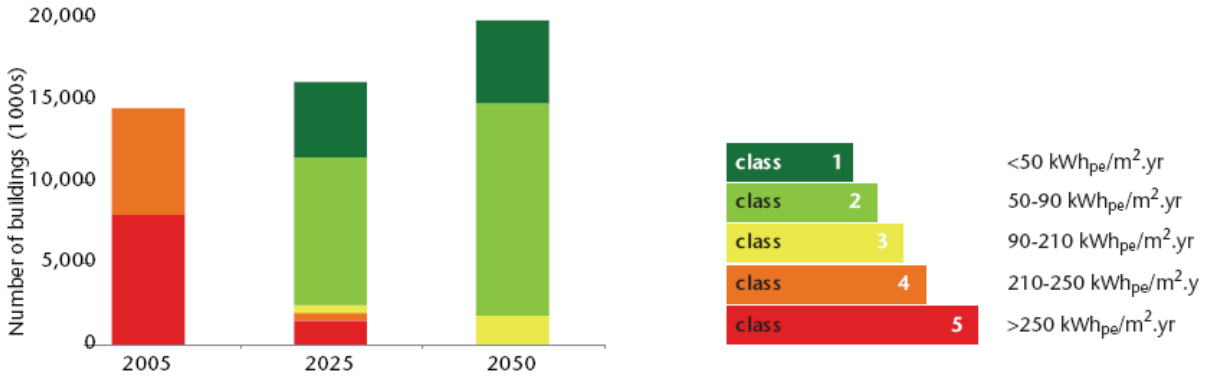


Figure 16 Shifts in building stock energy class under Transformation case[99]

All these illustrated changes due to regulatory actions, building trends, etc. will affect the quantitative impact upon property values. In summary, this implies that one cannot give a general rule for the quantitative (numeric) impact that fits for all markets on property values, rents and yields(e.g. always 20 bps premium on yield for non-energetic buildings). The following figure illustrates the evolution of the development within the building industry regarding “green buildings”:

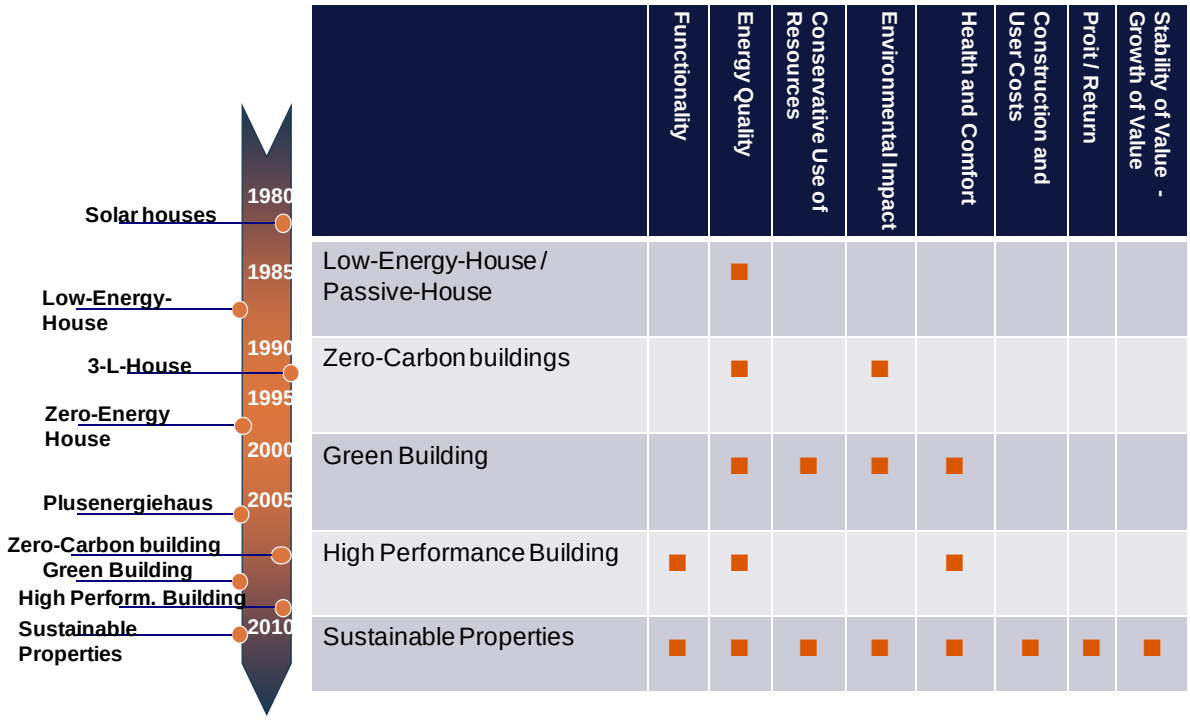


Figure 17 Green building movement

[99] Cf. WBCSD (2009), p.38

6.2.4 Rising use of green building rating tools

In recent years various European property markets have launched a lot of new green building rating tools. The development of implementation systems is higher if the label or certificate is compulsory (e.g. EPC, heat insulation ordinance) and not voluntary (like e.g. green building certification systems like LEED, BREEAM, DGNB). Interestingly, both the government as well as the industry had a hand the initiation of the labels. Worldwide there are around 20 voluntary rating systems and labels respectively that try to meet the conceptual complexity of the term "sustainability" as well as create standardized product identification, a seal of approval, for green and energy-efficient buildings.

Only few international recognised labels

However, most of these labels have only gained prominence at the national and regional level. Only a few "green rating" labels like BREEAM, LEED, Green Star and CASBEE have gained international recognition and serve as preferred standard for globally operating investors. The current numbers of certified and registered buildings according to these systems are illustrated by the following table.

Current numbers of certified and registered buildings					
	BREEAM	**LEED**	**DGNB**	**Green Star**	**CASBEE**
Number of units certified	~ 110,000	~ 2,700	~ 16	~ 50	~ 25
Domestic	98%	30%	0%	0%	0%
Non-Domestic	2%	70%	100%	100%	100%
Number of units registered	> 500,000	~ 20,200	N/A	N/A	N/A

Table 9: Current numbers of certified and registered buildings (as of April 2009)

As one can see in Table 9 the number of units registered is actually five to ten times higher than the number of units already certified. The international certification label LEED, for example, shows an intensive use in the last few years.

Registration boom increased throughout the last couple of years

The number of registered projects has tripled, particularly between the years 2006 and 2007, with a high proportion of registered buildings outside the United States – another hint that the broader public already demand greater transparency and cost/benefit analysis of sustainability aspects.

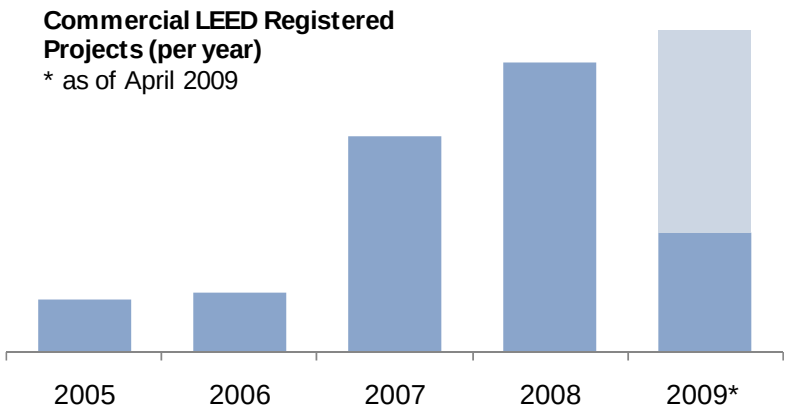


Figure 18 History of LEED registered buildings[100]

One can expect a considerable increase of certified buildings can be expected in 2010/11 due to the relatively long time frame between the project start (registration) and the beginning of operations (certification) of a building. In recent years, the cumulative amount of certified buildings have developed in a more or less consistent pattern as can been seen in Figure 19.

Figure 19 History of LEED certified buildings[101]

Due to the previous non-existence of their own certification and labelling system, a lot of European countries decided to implement LEED. Here the number of registered and certified buildings is also rising at a tremendous rate over recent years. While in 2008 there were no LEED-certified buildings in Germany, as of the middle of 2009 a total number of 74 projects

[100] cf. N.N., 2009, www.usgbc.org; RICS Research (2010)

[101] Cf. N.N., 2009, www.usgbc.org; UNEP (2010)

registered their buildings and have already begun the necessary documentation. The following map gives an overview of current LEED projects in some European countries.

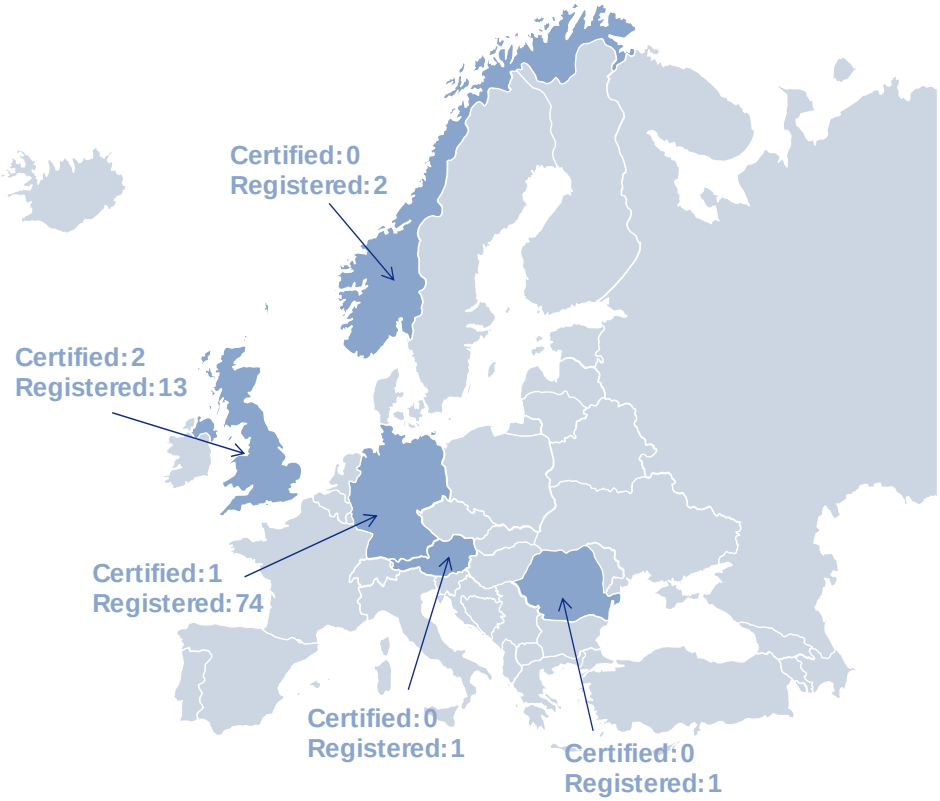


Figure 20: Overview of current LEED projects in some European countries[102]

Additionally, most of the existing green rating tools also cooperate. For instance, LEED, Green Star and BREEAM are developing a common method of measuring carbon emissions from new buildings. This cooperative attitude is based on the precedent that the bulk of these tools were developed and shared using multiple rating groups affiliated through the umbrella organization “world green building council”:

Figure 21: World Green Building Council

[102] Cf. N.N., 2009, www.usgbc.org

Value Impact of green rating tool is comparable to EPC

In the context of property valuation, the questions that arise in this respect are identical to those in the case of EPC. The valuers need to extract information that reveals and isolates figures and value drivers resulting from the energy efficiency stated in the label and the labels overall impact.

Due to recent developments in the field of sustainability and energy efficiency policies (e.g. introduction of EPCs), Many expect that low energy or passive housing standards become mandatory and ultimatly the new building standard/code in the long run. How this evolution will affect the above stated enforcement of voluntary green building rating tools, and further, whether green building rating tools might lose importance in the long run is unclear. Furthermore, there is no evidence available so far whether the introduction of EPCs will influence the currently tremendous enforcement of green building rating tools, or if both tools will coexist. Many expect that the EPCs will become more important in the long run due to related mandatory regulations (e.g. EPBD, etc.). Moreover, many also expect that current EPC will evolve further and may incorporate green building rating criteria and aspects.

6.2.5 Rising sensibility for Corporate Social Responsibility

Another driver which one could be regard as a proxy for the evolution in this process is the growing interest in corporate social responsibility (CSR) and within this context, corporate sustainability issues.

CSR has become a normative standard concerned with the integration of environmental, social and economic business strategies and practices.[103] Therefore, CSR describes firms' choices about inputs (e.g., the source and mixture of raw material), internal processes (e.g. the treatment of employees), and publicity (e.g., community relations). As Jones, et al.[104] conclude, with research that there is no common approach to CSR but rather a considerable variation in the nature and extent of the CSR issues. The following table illustrates the difference between CSR reporting and obligatory reporting according to leagal requirements today:

[103] Cf. Jones, P., Comfort, D., Hillier, D. (2006)

[104] Ibid, p.148

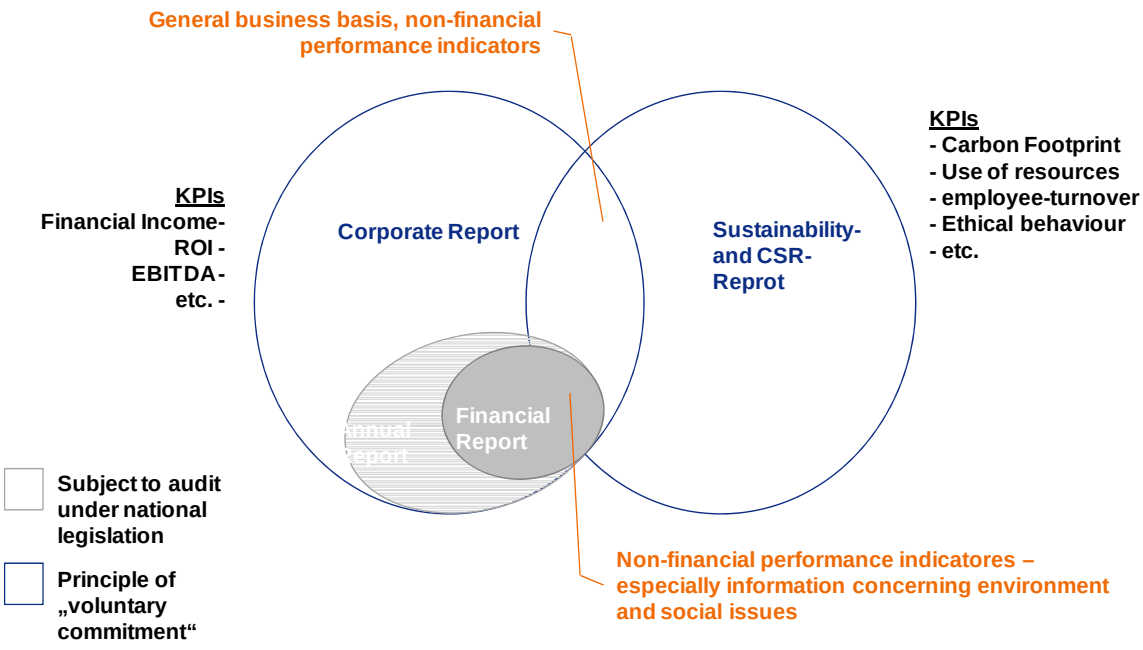


Figure 22: CSR and corporate reporting today[105]

CSR supports the implementation of sustainability aspects within companies

Although sustainability as a principle within the philosophy of a company is still a voluntary commitment, it is becoming more and more of an integrated element in companies' business plans and annual company statements. Beside monetary key data like turnover, internal rate of return and non-financial figures like e.g. the status of employee's illness or the reduction of CO_2-emission can demonstrate the success of a company. These aspects enable not only a sustainable relationship with employees and clients but also engender the trust of investors and creditors. Prospective firms already know that intelligent clients also set up their buying decisions on the eco-political and social engagement of their business partners.

One can expect to see regulation requiring large companies to report on social responsibility as a legal obligation in the future. In some countries non-financial performance indicators are already regulated by law (e.g. financial accounting changing law in Austria, called "Rechnungslegungsänderungsgesetz - ReLÄG").

Major companies just rent LEED-certified properties

In the real estate sector, the issues regarding eco-efficiency are mainly focused on the energy efficiency of buildings, the provision of a healthy and pleasant indoor air quality and on the

[105] Cf. GRI (2002); KPMG (2010)

initial investment and consequent operating inputs chosen to maximize investor returns. Some internationally-active companies like Siemens, SAP, Marriott, Nokia, Wrigley, etc. have set a global commitment to just hire or invest in LEED-certified buildings with a minimum certification level of silver. In addition to the expected reduction in operating costs due to these properties' efficiency, such firms also hope to garner a positive image effect and a better reputation in the market.

6.2.6 Knowledge deficit of property valuers regarding sustainability issues

In order for the valuer to provide adequate information about expected value of a green or energy-efficient building, it is essential that valuers have a basic understanding of the content and measurement of various green building features, and buildings' energy performance and efficiency. As e.g. Fisher et al [106] conclude, it is important that valuers ensure that they understand the principle of interdisciplinary focus on sustainability and its relationship with properties' worth and value.

Appraiser's knowledge of sustainability issues needs to be improved

Several observations by e.g Ellison and Sayce[107], or Warren-Myers and Reed[108] indicate – regardless of the region and country – that valuers in general have a large knowledge gap in terms of their background regarding sustainability issues. In particular the tendency to rely on industry rating tools like the overall result of a green building label seems to be worrying; taking into account that their understanding of differences between the content of tools/ results is fairly poor. Most research results indicate that the transparent communication of the green building features and not the applied green building rating tool and its aggregated result have an impact on the market value.

It is important that valuers overcome the knowledge gaps stated above to improve the integration of buildings' energy performance and efficiency into property valuation practices and linkage to EPCs and LCCA. Valuers could reduce this gap through professional training, participation at discussions and interaction with energy and sustainability experts.

It is the national and international property valuation association's task to offer specific education programs and seminars in the field of real estate sustainability (energy performance

[106] Cf. Fisher, R., Coll, L., Pelly, L., Percy, J. (2008)

[107] Cf. Ellison, L., Sayce, S. (2006)

[108] Cf. Warren-Myers, G., Reed, R. (2009)

and efficiency, carbon emission, LCCA, etc.) and its impact on property markets and property worth and value.

6.2.7 Country practice vs. European-wide common practice

Energy performance of a property and its building standards (e.g. EPC, mandatory regulations, etc.) are dependent, to a certain extent, on national regulations, ecological and economical climate, etc., and therefore vary between countries.

Beside the aforementioned, there are a couple of other reasons why country specific practices might be necessary:

(1) Different types of indicators used in EPCs (e.g. net heat demand, final energy demand, carbon dioxide emission),

(2) The general heterogeneity of EPCs (e.g. different illustration and labelling)

(3) Differences in value composition of energy performance indicators (e.g. final energy consumption) used in EPCs,

(4) Different calculation schemes and methodologies for EPCs.

Besides the differences regarding the EPC, the embodiment and application of LCCA is not harmonized in Europe. The main reasons for this include the fact that: (1) there are different methodologies and approaches for LCCA available, and (2) LCCA are voluntary and not mandatory and therefore are not regulated.

European-wide practice for integration is difficult to achieve

Consequently, evidence for the value impact of green or energy-efficient buildings must be observed and derived in the specific country and property market. An adaption or application of market evidence for green value impacts derived from other countries with heterogeneous market structures is not advisable and would possibly lead to misleading results.

Common framework for European-wide applicable methodologies

Even though there are differences, it is possible to establish a common framework and implement a guidance note on how valuers might be able to address energy performance and efficiency respectively EPCs and LCCA within property valuation and its reporting (see Chapter 6.3 and 6.4). Essential aspects are summarized in the following figure:

Figure 23: General findings / Background

6.3 Qualitative Integration into valuation process

Key Facts and Findings

- **Qualitative comments related to energy efficiency** as part of the sustainability characteristics of a property **must be integrated** in the valuation report by the valuer.
- Extension of the building description: a **separate (sub-) chapter for energy efficiency/sustainability** of the building construction and equipment should be inserted in the report structure accordingly.
- Especially if solid **market evidence** regarding teh value impact of good or poor thermal energy/sustainability characteristics is **hardly existing, an in-depht argumentation** and description **is essential** – especially if input parameters should reflect the green value impact..

Possible useful information sources for valuers might be:

- Energy Performance Certificate (EPC)
- Sustainability assessment tools (LEED, BREEAM, etc.)
- Publications, e. g. **Valuation Information Paper No. 13 published by RICS**
- Energy Bills can give hints about energy consumption and accrued costs if the EPC is not available
- Life Cycle Cost Analysis
- Illustration of the development of the energy costs during the last decade
- Illustration of limitedness of the fossil energy sources

Besides the question of how valuers can encompass quantitative considerations, the valuer may use the descriptive parts of the report to specify and demonstrate the energy efficiency of the property being valued, and form that basis, perform further calculations.

Due to the issue of necessity to integrate sustainability features in a qualitative manner the RICS recently published a Valuation Information Paper No. 13, which deals with the topic of "Sustainability and commercial property valuation." They stated the previously mentioned

point that "[o]ften it may be difficult for [sustainability factors] to be quantified; nevertheless it may fall within the remit of the valuer to provide some qualitative comments" on these issues.[109]

This quote means that in the event that the market and its participants recognize that energy efficiency and/or sustainability characteristics have an impact on the market, the valuer must inform and prepare advice relating to these special issues.[110] Actually, if the market already recognises the importance of sustainability aspects then the inclusion of the quantifiable aspects of sustainability seems indispensable (in chapter 6.4 different methodologies for this possible integration are described).

The forthcoming explanations possibilities to integrate energy efficiency into the valuation report. In the most cases suggestions can be used either for energy efficiency or sustainability in a broader sense, since both aspects are interdependent and in some cases they cannot easily separated.

6.3.1 Descriptive Integration of Energy Efficiency

A valuation report provides the documentation of the valuation process (see Section 5.1) and argumentation for the selection of certain input parameters that the valuer used in the calculations for any property valued. This report is therefore incomplete if it does not cover the aspects of energy efficiency and as well sustainability in the future.[111] If the valuer cannot isolate quantitative market evidence in the case of not-transparent markets, the superior or inferior energy levels ilding must be addressed by the valuer in the descriptive part of the valuation report. Such information regarding the existing energy qualities/deficits of the subject property when compared to its peers may support customer's decision making processes[112] and increase transparency.

In most cases, valuers use a proprietary valuation report that contains a separate chapter with the description of the building components. This chapter, named "Description of the Building," may contain up to 4 subsections (see left side of Figure 24).

In general, the building components (e.g. thermal insulation, type of windows/doors, heating/cooling installations) that are directly or indirectly related to energy consumption by users are already included in the valuation report per se. The question arising in this context is

[109] RICS (2009): p. 3.

[110] Ibid.

[111] Cf. Scherr, H. (2009): p.1 et seq.

[112] RICS (2009), p. 3.

how valuers can approach sustainability or simply the energy efficiency of the property in a more easily understood and replicable way.

Nowadays	Future
3. Description of the Building	3. Description of the Building
3.1 Basic Information	3.1 Basic Information
3.2 Construction and Equipment	3.2 Construction and Equipment
3.3 Shape	3.3 Shape
3.4 Further Information	**3.4 Sustainability/Energy Efficiency**
	3.5 Further Information

Figure 24: Possible Structure of the Building Description Nowadays versus Future

One could reasonably include the description of the building and integrate its energy related features within the chapter "Further Information." However, in order to underline the importance of the building's energy aspects or sustainability issues the valuer should create a separate subsection that could be named "sustainability/energy efficiency" (see right side of Figure 20). The introduction of a separate chapter, however, does not detain the valuer from also addressing sustainability issues in the other chapters of the building description.

Separate chapter for sustainability recommendations

This separate chapter should include the definition of energy efficiency/sustainability in the context of properties and therefore the three main columns of the Triple Bottom Line model: the environmental, economical and social features. The definition of sustainability for commercial buildings published within the Valuation Information Paper No. 13 of the RICS may be helpful in this context. [113]

„[A sustainable] building [...] minimise [s the] environmental impact through all parts of the building life-cycle and focus [es] on improved health for their occupiers [...]. [...] Sustainable buildings should optimise utility for their owners and occupiers and the wider public, whilst minimising the use of natural resources and presenting low environmental impact, including their impact on biodiversity.“[114]

Furthermore, there is an increasing number of sustainability assessment codes/tools already in use like BREEAM, LEED, Green Star, DGNB etc. When one applies such codes to the

[113] Cf. RICS (2009), p. 5 et seq.

[114] Cf. RICS (2009), p. 6.

property under investigation, the code provides the valuer with important information about the sustainable quality of the property.[115]

Besides the building description, one can estimate some quantitative adjustments of some valuation parameters like e.g. the market rent or the maintenance costs of an office building. The argumentation regarding the adjustment and its extent is highly correlated with the corresponding estimation of the particular valuation parameter itself. Therefore one must explain the adaptation within the descriptive chapter.

The following example is given to facilitate better understanding: Valuation of an office building with very low primary energy consumption: the EPC exceeds the national requirements of the comps. The valuer is going to adapt the market rent, i.e. estimates a premium. The structure of the valuation chapter within the valuation report and the estimation of the market rent might be adapted as shown on the right-hand side of Figure 25.

Lacking market evidence requires good argumentation and description

The need for proper argumentation and description is particularly true if little market evidence exists. The lack of market data increases the necessity for further information on sustainability and energy efficiency effects in order to meet the awareness of the market participants.[116] In this case the descriptive portion if the report is more relevant to argue that the subject property is “future-proof“ to a greater degree when compared to the rest of the market.

Another opportunity for the valuer to reinforce his or her decision to set a premium may be e.g. to illustrate the rising energy costs during the last decades, especially in the context of the worldwide decreased of natural energy resources as well as the advantage of the building being valued using alternative energy sources such as photovoltaic.[117]

Highlight Advantages and disadvantages, their middle- and long-term effects to underpin the adjustment of valuation parameters

At the very least, the valuer must show what advantages and disadvantages may arise due to the building components that are liable for the thermal quality of a building and the impact on the future usability of it. In this context, the valuer must assess and discuss some of these aspects:

[115] Ibid p. 6.

[116] Ibid. p. 15.

[117] Cf. RICS (2009)

(1) The floor area in the terms of usability and the possible impact on the overall running costs.[118]

(2) Insulation, its special features (e.g. heat bridges, type of windows, etc.) and the continuity of them in terms of durability, regional and legislative building standards.

(3) Type of energy source with regard in the grade of carbon emissions and the secure of it is continuity, [119]

(4) Water efficiency, especially in locations with scarce water supply, using grey water, recycling of water, etc., [120]

(5) The ability to replace and or perform remedial maintenance on the building components[121](e.g. the upcoming economic effort to replace an oil running heating system against a pellet heater to reduce operating costs due to rising energy costs).

This list contains only a few possible examples. In principal, the valuer is able to use the existing building components in comparison to national and/or international building standards to illustrate which possibilities are given and can be used to upgrade the building and it's facilities as the ongoing awareness of energy efficiency and/or sustainability of buildings improves.

As illustrated, documentation of the market awareness as well as the verification of the parameter market rent, yield, etc. may be extended with separate chapters like "Awareness due to Energy Efficiency/Sustainability" and "Adaptation due to/energy efficiency/sustainability". [122]

Nowadays

7. Valuation - Income Approach
   - 7.1 Description of the Valuation Method
   - 7.2 The regional Office Market
     - 7.2.1 The Investment Market
     - 7.2.2 Rental Market Office
   - 7.3 Estimation of the Valuation Parameter
     - 7.3.1 Market Rent
     - 7.3.2 Operating Costs
     - 7.3.3 Yield
   - 7.4 Calculation

Future

7. Valuation - Income Approach
   - 7.1 Description of the Valuation Method
   - 7.2 The regional Office Market
     - 7.2.1 The Investment Market
     - 7.2.2 Rental Market Office
     - **7.2.3 Awareness due to Energy Efficieny/Sustainability**
   - 7.3 Estimation of the Valuation Parameter
     - 7.3.1 Market Rent
       - 7.3.1.1 Estimation
       - **7.3.1.2 Adaptation due to Energy Efficiency/Sustainability**
     - 7.3.2 Operating Costs
     - 7.3.3 Yield
   - 7.4 Calculation

[118] Ibid, p. 9

[119] Ibid, p. 12

[120] Ibid

[121] Ibid, p. 11

[122] Cf. RICS (2009), p.11

Figure 25: Possible Structure of the Valuation - Nowadays versus Future

One of the most important aspects when one assesses sustainability is the level of energy performance of the building, i.e. its annual energy consumption and GHG emissions associated the energy the building uses. Such information is now included on a mandatory basis by European EPC's (see chapter 6.3.2). One can measure accrued energy costs via from the energy consumption and the tariffs. Further, LCCA may give additional guidance regarding the extent of the accruing energy costs during the whole lifetime and the influence as well as the dimensions of upcoming maintenance costs and special renovation necessary throughout the lifetime of the building (see chapter 5.3.1).

The report should discuss the following sustainability aspects (preferably in a separate chapter):

(1) land use,
(2) design and configuration,
(3) construction materials and services,
(4) location and accessibility considerations,
(5) fiscal and legislative considerations and
(6) management and leasing issues.[123]

The next chapter will gather some possible figures and information that the valuer could integrate into the valuation report if the EPC of the building being valued is exists and is made available.

6.3.2 Possible Considerations of data available from EPC

6.3.2.1 EPC is available

When the building EPC is available, the valuer must carefully analyze the information provided within this document. Furthermore, the valuer should check who issued the EPC not only to make sure it is an official document but also to ensure the credibility and correctness of the data published within.[124] Thus in order to perform this function, the valuer should be informed about the format and content of the EPC as well as the national system that supplies (by local or international experts) and registers EPCs (local authorities, national database).

[123] RICS (2009, p. 8 et seq.

[124] Cf. Scherr, H. (2009), p.2 et seq.

The valuer can use information from the EPC that can be correlated with the national standards over the time, such as:

(1) **Overall energy quality** expressed as an energy mark (0-100) or energy grade (A to G),

(2) Different annual **energy demands/consumptions** at final user (final energy) or total annual energy demand/consumption at the source (primary energy),

(3) **Costs of the required energy** needed to operate the whole building over one statistical year,

(4) **Level of energy loads** in comparison to the current standards in use,

(5) **Year of construction**: What were the energy related standards at that time? For example, what was the thermal quality required at that time for the building envelope?

(6) **Age and quality (efficiency) of the technical equipment** and

(7) **Recommended measures for improving the buildings' energy efficiency** (construction and equipment) and associated annual energy savings and investment costs.[125]

, The valuer should be able to assess the energy quality of the subject property in comparison to the current national energy standards or a given group of comparables based on the information provided by the EPC in different formats in each EU country. Table 10 illustrates one possibility how the valuer can use and aggregate EPC information dependent on the existing main types of energy.

type of energy	thermal	electric	gas	solar	biomass	other
Supplier						
Type and equipment						
Final demand or consumption/m² and year						
Primary demand or consumption/m² and year						
Costs/m² and year						
CO_2/m² and year						

Table 10: Possible Summary of the Output-Data of the EPC

6.3.2.2 EPC is not available

Although already compulsory, there will be still cases where the EPC is not available or not trustworthy. In this case, the valuer should utilize the basic approach of collecting data and information through an in-situ visit of the property being valued. The valuer can evaluate

[125] Cf. Hofer et al. (2009), p.17.

features based on his or her knowledge or he/she can acquire valuable information from the building owner, tenants or technical material.[126]

Inspection, building description / technical equipment and operating expenses deliver important information

In order to get a rough picture of the building, the valuer may also apply simplified measures instead of a comprehensive inspection of the building elements. An example is the so-called "Energy Profile," an approach developed by the German IWU that requires only a few input parameters to get preliminary but already quantifiable information about the building energy performance[127].

Furthermore, valuer can get some references about the average energy consumption of the building with the aid of the effective operating expenses occurred within the last two or three years.

In addition, the valuer can use the results of LCCA calculations in the descriptive part of valuation report to contribute to a more complete property valuation.

[126] Cf. Scherr, H. (2009): p.1 et seq.

[127] Tobias Loga et al., Entwicklung eines vereinfachten, statistisch abgesicherten Verfahrens zur Erhebung von Gebäudedaten für die Erstellung des Energieprofils von Gebäuden, Darmstadt 2005

6.4 Quantitative integration into valuation process

6.4.1 General background concerning the valuation approaches

Key Facts and Findings

- Avoid Redundancies and interdependences when addressing impacts of buildings' energy performance within property valuation.
- As a first step, develop possible theoretical starting-points for each valuation approach and search for market evidence.
- Next, try to find an appropriate approach for developed as well as less transparent (opaque – limited data and market evidence concerning energy-efficient buildings) markets.
- Adjustment of potential gross income - based on the expectation of increased rents in case of lower (recoverable) operating cost and vice versa – is assumed to be a major leverage for the reflection of buildings' energy performance within property valuation.
- Since property valuation in general uses information from comparable reference cases, it is advisable to use cost differences due to specific building characteristics – e.g. the total potential of reduced operating cost, which in a well-informed and transparent market should become transferable into increasing gross income.
- In this context it is important to keep in mind that not the total potential energy cost savings due to energy efficiency might be reflected in the properties market value (premium), because the tenant might bargain regarding the rent.

Besides the qualitative integration of energy efficiency aspects via explanatory notes, the main challenge will be reflecting these findings in adequate, quantitative and profound numerical figures that are suitable for the subject property.

The following approximation technique was chosen in order to find appropriate methods that valuers can use to handle the buildings' energy performance and other related aspects. (see Figure 26). As already mentioned in previous chapters, the scope of this report primarily focuses on the integration of energy performance information (EPC, LCC, etc.) into property

valuation and therefore reduces the complexity through blinding out the more holistic sustainable or green building aspects (e.g. ESD, RPI).

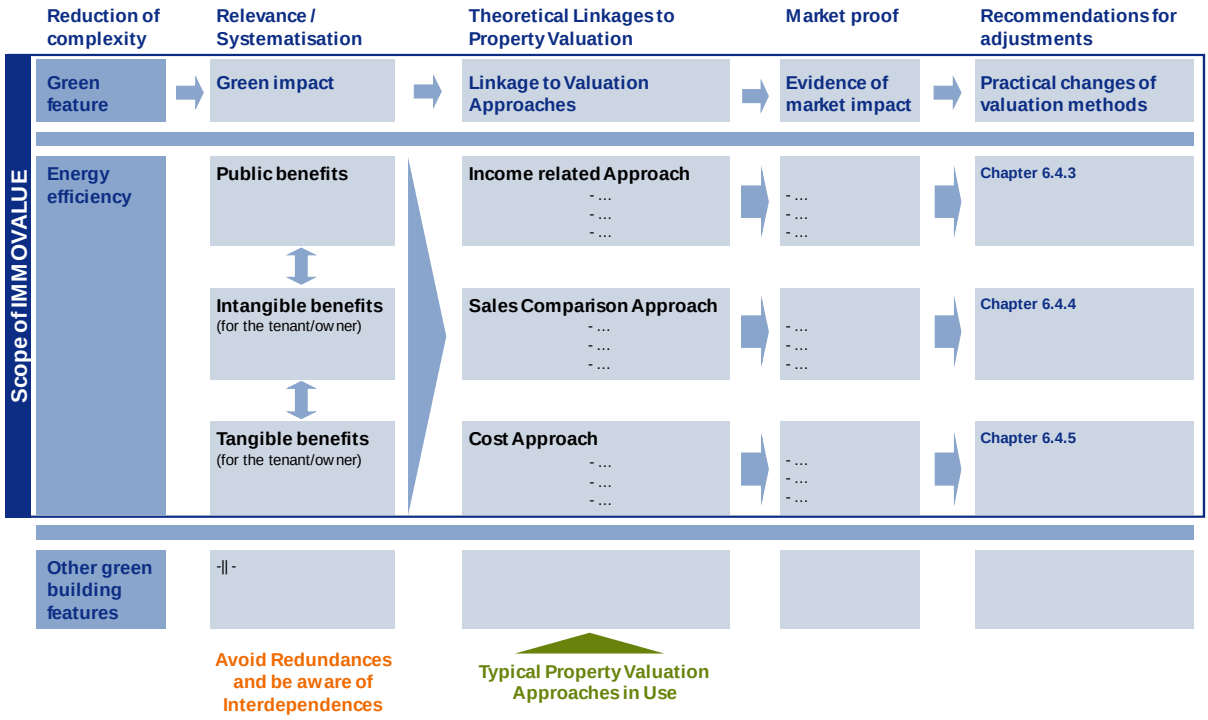


Figure 26: General approach for quantifying property valuation adjustment methodology

First, the valuer must quantify the key tangible and intangible impacts of a buildings' energy performance in order to be able to quantify the possible linkages to each of the three basic property valuation approaches (cost, sales comparison and income approach).. It is also important that the valuer avoid redundancies as well as be aware of interdependences.

Identify green value drivers for each valuation method

Due to the fact that valuers reflect and do not drive the market, the markets' maturity in sense of sensitivity for energy efficiency and related data availability play a substantial role for the broader acceptance of valuation adjustments due to energy-efficient or other sustainable building features in the future.

Make sure modified approach can also be applied in less developed markets

Apart from these general obstacles, the following chapters highlight possible ways that valuers can integrate energy performance features into the various existing valuation

approaches even if market evidence is still limited. Therefore, the following paragraphs differentiate between approaches that one can be apply in "developed" or "opaque" (undeveloped) real estate markets. In following sections, the report addresses a market as developed if profound data on recent sales of comparable energy-efficient properties, rental data and market evidence of energy-efficient buildings' effects are revealed in greater numbers and with higher validity. In contrast, "opaque" and respectively "undeveloped" refers to the absence or limited data and market evidence regarding premium for energy-efficient buildings (e.g. as in Germany or Austria), and in few cases it refers to limited availability of any kind of property market information in general, which is typically the case in emerging markets such as e.g. Belarus or Turkey (see Figure 27).

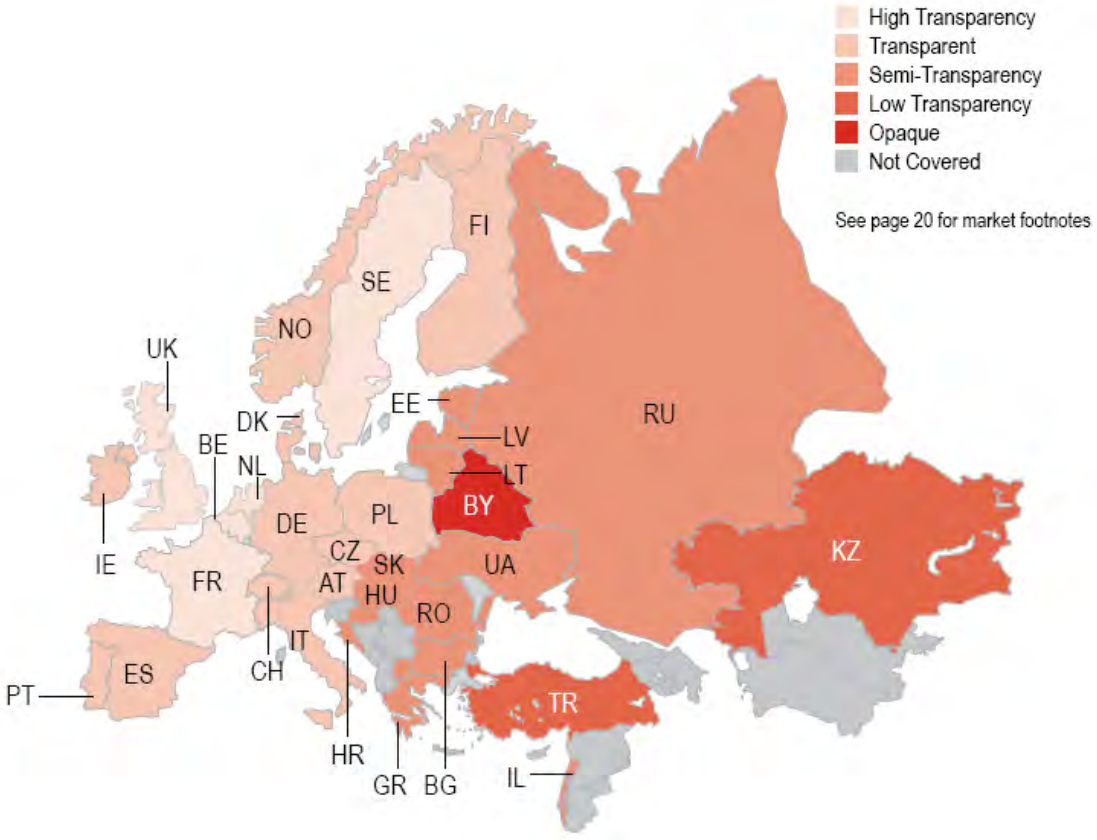


Figure 27: Transparent vs. opaque property markets[128]

To successfully integrate energy-efficient building aspects in the valuation process, one must take into account all stakeholders that are relevant to the valuation results. This means that one needs to focus on property occupiers as well as investors and developers.[129] Further, the

[128] Jones Lang LaSalle (2008), p.11

[129] Cf. Warren-Myers, G., Reed, R. (2009)

developed method used to integrate buildings' energy performance (EPC) and LCCA into any valuation must be simple or at least easy to understand.[130]

6.4.2 Operating Cost as major link between valuation and EPC/LCCA

As described in the following chapter 6.4.3.2, one assumes the adjustment of potential gross income – based on the expectation of increased rents in case of lower (recoverable) operating cost and vice versa – to be a major leverage for the reflection of energy performance resp. LCC of a building within property valuation.

In order to use this leverage, it is necessary to go beyond the usually rather rough figures on operational costs used in current valuations and come up with solid forecast of future operating cost – differentiated into recoverable and non-recoverable cost. As described in chapters 5.2 and 5.3, the information available from the EPC and a LCCA serve as a transparent and traceable basis for such a forecast.

The forecast of operating costs applicable in property valuation mainly includes the following cost elements (compare also the table on LCC cost categories described under 5.3.1):

cost item	description	relevance from an EPC/LCC perspective
Building related facility management costs	Costs for regular and routine activities such as cleaning, inspections, caretaking, management of planned service contract, products or materials used for mentioned activities	A precise analysis of costs for cleaning is necessary with respect to the building façade, since different façade systems (with highly different energy performance) may also show high discrepancies in cleaning cost. In addition the cost for inspection and caretaking will increase with increased complexity of the technical systems in the building.
Utilities - energy, water, sewage	Costs for energy such as fuel for heating, cooling, power, lighting as well as water and sewage costs	Cost for energy can be derived from the EPC – using a careful "interpretation" of the figures from the EPC (see in detail below)
Repairs and replacement of minor components	Regularly maintenance costs defined by value size of area, contract term	As a simplification maintenance costs are often calculated as a fixes share of construction cost. In reality, however, maintenance costs are not a direct function of construction cost but depend to a high degree on the complexity of the technical system and on other building characteristics. LCCA can derive solid figures on expected maintenance cost from comparisons with buildings with the same characteristics (at least in some building elements that are

[130] Cf. Warren-Myers, G., Reed, R. (2009)

		assumed to be “cost drivers”)
Replacement of major system and components	Costs to keep the performance of building elements including design and project management such as exchange roof or facade	For a solid forecast of replacement cost the SLP approach as described in chapter 5.3.1 is very helpful. Also in this case comparisons with buildings that use similar technical solutions for “critical” elements – such as shading systems, ventilation systems etc. – produce traceable cost assumption in this field.
Refurbishment	Costs to improve the performance of a building including design and project management, such as new chillers or boilers with higher energy efficiency	In the context of property valuation this cost elements plays a role mainly in those cases where a refurbishment is needed because of lacking functionality of the old system.

Table 11: Main Operating Cost items

6.4.2.1 Deriving energy cost from the EPC

Deriving energy costs from the EPC in a way that they are useful for property valuation is not a simple task. The following principles are crucial:

(1) The **final energy consumption/demand** – expressing the different energy carriers delivered to the building – is a starting point.

(2) In order to derive actual consumption for a given building one must use the **“tailored” consumption figure** that is calculated with climate, occupancy, and surroundings data **adapted to the actual conditions**.

(3) If comparison with other buildings is needed, one should use **“standard” consumption figures**, based on conventional climate, use, surroundings and occupant-related input data.

(4) The delivered energy **carriers have to be valued with the actual tariffs** in the building or with average energy cost per kWh, which in practice is more applicable since the EPC usually does not contain information on expected load patterns.

(5) The **calculated energy costs** derived in the way described above must be cross-checked with the energy costs from the bills. If there are major differences, the valuer must investigate and explain them.

6.4.2.2 Using cost difference

A “full” LCC is usually very costly and does not help very much with respect to property valuation. Since property valuation in general uses information from comparable reference

cases, it is more advisable to focus the LCCA on cost differences due to specific building characteristics which distinguish the given building from conventional buildings. One can find a more comprehensive description of this approach in chapter 5.3.2.2

A result which can be immediately integrated within property valuation (mainly when applying the income related approach) is the so-called “Operating Cost Saving Potential”. This amount reflects the total potential of reduced operating cost in comparison to a peer-group. This starting point will be further discussed in chapter 6.4.3.2.2 (income related approach for opaque markets). However it is important that one consider the possibility of tenant negotiating within this context. This means that the total potential energy cost savings due to energy efficiency might not be reflected in the properties market value (premium), because the tenant might bargain regarding the rent. Further, due to mandatory regulations (such as e.g. the Austrian tenancy law), just a part of the potential premium or discount of energy-efficient building characteristics might be applied.

In any case, there is a need for easy applicable LCCA tools. Appendix A includes examples of LCCA models for the calculation of operational cost of buildings.

6.4.3 Income related Approaches

Key Facts and Findings

- In general the following valuation parameters within the income valuation seem to be adequate for an adjustment related to green or energy performance aspects:
  - (1) Potential gross income
  - (2) Operating expenses
  - (3) Lease terms and tenant retention
  - (4) Remaining economic life-time
  - (5) Yield / Cap rates
- The way in which energy efficiency and LCC can be integrated in property valuation as well as the way the above mentioned parameters are influenced is dependent on the specific property market maturity (which is the markets willingness to pay for green or energy-efficient buildings).
- DCF might offer more holistic integration possibilities to reflect the impact of energy efficiency and would also allow to linkage to further LCCA-tools or risk analysis.
- Main green value drivers can be classified in tangible benefits (e.g. lower energy costs, maintenance costs, etc.), intangible benefits (e.g. improved occupancy productivity, lower churn rate, etc.) and public benefits (e.g. tax savings, subventions, etc.).
- Modification of basic approach seems to be achieved most likely by adjustment of the potential gross income, the applied yield and the buildings‘economic lifetime.

The income related approach and all its variations are based on the expectation of future rental income, which implicates that these approaches are used for income producing properties such as offices or other commercial buildings. Due to the fact that this approach is the most important valuation approach worldwide, one must pay special attention when quantifying adequate adjustments to link energy-efficient property features to this approach in order to achieve acceptance.

Widespread use of income approaches underlines the need for proper integration of green features

In contrast to the cost or sales comparison approach, the income approach offers a broader range of possibilities for the integration of energy performance information and indicators from e.g. the EPC and their market implications. As it is illustrated in Figure 28 using the example of the direct capitalization approach, one can achive such adequate adjustments by modifying the potential rental income, the operating expenses, the applied yield or adjustments for other value effecting characteristics.

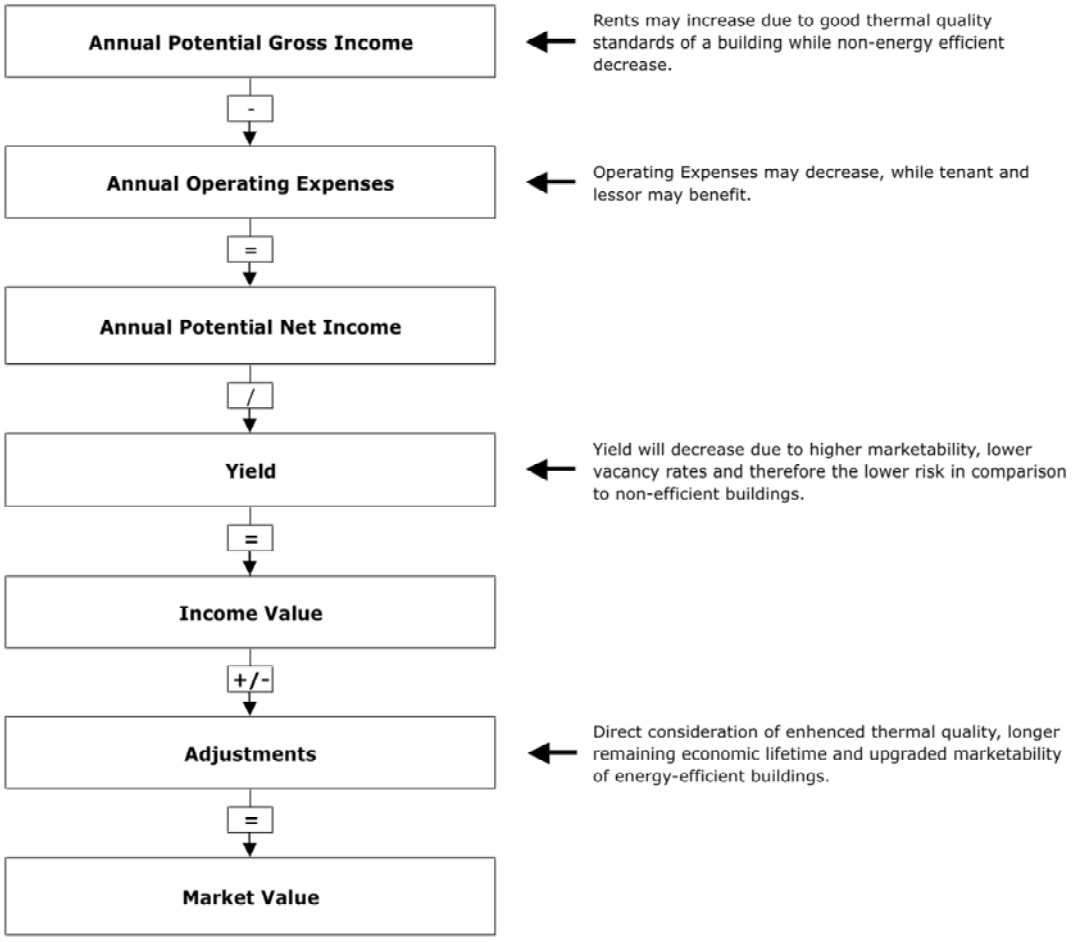


Figure 28: Theoretical linkages within the Direct Capitalisation Approach

One can further address similar adjustment possibilities within the Discounted-Cash-Flow approach. In comparison to the direct capitalization approach, the DCF-approach offers more holistic ways to reflect the impact of energy-efficient building features within the potential rental income and the operating expenses.

DCF might be very helpful for proper integration

This methodology would also allow possibilities for one to link property valuation to risk analysis or LCCA tools in order to model operating expenses, etc. One example might involve using the LCCA as an adequate tool to forecast long term effects related to energy efficiency improvements and investments. Additionally, risk analysis tools (e.g. Monte-Carlo-Simulations, etc.) are sufficient makeshifts to display and derive various scenarios for e.g. growth expectations of energy prices, etc.

In order to decide which adjustments one should apply based on the available information, valuers must be able to discern which aspects are relevant, in which ways and in what quantity. Therefore Chapter 6.4.3.1 outlines in a comprehensive overview the different possibilities.

Furthermore, the quantification of adequate numerical figures for the value impact is dependent on the property markets' transparency (developed vs. opaque property markets). Taking this perception into account, the report will introduce different approaches for developed as well as opaque ("undeveloped") markets (see Chapter 6.4.3.2).

6.4.3.1 Main green value drivers

Before beginning any calculation, one needs to understand the most important "green" value drivers and possible adjustment parameters within the income approach.

Three typical kinds of impacts could be isolated that directly or indirectly influence the properties' value: tangible, intangible and public impacts. All of these aspects persuade different value implications that more or less affect similar valuation parameters as illustrated in Table 12. As stated in the introduction to Chapter 6.4 (Quantitative integration), we use the framework developed and displayed in Figure 17.

Green feature	Green impact	Theoretical linkage: added value to owner?	Evidence of market impact	Recommendation for adjustment
Energy efficiency				
Energy efficiency	Public benefits	• Only if tax savings / subventions etc. directly connected to the property are in place.	If applicable easy to assess.	**Adjustment of income (if clear regulation shows positive effect compared to Peers. BUT penalties for non-green might be more relevant in the future).**
	Intangible benefits for tenants (Improved occupant productivity, lower churn rate, Increased turnover etc)	• Higher turnover rent if applicable. • Generally increased willingness to pay higher rent must be tested. • General lease agreements could be more favourable for owner. • Potentially lower vacancy and collection loss. • Potentially decreasing risk of economic obsolescence and therefore lower yield. • Longer economic life. • Higher marketability leads to faster lease up, lower vacancies and lower fluctuation.	Rare market evidence and difficult to isolate so far.	**Adjustment of income (only if market impact compared to Peers can be revealed).** **Reduce vacancy and collection loss slightly** **Reflect effect of potentially more favourable lease agreements accurate.**
	Tangible benefit A) Lower energy costs (for the tenant)	• Higher rent for new leases (but: bargaining and ending top-slice?) • Higher rent for "prestige"? • Lower yield for future proved property.	Pure cost cutting effect will have an impact but regression etc. must be carried out. „Prestige" probably just a first mover bonus that will disappear soon. Yield impact crucial but hard to isolate. 10 to 20 BP were benchmarks in other markets.	**Adjustment of income (not permanently and not the whole delta and only if leases are actually negotiable)** **(Adjustment in case of gross leases of course bigger!)** **Yield only if at least countrywide evidence can be stated.**
	B) Maintenance costs	• Both way (higher and lower) might be the case depending on the technical level of the building		**Adjustment of maintenance costs in both ways is possible**
Other green building features				
Sustainable site development **(Water efficiency, etc.)** ...	....	....	....	....

Table 12: Overview of green value drivers – income related approach

Tangible refers to direct impacts that effect e.g. energy consumption and costs, maintenance costs, or capital expenditures due to building improvements related to energy efficiency, etc. Usually the valuer can extract such information from the EPC, LCCA or other building information resources. Intangible effects influence valuation parameters indirectly via e.g. occupants churn rates, tenant retention. These aspects are hard to measure and isolate so far. Furthermore, there might be impacts of public origin such as tax savings or subventions in the future due to specific mandatory energy performance standards, which also influence the value.

Based on the figure above, one could also construe that the adjustment of rental income and operating expenses are the most likely. However, in which way and to what extent EPCs or energy efficiency will influence these parameters has yet to be verified and quantified.

Even though various studies have already tried to quantify the impact of green or energy-efficient properties, they are not usually detailed enough (see Chapter 5.1) and invariably dependant on their respective market of reference.

The following chapter 6.4.3.2 will analyse the parameters where an adjustment under certain circumstances is recommended in detail and explain how the valuer can process information.

6.4.3.2 Derivation/modification of basic approach for integration

In general, the income related approach express forecasted and discounted revenues more or less. The appraiser uses the estimated rental value (ERV) based on market-data and currently available rental information in order to determine the gross potential income of the property being valued. The motivation for integrating the EPC at this point of the valuation process relies on the fact that the energy efficiency level of a building might influence the tenant's willingness to pay in the long run.

The following potential linkages are specified to show the range of possible valuation adjustments within the income related valuation approaches in order to provide the reader with an overview of how valuers might quantify and integrate such factors into property valuation.

Adjustment of the potential gross income

First and foremost, if tenants have to pay a lower energy bill then they might be willing to spend the delta on the actual paid rent (here the potential gross income).[131] The basic hypothesis behind this assumption is the fact that that tenants benchmark their total occupancy cost rather than just the rental payment (see Figure 29).

This hypothesis is strengthened by the expectation that in gross rent-orientated property markets where evidence of rental changes due to optimized energy-efficient buildings should be forced more rapidly than in net rent-orientated markets because of the direct monetary benefits for the property investor or owner.

[131] Eddington, C., Berman, D., Hitchcock, D., et al. (2009), p.3

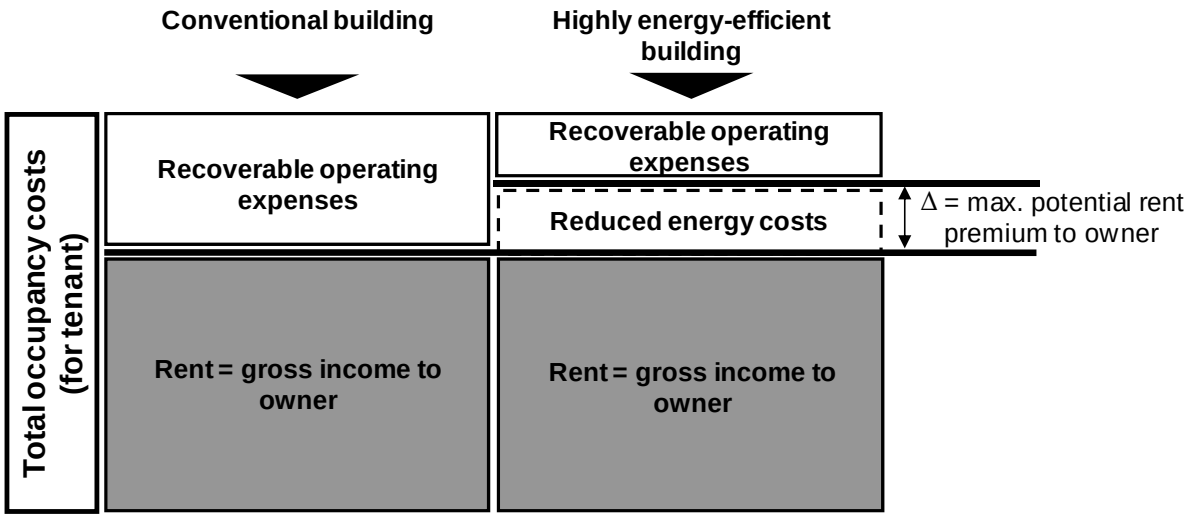


Figure 29: Theoretical potential rent premium

However, tenants will probably bargain. Therefore the reduction might only lead to a reduction in overall occupancy costs for the tenant but not necessarily to a higher rent for the landlord.

Furthermore, energy efficiency can also, to a certain extent, influence the non-recoverable operation expenses (the costs that cannot be passed on to the tenant) due to the fact that energy-efficient buildings might achieve longer economic lifetime, increase tenant retention and therefore reduce vacancy rates and imply lower maintenance costs.

Also, higher demand fo with energy efficient buildings might lead to a higher tenants' willingness to pay just because these buildings are more "prestigious/desirable," while rents for buildings of a poor thermal quality tend to decrease. In this case the question is for how long the tenant might want to pay this premium, since every new product or idea will lose its´ "bonus" over time.

Also, it is very important that one consider the fact that all of the above mainly refers to new lettings / new tenants. During the term of a rental contract there will probably only be a few cases where the chance to increase the rent just because the thermal quality has been improved. In a lot of countries more obstacles of this kind might arise. There could, for instance, be laws in place which prevent the owner from increasing the rent for new leases if the house has a certain age no matter how much the owner invested in sustainable features.

To what extent the net rental income will increase compared to non-green/non-energy-efficient comps is not predictable on a general level. The market will set "new" prices for energy-efficient buildings and inefficient buildings. Furthermore, one must consider a number of different factors, e.g. the location of the building: Retail units in top-locations tend to be

leased at a higher price and show lower vacancy rates, regardless of the thermal quality. On the other hand, in times of oversupply for “standard” buildings, energy efficiency will play a crucial role in marketability. Both arguments reflect the fact that the relevance of energy efficiency will be dependent on different factors like market state, vacancies, location, usage etc.

However, since most markets today do not reflect good results concerning energy savings in the sense of higher revenues, valuers should not estimate this fact pro-actively by pricing in assumed reactions of the market. A fundamental principle behind this is that an appraiser must reflect the market and current state but must not influence it. As long as nobody knows how the new transparency achieved by EPCs will affect the market, valuers must observe and analyse market behaviour.The fact that the rental income reflected in the valuation process today must also account the future rental growth which might be linked to energy efficiency might also be viewed at “tricky”. This leads to another possible adjustment, the yield, since rental growth within the income approach (except DCF-Models) is incorporated in the yield applied (see adjustment of yield).

Adjustment of lease terms

In general, the lease agreement should be discussed in connection with the rental income that results based on these agreements. However, the simple direct capitalization approach fails to reflect certain lease terms in the valuation process. Since these might be influenced by green building features respectively green lease terms, this is therefore a strong argument for the application of more advanced techniques like DCF when it comes to:

(1) Shorter lease up periods,

(2) Tenant retention, or

(3) Longer leases.

Long rentals are in some cases - for the government or big companies - a substitute for the higher rents they can avoid when leasing energy-efficient buildings.

Adjustment of the non-recoverable operating expenses and vacancies

The potentially lower vacancy rate will lead to higher overall revenues and could therefore be discussed in connection with the rental income (see adjustment of the potential gross income). Moreover this will lead to a lower vacancy and collection loss which ranges e.g. in German and Austria for ordinary building between 3 % and 4 % of the potential gross income. Since these expenses reflect the fluctuation and overall quality of tenants, these aspects must be

influenced. Indeed, the possibility of attracting class-A-tenants with a good economic background and a chance to increase the probability of renewal of lease agreements are often stated arguments for green buildings.

This hypothesis is based on the assumption that the marketability of buildings of a high thermal quality will (probably) increase in the future (while that of buildings of a poor will decrease) - this leads to lower (higher) vacancy rates.

Again, the amount of reduction will be market driven and cannot be a general result.

Since other operating expenses that might be discussed in this section only refer to the non-recoverable expenses, there is little left where one could identify a positive impact on. While the costs for vacant units (which are likely to decrease anyway) should be lower, but administration costs will probably remain unchanged.

The effects we discussed above mainly refer to changes on the demand side of the market. The introduced approaches are based on the assumption that the availability of the energy certification will raise consumers' awareness regarding the energy efficiency of buildings and consequently shift consumers' demand. On the other hand there are effects in context of energy certification, which do not result from the market-side but from the technical quality of properties. Maintenance costs are an example for a technical influence and refer to the expenses of keeping a property in a good state of repair. The idea of adjusting the maintenance costs in context of energy certification is that e.g. buildings in a good efficiency level are in top-condition and therefore cause lower maintenance costs. Or, as the other side of the coin, cause higher costs because of sophisticated technical equipment like heat pumps or solar heating systems.

Maintenance costs must be derived from the qualities and the condition of the technical equipment, independent from the energy certificate or energy efficiency itself. Therefore, the introduction of the energy certificates itself will not change anything. On the other hand, one should mention that an energy certificate provides a significant amount of data that could be useful for the derivation of the "correct" maintenance costs. Thus, a more detailed calculation of the maintenance costs using LCCA will become more important in the future.

Probability of (re)letting

An important issue already reported by different real estate market players is the fact that letting of sustainable assets is, on average, easier when compared to conventional buildings. In the DCF methodology, one can model periods of (re)letting in detail, thus giving an

additional value to those assets which show longer letting periods, quicker reletting and shorter periods of vacancies.

Adjustment of the remaining economic life

In comparison to the Anglo-Saxon income approach, where just a yield/cap rate is used to express a year's purchase (which encompasses the remaining economic lifetime implicitly), the German or Austrian income approach uses a so called "Liegenschaftszinssatz" / "Kapitalisierungszinssatz", which reflects the remaining economic lifetime explicitly to estimate a specific multiplier ("Vervielfältiger"). The remaining economic life of a building is the period of time for which one can expect in the future. This life can be further extended by carrying out several refurbishments or reduced due to insufficient maintenance etc. However, the potential changes due to energy-efficient building characteristics are impossible to measure at this stage. Since properties which offer an up-to-date (high) standard are to some extent more "future-proof," one can expect that the remaining economic lifetime is longer as opposed to conventional comps.

But it is also necessary to mention that - assuming a comprehensive market change will take place in the upcoming years - there will be a potential influence from the market side, but relating to non-green/non-energy-efficient properties. To give an example: if one assumes that buildings of a certain poor thermal quality are not marketable in the future, the result would manifest in the form of a reduction of the remaining economic life caused by the demand-side of the market.

Adjustment of Yield

If the effects are related to the overall risk and not already reflected in the rent or other aspects, then it may be appropriate for the valuer to make an adjustment of the applied yield concerning these long-term effects.

The derivation of the yield is one of the most important parts when one applies direct capitalisation as well other, non standardized approaches like e.g. the discounted cash flow method. The idea of integrating the energy certification at this point of the appraisal process will affect transparency concerning energy efficiency and ultimately change the demand side of the market to some extent. Buildings of a good thermal quality will have a lower risk concerning marketability while buildings of a poor thermal quality will probably suffer. The attribute "Future proofed" against rising energy costs and economic obsolescence results in a lower risk profile and therefore a lower yield. This argument is not redundant to higher

income, since the likelihood of a better growth prospect needs to be reflected in the yield even so if at the present, the income profile has not changed to a great extent. On the other hand the appraiser must of course avoid redundancies in his valuation.

Finding the “right” yield is the crucial point for every valuation and in a lot of European countries the applied all risk, terminal, equated, equivalent and so on yields are potentially the most vulnerable part for the valuer - on the other hand it’s “his professional judgment” and therefore the explanation is just his “market feeling.” We have analysed valuations for assets worth more than 6 Billion Euro of various valuation companies and no matter how profound the market research performed, the best explanation for the yield is in most cases just the net initial yield for three comparables (without a proper definition for the NIY in most cases). The point is that there is still a huge gap between theoretically profound calculations of yields and practical application as well as available market data. This leads to the fact that even if green-/energy efficiency features were priced in by adjusting the yield, we must be realize that for appraisers, this will be very difficult to accomplish in valuation practice. Furthermore, the possible adjustment of yields seems to be less then preferable because of a lack of market evidence in light of the fact that energy-efficient building features on property yields might be overestimated.

In the case of DCF calculations, it has been suggested that only the terminal yield should be adjusted, because the discount rate does not encompass e.g. growth rates of energy costs, etc. implicitly.

Implication for comparables

A fundamental task when one performs a good property valuation is to find enough comparable data – not only when applying the sales comparison approach – and analyse this data to derive input figures which could be used within the valuation of the subject property. The essential rule to ensure that the outcome is correct is therefore: do compare apples with apples! Comparables must have the same building characteristics in terms of location, technical equipment, condition etc. and also with respect to the green-features such as the typical energy efficiency level of comparable properties. However, with the introduction of yet another aspect which needs to be comparable, valuation will inevitably become far more complex.

The solution could be to use statistical analysis to a certain extent. Unfortunately such advanced analytic tools require a high level of market maturity and transparency (so-called “developed markets”), which in general is not the case.

Regardless, the following subchapters try to establish appropriate and practical methods that valuers can use to handle energy efficiency within property valuation in a quantitative manner in line with the common existing valuation standards. Nevertheless, one must recognize that there is a difference between a valuation in transparent markets (developed market) and situation where just rare market data (opaque markets) is observable.

6.4.3.2.1 Methodology for developed markets

Key Facts and Findings

Basic description of proposed income approach adjustment

- In transparent property markets where market evidence for the value impact of energy-efficient buildings and related data in great numbers with high validity, econometric and statistical methods (such as hedonic pricing models (OLS) and regression analysis) can be applied to derive the quantitative impact factors for the relationship between properties' energy performance and markets' willingness to pay for it (e.g. quantitative impact on various green value drivers such as rental income, operating expenses, applied yield or remaining economic life-time).
- Due to the fact that the advanced econometric methods (semiparametric models, penalized least squares (PLS), spatial effects, Splines) go beyond the scope of ordinary day-to-day property valuation practices and therefore require (1) a huge sample of totally transparent and comparable information and (2) statistical know-how, it is recommended that national property valuation committees and associations (such as e.g. RICS, BIIS, ANEVAR, NTF or ÖII), who have access to such information, should assure access to such analytic results for the specific property market and property type.
- These valuation impact factors provided by national organisations can then be used directly within the income related approach by valuers and serve as a benchmark for them.

Short rationale for the proposed methodologies

- Due to the fact that the markets' willingness to pay for green or energy-efficient buildings plays the key role and can be derived in developed and transparent markets by simple market observation and more sophisticated analysis, the application of econometric and statistical approaches therefore seems to be the most appropriate method.

Expected impacts on property value

- On the basis of empirical case studies (see Chapter 6.4.3.3 and 6.4.3.4) an impact of buildings energy performance on achievable rental income in German and Austrian

property markets could be observed compared to non-energy-efficient comps.

In developed markets, as it was already mentioned previously, information regarding real estate rental data from recent sales of comparable properties can be used by the valuer to to derive estimated rental values, etc. and can be found in great numbers and with a high validity. This data is therefore qualified enough for application in statistical methods in order to isolate market levels / effects that could be regarded as relevant for the derivation of a value for a specific property being valued. This means that in order to quantify adequate numerical figures for the value impact of EPCs, valuers could carry out econometrics and statistical analytic tools. Futher, this method seems to be the most reliable method to isolate the rental premium of an energy-efficient building in developed markets.

One strongly recommended method that seems to be the most adequate is the application of regression analysis, which describes the structure of dependency between two or more characteristics. To understand the fundamentals of such analytical tool, this report will explain the main features of the classical linear regression (so-called Ordinary Least Squares, OLS).

For example, hedonic pricing models, which describe the impact of location and other building characteristics on the price or rent for a property-- often applied in real estate economics--could be a useful approach to derive market evidence for the relationship between properties' energy performance and the markets' willingness to pay for it.

Application of hedonic pricing model

In economic theory, real estate is considered a *differentiated* or *composite good*, meaning that although buildings or flats consist of a wide range of characteristics that make each object unique, they are regarded as being one commodity as they are traded in bundles on an implicit market. The explicit market, with observed prices and transactions, is for the bundles themselves and includes several implicit markets for the property's characteristics.[132]Originally developed for automobiles by Court[133], hedonic pricing models have been used extensively in applied economics since the seminal work of Rosen[134]. Other often cited classic references include Lancaster[135] and Griliches[136]. The theoretical

[132] Cf. Sheppard, S. (1999)

[133] Cf. Court, A.T. (1939)

[134] Cf. Rosen, S. (1974)

[135] Cf. Lancaster, K. (1966)

underpinnings are well described e.g. in Follain and Jimenez[137] as well as Sheppard. In his 2002 paper, Malpezzi[138] presented a review of the hedonic price literature, and Sirmans et al.[139] provided a review of specifications and characteristics that have most frequently been used in hedonic pricing studies.

Since a property is fixed in space, by selecting a specific object, a household implicitly chooses many different goods and services. Therefore, in the concept of implicit markets it is supposed that dwelling characteristics are traded in bundles. The explicit market, with observed prices and transactions, is for the bundles themselves and includes several implicit markets for the property's characteristics.[140] A hedonic price function describes how the quantity and quality of these characteristics determine its price in a particular market.

According to hedonic price theory, differentiated goods like real estate are valued for their utility-bearing characteristics.[141] Since a property is fixed in space, by selecting a specific object, a household implicitly chooses many different goods and services. The price that is paid may depend on structural and location attributes and varies over time. The implicit prices for the various characteristics are supposed to clear the market, i.e. to lead to equilibrium of supply and demand for those characteristics. The households or firms that want to rent or buy real estate represent the consumers (demand), and the owners of the flats represent the production side and determine the level of supply. This equilibrium is summarized by what is called a hedonic price function, which describes how the existence, quantity and quality of a certain characteristics determine the price of the object (so this function can be regarded as a reduced form of supply and demand). It is therefore important to notice that the price functions for one market cannot be easily transferred to another market, as they are the result of particular market conditions.[142]

For ease of discussion, we will limit our remarks on residential real estate. Let us now assume that a particular property is described by its vector of k characteristics

$$\mathbf{Z} = (z_1, z_2, ..., z_k) \qquad (2)$$

---

[136] Cf. Griliches, Z. (1971)

[137] Cf. Follain, J., Jimenez, E. (1985)

[138] Cf. Malpezzi, S. (2002)

[139] Cf. Sirmans, G., et al. (2005)

[140] Cf. Sheppard, S. (1999)

[141] Cf. Rosen, S. (1974)

[142] Cf. Day, B. (1999)

where we assume that these characteristics are "goods" for simplicity. If a household buys a particular flat, it selects a set of values for each of these (structural and location) characteristics. Therefore, the price of the flat is a function of the whole bundle of characteristics, or

$$P = P(\mathbf{Z}) \tag{3}$$

This function is known as the *hedonic price function*. Due to the assumption that differentiated goods cannot be easily untied and the resulting impossibility of arbitrage, marginal prices of property characteristics are not constant. [143] Furthermore, the price of one characteristic may depend on the quantity of another. Therefore, we might expect to observe nonlinear relationships between the market price and its measured attributes.

To illustrate this interrelationship, consider the left panel of Figure 30, which shows how the price of the flat changes if the quantity of a certain characteristic, e.g. the area of the flat, is increased, all other characteristics held constant. Obviously, we face decreasing marginal prices of this characteristic.

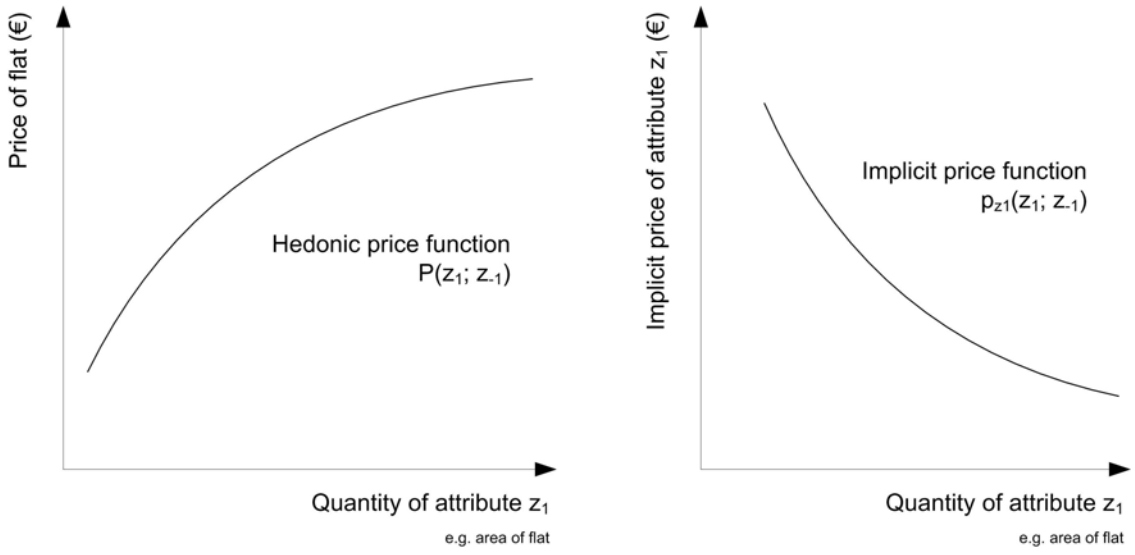


Figure 30: Hedonic price function vs. implicit price function

The right panel of this figure displays the marginal prices (i.e., the partial derivative of the hedonic price function with respect to characteristic z_1), or

$$p_{z_i}(z;\mathbf{Z}_{_i}) = \frac{\delta P(\mathbf{Z})}{\delta z_i} \tag{4}$$

[143] Cf. Rosen, S. (1974)

This function is also sometimes called the *implicit* price function of the characteristic, as the amount households are willing to pay for a characteristic is revealed to us indirectly through the price of the whole property. [144]

As mentioned above, the hedonic price function is the result of the interaction of supply and demand on the property market. Rosen[145] derives this equilibrium under the following assumptions:

(1) Individual households are price takers.

(2) Households only purchase one property.

Households choose the characteristics of the flat and a composite good or *numeraire* (x) to maximize their utility function

$$U(\mathbf{Z}, x; \mathbf{s}) \tag{5}$$

where **s** represents the characteristics of the household, under the budget constraint

$$y = x + P(\mathbf{Z}) \tag{6}$$

where y is the household income.

Maximizing the utility function with respect to z_i, i = 1,…, k and x gives the conditions for optimal household choice of residential location

$$\frac{U_{z_i}}{U_x} = p_{z_i}(z_i, \mathbf{Z}_{-\mathbf{i}}) \tag{7}$$

where the partial derivative of the hedonic price function with respect to characteristic z_i is ratio of marginal utilities, which is called *bid function* by Rosen[146]. One can interpret this as a marginal rate of substitution, so it is the slope of the indifference curve of a household. It represents the rate at which households give up money in order to get more of a flat attribute.

Taking the budget constraint into account explicitly, we can write the hedonic price function as

$$\theta = y - x(\mathbf{Z;s}, u) \tag{8}$$

where y is the household income and θ is the bid function, the total amount a household could pay on a flat given the choice of x. One can interpret the bid function as "the maximum amount that a household would pay for a property with attributes **Z** such that they could achieve the given level of utility, u, with their income, y."[147] The right panel of Figure 31

[144] Cf. Day, B. (1999)

[145] Cf. Rosen, S. (1974)

[146] Cf. Rosen, S. (1974)

[147] Day, B. (1999), p.34

shows such bid curves. It is easy to see that bid curves can be represented as indifference curves by just flipping the vertical axis (see the left panel of this figure), so they express indifference relationships.

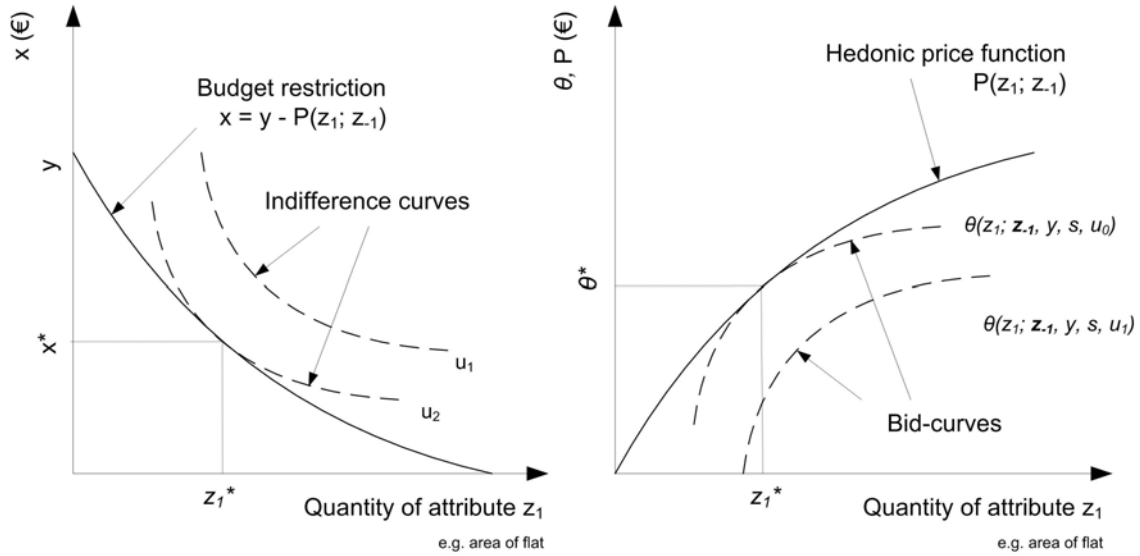


Figure 31: Indifference curves vs. bid-curves

However, notice that the budget constraint is not linear. The optimal choice for each household is therefore the point of tangency between the highest bid curve and the budget constraint, resulting in the optimal bundle of flat characteristics composite goods for every household. Therefore, as discussed above, marginal prices are not constant. Since households do not have the same income or preferences, the optimal choices "move" along the budget constraint (of course achieving different utilities), which makes the bid curve identifiable.

Similarly, we can derive what Rosen[148] calls the offer function for the supply side. We now deal with profit instead of utility. Otherwise said, "the offer function describes the rent the landlord would need to receive in order to achieve a profit of π." [149] Again different suppliers will provide different bundles of characteristics that make the offer curve identifiable.

If we bring the choices of consumers and of suppliers together in the property market, we can derive market equilibrium: The market clears in the hedonic price function, where demand equals supply (see Figure 32). The hedonic price function is therefore called a *joint envelope function* of all individual optimal bid and offer functions.

[148] Cf. Rosen, S. (1974)

[149] Day, B. (1999), p.41

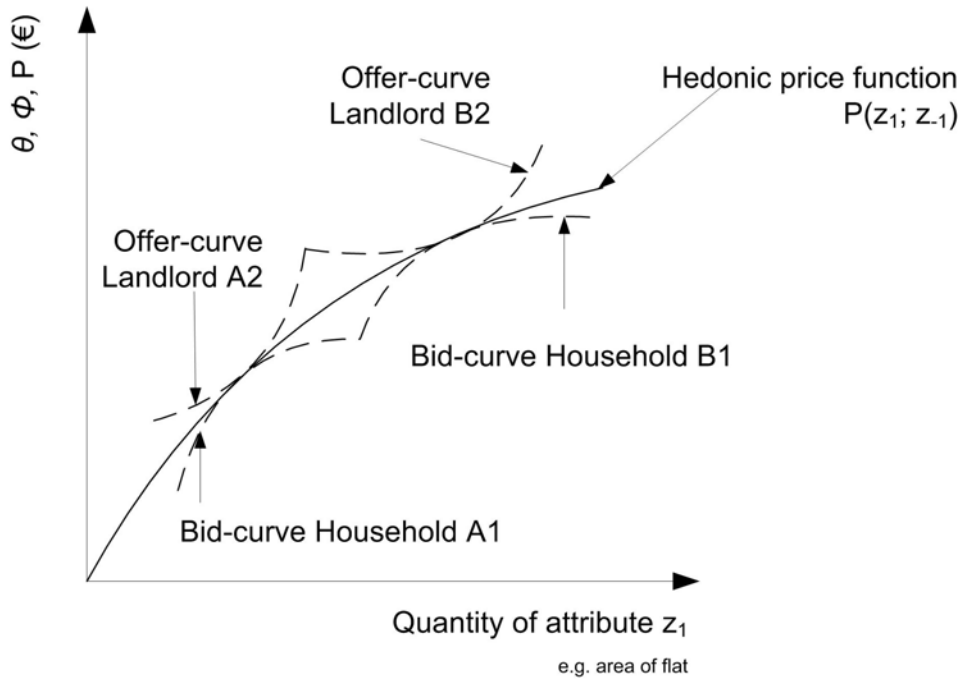


Figure 32: Hedonic price function

However, although bid and offer functions are theoretically identifiable under certain assumptions, the complexity of hedonic markets and the unavailability of supply and demand shifters usually make it necessary to concentrate on the reduced form of the hedonic price function in our empirical analysis.

Application of different Regression Analysis

The term regression was originally introduced by the famous Sir Francis Galton (1822 – 1911) and described the fact that in large populations a recurrence to the mean value of all values was observable.[150]

In the following paragraphs, we will review the statistical concepts used to study the effect of energy efficiency on rents.

The Linear Regression Model

Basically, a regression model consists of a deterministic as well as a stochastic component. The deterministic component describes the influence of what is called an explanatory variable(s) (also called covariate, independent variable, control variable, or *regressor;* these names are used interchangeably henceforth) on an *explained variable* (also called *dependent*

[150] For a complete discussion of the history of regression see Stigler, (1988)

variable, response variable, predicted variable, or *regressand;* again used interchangeably). [151] In matrix notation, we will denote the explanatory variables as *n*x*1* vectors $\boldsymbol{x_0}$, $\boldsymbol{x_1}$, …, $\boldsymbol{x_k}$, where $\boldsymbol{x_0}$ is a vector of ones in a model with intercept, or as *n*x*(k+1)* matrix **X**, the dependent variable as **y** and the stochastic component as **u**, both *n*x*1* vectors, where n describes the number of observations. Hence, the deterministic part of the model displays the notion of a causal effect with an additional amount of random noise. The notion of *ceteris paribus* (which means "other (relevant) factors being equal") plays an important role in causal analysis. If other factors are not held fixed, one cannot know the causal effect of a characteristic, say, energy efficiency, on the explained variable, say rents per square meter.

The stochastic component, called *error term* or *disturbance*, represents other factors not captured in the study design. However, it is important to notice that the disturbance should not contain any interpretable structure.

Therefore, we can write the regression model as

$$\mathbf{y} = \mathbf{X\beta} + \mathbf{u} \tag{9}$$

For a single observation, the relationship can be written as

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_k x_{ik} + u_i \,.^{152} \tag{10}$$

This simple model states that the influence on y is determined by x plus an individual error u. The coefficient β_0 denotes the intercept, β_1, …, β_k the slope parameters of the function. If we only have the intercept and one explanatory variable, the model is called a simple or bivariate linear regression model.

In order to find the best fitting function i.e. the function that minimizes the error term, several attempts are possible. The Ordinary Least Squares (OLS) method tries to find the best fitting function by minimizing the squares of the individual error term. This is described in the following equation.[153]

$$\min_{\beta_0,\beta_2} \sum_{i=1}^{n} \left(y_i - \beta_0 - \beta_1 \cdot x_i\right)^2 \quad for\ i = 1\mathrm{K}\ n \tag{11}$$

This method was originally introduced 1805 by Adrien Marie Legendre (1752-1833) with further contributions by Carl Friedrich Gauss (1777 – 1855). The OLS method yields the parameters b_1 and b_0 as estimates for β_0 and β_1. It can be shown that the OLS estimator is the

[151] See Wooldridge (2006), pp. 22-23

[152] In this case, of course we can omit x_{i0}

[153] Stocker, H. (2007), pp.83-110

best linear unbiased estimator (BLUE) [154] under the following conditions (referred to as the Gauss-Markov-Assumptions):[155]

(1) Assumption No. 1 – Linearity of Parameters

This assumption basically states that the true relationship between the explanatory variable and the explicated variable is linear in parameters. For k Parameters this can be written as:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_k x_{ik} + u_i \quad (12)$$

This assumption seems very restrictive but by transforming the variables appropriately one can model nonlinear relationships.

(2) Assumption No. 2 – Random Sampling

Basis for the regression is a random sample of size n.

(3) Assumption No. 3 – Sample Variation in the Explanatory Variable

This assumes that the independent variables are deterministic and the data generating process generating *x* is independent from the one generating the *y* variable. This also implies that

$$E(u_i x_i) = 0.$$

(3) Assumption No. 4 – Zero Conditional Mean

The error terms of the population have the conditional mean of zero.

$$E(u_i x_i) \equiv E(u_i) = 0 \quad (13)$$

(4) Assumption No. 5 – Homoscedasticity

This means that all u_i have the same variance of σ^2. This assumption is not necessary for the regression itself, but for inference on the regression parameters.

In order for these assumptions to hold, one must find a a correct model. This means that dependent and independent variables must be in correct functional form in order to estimate a linear relationship in the parameters. A common model specification designed to address the nonlinearity in hedonic price functions takes the log or semi-log form, which furthermore mitigates the problem of heteroscedasticity. [156]

As a (semi-)log model, we define a model with a logarithmically explained variable and logarithmic or linear explanatory variables. Consider the model

[154] This means that: E(b) = β as well as Var(b) < Var(b*) where b* is the estimate of any other linear estimation process

[155] this closely follows Wooldridge (2006), pp. 51 f

[156] Cf. Malpezzi, S. (2002)

$$\ln(rent_psqm) = \beta_0 + \beta_1 \ln(energy_psqm) + \beta_2 age + \mathbf{u} \qquad (14)$$

where ln(.) is the natural logarithm, *rent_psqm* is the rent per square meter, *energy_psqm* is the energy costs per sqare meter, and *age* is the age of the building. In this model, one can interpret the coefficient β_1 as the elasticity of rent per square meter with respect to energy costs per square meter. If the coefficient is -0.1, then an increase in energy costs per square meter of 100 % reduces rents by 10 %. The coefficient β_2 is sometimes called semi-elastic, meaning that if it is multiplied by 100, it gives an estimate for the percentage change in rent per square meter if age is increased by one unit. For example, if this coefficient is 0.01, then one year of further age results in 1 % of rent decrease.

Nevertheless, as stated e.g. by Martins-Filho and Bin[157], a frequent concern in hedonic price literature is the adequacy of parametric specifications. This specification problem arises because economic theory does not provide clear guidance concerning the functional form of the dependence of price on quality.[158] As explained e.g. in Wallace[159], this suggests that functional forms used to estimate hedonic prices should allow for the possibility of nonlinearity in the hedonic price functions.

In light of the potentially serious consequences of functional misspecification, there have been some attempts to estimate hedonic price models using semi- or nonparametric methods. The fundamental goal of these approaches is a flexible modeling of the influence of continuous covariates on the dependent variable. Semiparametric and nonparametric approaches for real estate can be found e.g. in Pace[160], or Clapp[161].

[157] Cf. Martins-Filho, C., Bin, O. (2005)

[158] Cf. Anglin, P.M., Gencay, R. (1996)

[159] Cf. Wallace, N. (1996)

[160] Cf. Pace, R. (1998)

[161] Cf. Clapp, J.M. (2004)

Semiparametric Models

In a semiparametric model, the covariates are partitioned into the two parts $\mathbf{X_1}$, which contains the continuous covariates, and $\mathbf{X_2}$, which contains categorical and linear covariates. Hence we estimate a model of the form

$$\begin{aligned} \mathbf{y} &= f(\mathbf{X_1}) + \mathbf{X_2}\boldsymbol{\beta} + \mathbf{u}, \\ \mathbf{u} &\sim \mathrm{N}(\mathbf{0}, \sigma^2 \mathbf{I}) \end{aligned} \tag{15}$$

where f(.) is a nonparametric function of the continuous covariates and $\boldsymbol{\beta}$ are parameters of the binary (categorical variables have been decomposed into dummies) or linear covariates.

P(enalized)-splines as first proposed by Eilers and Marx[162] is a well established approach for modeling nonlinear effects of unknown shape. First, the range of a particular covariate z is divided into m equally spaced intervals bounded by the $m+1$ equidistant knots $z_{\min} = \kappa_1 < \kappa_2 < \mathrm{K} < \kappa_{m+1} = z_{\max}$. Then, a spline $f(z)$ has the following two properties: in each of the intervals the spline f is a polynomial of degree l, and at the knots (the interval boundaries) the spline is $l-1$ times continuously differentiable. The second assumption ensures that the polynomial pieces fit together smoothly (at least for $l > 0$). Typically $l = 3$ is assumed.

Splines of degree l can be represented by a linear combination of a set of $h = m + l$ basis functions $B_j^l(z_i)$, $j = 1,2,\mathrm{K}\,,h$ at a given observation z_i (De Boor, 2001)

$$f_i = \beta_1 B_1^l(z_i) + \beta_2 B_2^l(z_i) + \mathrm{K} + \beta_h B_h^l(z_i) \tag{16}$$

It is convenient for further analysis to write the basis functions into a matrix $\mathbf{Z}$ containing elements $\mathbf{Z}[i, j] = B_j(z_i)$, where the value of the j-th basis function at the i-th observation is in i-th row and j-th column. Analogously, the parameters are stacked into a vector $\boldsymbol{\beta}$ and the whole effect of covariate z can be written in matrix notation as $\mathbf{f} = \mathbf{Z}\boldsymbol{\beta}$.

The crucial point in modeling nonlinear relationships through splines is the determination of the number (and position) of knots. Too few result in an overly restrictive spline that might not be able to capture the true variability of the data. On the contrary, a too large number of knots tends to produce statistical artifacts based on an overfit to the data. In order to overcome these difficulties, Eilers and Marx[163] have proposed a penalization (P-spline) approach. To start, a moderately large number of equidistant knots (usually between 20 and 40) are chosen

[162] Cf. Eilers, P.H.C., Marx, B.D. (1996), pp.89-121

[163] Cf. Eilers, P.H.C., Marx, B.D. (1996), pp.89-121

to guarantee enough flexibility. Next, a roughness penalty is imposed by punishing large (first or second order) squared differences between two adjacent coefficients β_j and β_{j+1}. This can be accomplished in a frequentist setting by penalized least squares (PLS).

The PLS approach incorporates an additional term that penalizes deviations

$$\mathrm{PLS}(\lambda) = \sum_{i=1}^{n}\left(y_i - \sum_{j=1}^{h} \beta_j B_j^l(u_i) \right)^2 + \lambda \sum_{j=k+1}^{h} (\Delta^k \beta_j)^2 , \tag{17}$$

where Δ^k is the k-th difference operator and λ governs the trade-off between smoothness and fit to the data. First order differences ($k=1$) penalize abrupt jumps between successive parameters, second order differences ($k=2$) penalize deviations from the linear trend. The larger (smaller) λ is the more (less) influence gets the penalization term and the smoother (rougher) is the resulting function. In matrix notation, the penalization term can be rewritten as

$$\lambda \sum_{j=k+1}^{h} (\Delta^k \beta_j)^2 = \lambda \boldsymbol{\beta}' \mathbf{D}'_k \mathbf{D}_k \boldsymbol{\beta} = \lambda \boldsymbol{\beta}' \mathbf{K}_k \boldsymbol{\beta} , \tag{18}$$

where $\mathbf{D}_k$ is a difference matrix of order k and $\mathbf{K}_k$ is referred to as a penalty matrix. Therefore, the penalized least squares equation can be rewritten as

$$\mathrm{PLS}(\lambda) = (\mathbf{y} - \mathbf{Z}\boldsymbol{\beta})'(\mathbf{y} - \mathbf{Z}\boldsymbol{\beta}) + \lambda \boldsymbol{\beta}' \mathbf{K} \boldsymbol{\beta} . \tag{19}$$

Minimizing this expression with respect to $\boldsymbol{\beta}$ yields the PLS estimator

$$\hat{\boldsymbol{\beta}} = (\mathbf{Z}'\mathbf{Z} + \lambda \mathbf{K})^{-1} \mathbf{Z}\mathbf{y} . \tag{20}$$

The estimated vector of function values $\hat{\mathbf{f}} = (\hat{f}(u_1), \mathrm{K}, \hat{f}(u_n))'$ can then be written as

$$\hat{\mathbf{f}} = \mathbf{Z}\hat{\boldsymbol{\beta}} = \mathbf{Z}(\mathbf{Z}'\mathbf{Z} + \lambda \mathbf{K})^{-1} \mathbf{Z}'\mathbf{y} . \tag{21}$$

The choice of the smoothing parameter λ is crucial as we may obtain quite different fits by varying the smoothing parameter. In a frequentist setting, the smoothing parameters are either chosen by minimizing some goodness of fit criterion (e.g. AIC, GCV etc.), see e.g. Wood[164] for details; alternatively, one may rewrite the model as a linear mixed model. Inference for the smoothing parameters is based on the restricted maximum likelihood; see Fahrmeir et al.[165], or Ruppert et al.[166] for details. In this paper, inference is based on a fully Bayesian version of

[164] Cf. Wood, S. (2006)

[165] Cf. Fahrmeir, L., Kneib, T., Lang, S. (2004)

[166] Cf. Ruppert, D., Wand, M.P., Carroll, R.J. et al. (2003)

P-splines as proposed by Lang and Brezger[167]. The Bayesian version defines priors for the regression coefficients and the smoothing parameters and therefore allows simultaneous estimation of the function f and the amount of smoothness governed by the smoothing parameter. We used the software package BayesX for estimation; see Brezger et al.[168]. The homepage of BayesX (http://www.stat.uni-muenchen.de/~bayesx/bayesx.html) contains also a number of tutorials.

In order to illustrate the P-spline approach, we show the construction of a P-spline of degree $l = 3$ for a simulated dataset that incorporates an abrupt jump. The data was generated according to the model

$$y = f(x) + \varepsilon,$$

where

$$f(x) = \begin{cases} \sin(2\pi - \pi/2) - \ln(x + 0.1) + x - 0.5x^2 + 0.2x^3 - 0.1x^4 + 3 - 1.5 & \text{if } 0.5 \le x < 0 \\ \sin(2\pi - \pi/2) - \ln(x + 0.1) + x - 0.5x^2 + 0.2x^3 - 0.1x^4 + 3 & \text{else} \end{cases} \quad (22)$$

,

and

$$\varepsilon \sim N(0, 0.5^2).$$

First, one calculates a full spline basis for a given number m of intervals (in this case, $m = 10$, giving a total of $h = m + l = 13$ basis functions). As one can easily see in the following Figure 33, each of these functions has non-zero values in $l + 1$ intervals and overlaps with $2l$ adjacent basis functions. Vertical lines indicate the position of the inner knots. Note that we have to expand the number of knots to $m + l + 1$ in order to define the set of basis functions in every interval of the range of *area*.[169]

[167] Cf. Lang, S., Brezger, A. (2004), pp.183-212; and Brezger, A., Lang, S. (2006), pp.947-991

[168] Cf. Brezger, A., Kneib, T., Lang, S. (2005a), pp.1-22; and Brezger, A., Kneib, T., Lang, S. (2005b)

[169] Cf. Fahrmeir, L., Kneib, T., Lang, S. (2007)

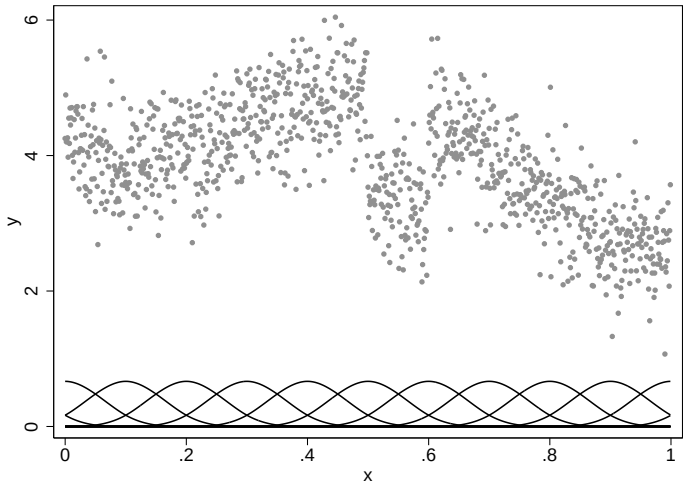


Figure 33: Illustration on full-Spline basis

The basis functions are then scaled by the estimated parameters $\beta_j,\ j=1,2,\mathrm{K},h$, which provide the respective amplitude. Summation of the scaled basis functions leads to the estimated function (in the following Figure 34, this is represented by a thick line). In a non-penalized approach, this may lead to considerable variability of the function, as can be seen in the left panel of this figure, especially where the abrupt jump was simulated. In contrast, the P-spline approach leads to a relatively stable fit (right panel).

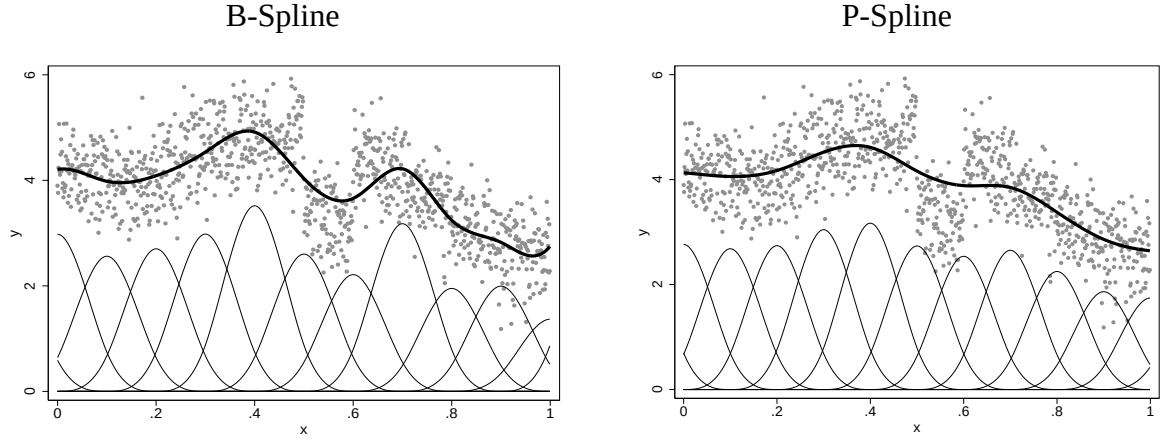


Figure 34: Illustration of B-Spline vs. P-Spline

One can further extend the P-spline approach to modeling more than one nonlinear covariate. Suppose that z_1,K,z_q are continuous covariates to be modeled nonlinearly by P-splines. Further, x_1,K,x_p are covariates with linear effects. Define design matrices $\mathbf{Z}_1,\mathrm{K},\mathbf{Z}_q$

corresponding to the q continuous covariates and a design matrix $\mathbf{X}$ for the remaining covariates with linear effects. In matrix notation we obtain the model

$$\mathbf{y} = \mathbf{Z}_1\boldsymbol{\beta}_1 + \mathrm{K} + \mathbf{Z}_q\boldsymbol{\beta}_q + \mathbf{X}\boldsymbol{\alpha} + \boldsymbol{\varepsilon} = \boldsymbol{\eta} + \boldsymbol{\varepsilon} \tag{23}$$

where $\boldsymbol{\beta}_s$ is the vector of regression coefficients for the s-th nonlinear term of covariate z_s, the vector $\boldsymbol{\alpha}$ contains the regression coefficients of linear effects, and $\boldsymbol{\eta}$ is the predictor vector. The parameters are estimated by minimizing the extended PLS criterion

$$\mathrm{PLS}(\lambda_1, \mathrm{K}\ \lambda_q) = \sum_{i=1}^{n}(y_i - \eta_i)^2 + \sum_{s=1}^{q}\lambda_s\boldsymbol{\beta}_s'\mathbf{K}_s\boldsymbol{\beta}_s\ , \tag{24}$$

where $\mathbf{K}_s$ is the penalty matrix of the s-th nonlinear term. The smoothing parameters involved are again estimated by minimizing a goodness of fit criterion, using the connection to linear mixed models or via a fully Bayesian approach, see the literature cited above.

Spatial Effects

Along with the spatial fixation of real estate comes considerable interest in dealing with spatial dependence and variation in hedonic price equations. Therefore, one could model the relationships between observations as functions of their locations. Basically, there are two spatial phenomena that could affect hedonic price equations: Spatial autocorrelation and spatial heterogeneity.[170] A comprehensive review of various spatial or spatiotemporal econometric models and recent developments is given in LeSage and Pace[171] as well as Anselin, Florax, and Rey[172]. is The spatial regression family isvery popular in this context and was made so by Anselin[173]. Spatial autoregressive (SAR) models allow for both spatially lagged dependent variables and spatially lagged disturbance terms. However, there is a wide range of alternative models, especially semiparametric and nonparametric spatial approaches that are particularly appropriate in modeling spatial heterogeneity. Prominent examples are kriging (e.g. Cressie[174]), 2D tensor product spatial smoothing (e.g. Wood[175]), approaches

[170] Also under these circumstances, the Gauss Markov assumptions are violated.

[171] Cf. LeSage, J., Pace, R. (2004)

[172] Cf. Anselin, L., Florax, R.J., Rey, S.J. (2004)

[173] Cf. Anselin, L. (1988)

[174] Cf. Cressie, N.A.C. (1993)

[175] Cf. Wood, S. (2006)

based on spatial penalization (Besag & Kooperberg[176]; Fahrmeir, Kneib, & Lang[177]), and geographically weighted least squares (GWR; Fotheringham, Brundson, & Charlton[178]).

In the case study using the CREIS dataset, a city-specific dummy variable (an unconstrained fit) or by a city-specific random intercept can capture special heterogeneity. In the first case, one could create dummy variables for every city. As in many cities, we only have one observation but this would lead to large variation in the estimates for the dummy parameters. Therefore, we decided to generate dummy variables only for cities where we have more than 4 observations.

One can estimate city-specific random intercepts $\boldsymbol{\gamma}_{0d}$ by adding an additional term $\mathbf{Z}_{\gamma_0}\boldsymbol{\gamma}_0$ in (1) and by adding the ridge type penalty $\lambda_{\gamma_0}\boldsymbol{\gamma}_0'\boldsymbol{\gamma}_0$ in the PLS criterion (2), where the matrix $\mathbf{Z}_{\gamma_0}$ is an incidence matrix with entries 1 in row i and column j if observation i is in city j. The effect of the penalty is to shrink estimated parameters $\boldsymbol{\gamma}_{0d}$ towards zero. Hence the penalty prevents possibly large variation in the estimates for $\boldsymbol{\gamma}_{0d}$ due to the large number of city specific parameters. For sufficiently large sample sizes within each city the estimated parameters automatically tend toward an unconstrained fit.

Omitted variables

Another important problem in regression analysis is the topic of omitted variables. This is also called the problem of excluding a relevant variable or underspecifying the model. In the case of omitted variables, OLS is biased, and hence the results of the respective regression analysis are not valid. This is specifically true for most hedonic regression studies, where energy efficiency does not play any role. In order to illustrate this problem, we start with the case where the true population model has two explanatory variables,

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + u_i \tag{25}$$

where x_1 is, say, the condition or age of the building and x_2 the energy efficiency. Now suppose that due to ignorance or data unavailability, we only estimate a model excluding x_2, specifying the simple regression model

$$y_i = \tilde{\beta}_0 + \tilde{\beta}_1 x_{i1}. \tag{26}$$

Deriving the OLS estimator for the slope parameter of this model, we get

[176] Cf. Besag, J., Kooperberg, C. (1995)

[177] Cf. Fahrmeir, L., Kneib, T., Lang, S. (2007)

[178] Cf. Fotheringham, A., Brundson, C., Charlton, M. (2002)

$$\tilde{\beta}_1 = \frac{\sum_{i=1}^{n}(x_{i1} - \bar{x}_1)y_i}{\sum_{i=1}^{n}(x_{i1} - \bar{x}_1)^2}. \quad (27)$$

Plugging in the true model for y_i and taking expectations yields[179]

$$E(\tilde{\beta}_1) = \beta_1 + \beta_2 \frac{\sum_{i=1}^{n}(x_{i1} - \bar{x}_1)x_{i2}}{\sum_{i=1}^{n}(x_{i1} - \bar{x}_1)^2}, \quad (28)$$

which is not generally equal to β_1.The estimate is therefore biased. The ratio multiplying β_2 has a simple interpretation; it is the slope coefficient from the regression of x_2 on x_1. Therefore, the two covariates are correlated, the stronger the bias. The direction of this bias is displayed in Table 13:

	$Corr(x_1,x_2) > 0$	$Corr(x_1,x_2) < 0$
$\beta_2 > 0$	positive bias	negative bias
$\beta_2 < 0$	negative bias	positive bias

Table 13: Dependency of bias due to correlation of covariates

In the case of real estate, the condition or age of a building is likely to be correlated with energy efficiency, which is why it is likely for most studies to exhibit such a bias due to the negligence of energy efficiency.

Concluding notes

Ascan be noted from the above illustrated and explained statistical analysis, one must mention that such advanced interpretation methods to derive valuation input parameters go beyond the scope of usual property valuation practice and (1) require a huge samples of totally transparent and comparable property information that are usually not available to property valuers in practice and (2) can only be performed with advanced statistical training. Consequently, one cannot expect valuers to extract statistically significant results and to perform such detailed analysis within the valuation process.

[179] See Wooldridge (2006), pp. 90- 91)

To solve this obstacle it would be useful if such analysis were carried out and contributed by national committees of valuation experts or other real estate associations (e.g. RICS, etc.), who have a access to a large amount of market information and related datasets. The German local "Gutachterausschüsse" are a good example of a possible organization that would be capable of performing such calculations. Property valuers could subsequently use this quantified and specific evidence regarding the relation between energy performance and potentially other sustainability criteria and its impact on market rents theoretically as a direct adjustment parameter for the valuation of the subject property (see Case Study 1).

However, as recent RICS research[180] shows, even a "centralised" preparation of data will be difficult simply because of **serious problems in obtaining complete data sets**. In order to conduct hedonic modelling on price effects of energy efficiency / sustainability performance of buildings the following key data are needed:

- Asset (rental and capital) values and prices;
- Asset attributes influencing rental and sale prices (e.g. age, size, location, lease terms, different aspects of building quality;
- Asset environmental/energy performance or rating

Although this data is available in principle for many countries and regions, it tends to be split in very different databases and there are likely substantial costs involved in when trying to linking these databases due to definitional problems (different definitions of similar items in different sources).

Another issue is that empirical **market analysis always lags behind the market**. This is an important issue for uprising topics such as energy efficiency and sustainability in the real estate markets. In fact it gives a picture rather on how markets have been 1-2 years before than on how they are in the moment of the subject valuation.

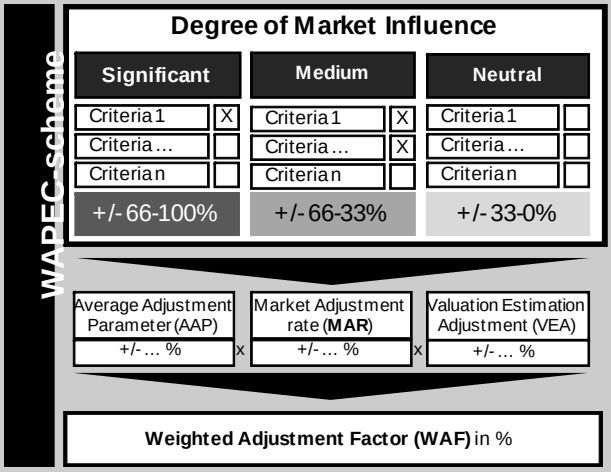
[180] Fuerst, Allister, de Wetering, Wyatt: Establishing a data framework for the investigation of the price effects of eco-labelling commercial property assets, University of Reading, RICS Research Report May 2010

6.4.3.2.2 Methodology for opaque markets

Key Facts and Findings

Basic description of proposed valuation approach

- In opaque property markets one cannot apply advanced statistical methods as it is hard to find reliable evidence of the value impact of green or energy-efficient buildings. Still, it is useful to quantify the degree to which the property market seems to be already influenced by green or energy-efficient building developments.
- An appropriate way to quantify this degree could be provided by applying a newly developed scoring model – the so called WAPEC (Weighted Adjustment for Valuation Parameter Effecting Characteristics) as illustrated below:



- The result of the easy-to-handle scoring model is an adjustment factor in percent that a valuer can use to adjust the market data of comps for the subject property being valued.

Short rationale for the proposed approach

- One of the main reasons why a kind of scoring model was suggested as basis for the WAPEC was the fact that such tools have already been used and applied under different circumstances within property valuation and therefore can be seen as an accepted and generally well-known technique

Expected impact on property valuation

- We expect that due to the adjustability and flexible applicability of the WAPEC, the majority of European property valuers will be in favour of an adjustment scheme

such as the WAPEC-methodology because of the possible adaptability, flexibility and applicability.

- The WAPEC-model gives guidance for the valuer to process his thoughts regarding the integration of energy efficiency and other sustainability issues into his valuation in a structured and transparent way.

In the case of an opaque property market and the related lack of market evidence and information, alternative ways to derive and handle energy efficiency and sustainability aspects within the valuation process are required. An opaque market can be a market where all comps are non-efficient or a market where sales and rental data is not fully available to the public.
So far there are no ascertained approaches or guidelines available that describe how valuers could methodologically include energy/environmental performance even if the necessary market evidence were available.
To establish the linkage to property valuation in a useful way it is essential that one comprehend that in an opaque market the key to quantifying the value impact of buildings' energy performance relies on the degree to which the market appears to have already been influenced by said technologies.

Scoring model to guide the valuer and provide a structured process

A scoring model could be one possible and appropriate way to quantify the extent to which an opaque market focuses on energy efficiency as well as energy-efficient buildings respectively. The idea of using scoring models or profiles is not new; these tools are already used within the valuation processes for different tasks – (e.g. adjustment for quality of location[181]) and therefore can be seen as generally accepted techniques to handle intangible effects.

Easy to handle adjustment factor for daily business

Therefore, the so-called "Weighted Adjustment for Valuation Parameter Effecting Characteristics" (WAPEC) was developed for the daily practice of valuers. By isolating the importance of energy efficiency (and potentially other sustainability aspects) within a specific property market due to various predefined aspects and characteristics the appraiser can derive an indication to which degree energy efficiency and/or other related issues already affect the

[181] See also Kleiber, W., Simon, J., Weyers, G. (2002), p.1241; Real Estate Norm Netherlands Foundation (1992), pp.2

property markets. This indication is expressed through the so-called **"Market Adjustment Rate" (MAR)**, which the valuer can use to describe the quantity of the markets' attention and willingness to pay for energy-efficient buildings. The valuer needs to fill in a scoring model that addresses different aspects like price elasticity, economic (market) conditions, consumer awareness, etc.. The MAR ranges from "neutral" (0 %) to high impact" (100 %). It is important to understand that the developed scoring model is not a complete and full enumeration of all green aspects and therefore the valuer can still be adap and apply the method for every single green-value-driver.

The following scoring model (Figure 26) shows how valuers are able to reflect the potential changes for the estimated rental value (ERV ≈ market rent).

Key Valuation Parameter	Market maturity	**Significant** adjustment	**Medium** adjustment	**Low** adjustment	**neutral**
Market rent	**Opaque (Emerging) Market** --> Premium for energetic building (primarilly in emerging market)	- high price elasticity ☐	- ... ☐	- ... ☐	-low price elasticity ☐
		- high awareness of tenants for sustainability and energy efficiency ☐	☐	☐	- tenants do not pay attention on sustainability and energy efficiency at all ☐
		- omnipresence of green building issues in the media ☐	☐	☐	- media does not recognise green buildings benefits at all ☐
		- high market sensitivity for operating expenses and energy costs (especially in gross rent-orientated property ☐	☐	☐	- majority of property market is not willing to pay rent premium for green buildings ☐
		- good general economic conditions ☐	☐	☐	- suffering economic situation ☐
		- ... ☐	☐	☐	- ... ☐
	-->Discount for non-energetic building (mainly in further developed markets)	- building does not achieve energy performance standards/codes ☐	- ... ☐	- ... ☐	- building achieve green building requirements ☐
		- market postulate green building standards/codes ☐	☐	☐	- market does not postulate green buildings ☐
		- high obsolescene and potential loss of occupier demand ☐	☐	☐	- no effect on occupier demand ☐
		- ... ☐	☐	☐	- ... ☐

Market adjustment rate (MAR)	+/- 75-100 %	+/- 50-75 %	+/- 25-50 %	+/- 0-25 %

x

Average adjustment parameter (AAP)* +/- ☐ [%] –> *AAP derived from market evidence / valuers expectations due to replicable argumentation or estimation*

x

Valuers estimation adjustment (VEA)** +/- ☐ [%] –> *Valuers estimation adjustment due to probability of occurrence, uncertainty, etc. regarding the AAP*

=

--> Weighted Adjustment Factor (WAF) +/- ☐ [%] –> *= MAR x AAP x VEA*

Key Valuation Parameter (KVP)

x ☐ [€/m² p.m]

Valuation Parameter Adjustment [VPA]

= ☐ [€/m² p.m.]

Figure 35: Example of WAPEC for market rent (ERV)

Operational cost differences set the margin

In addition to the verification of the MAR by applying the scoring model, valuers must also quantify the maximum range of willingness to pay for energy performance or other sustainability issues. In a rational property market one can describe this using the **"Average Adjustment Parameter" (AAP)**. If only **energy efficiency** is relevant for the AAP (given in percent of the evaluated parameter at market level), the maximum amount would be the

"Energy Cost Saving Potential" (ECSP). The ECSP in percent is derived by applying the ratio between the gap of expected cost for energy consumption of a reference building (comparable group of properties) in comparison to the property being valued (subject property) and the annual rental income. The reference building in this case refers to the mean of comparable buildings at the date of valuation.

The approach can be expressed in the following equations:

$$ECSP = \frac{\sum_{i=1} \left(E_{ref,i} \times p_{e,i}\right) - \sum_{i=1} \left(E_{sub,i} \times p_{e,i}\right)}{r_M \times 12} \quad (29)$$

where:

$E_{ref,i}$ - final energy consumption of specific energy carrier i of reference building (e.g. average of comparables) [kWh/m² a]

$E_{sub,i}$ - final energy consumption of specific energy carrier i of the property being valued [kWh/m² a]

$p_{e,i}$ - average price for energy carrier i [€/kWh]

r_M - observable market rent of the comparable properties [€/m² p.m.]

When setting the energy prices one can use the actual prices as well as expected prices, depending on whether there is an assumption that energy price increases would outreach average price increases. A more detailed description on how the calculate energy costs based on energy performance figures given in the EPC is included in chapter 6.4.2.1.

As this procedure of estimating the AAP still implies uncertainty regarding the probability of occurrence, valuers have in addition option when appling another adjustment factor called **"Valuation Estimation Adjustment" (VEA)**, which expresses the probability of occurrence as an expected percentage.

If valuers have estimated the MAR, AAP and the related VEA accordingly, the **"Weighted Adjustment Factor" (WAF) -** expressing the degree to which market rent for the subject property has to be adjusted (compared to the comparables) - can be quantified by simply multiplying these variables.

$$WAF = MAR \times AAP \times VEA \quad (30)$$

where:

MAR - states the valuer's estimation of the property market maturity regarding the degree of energy efficiency and other aspects that already affect the property market.

AAP - is derived from market evidence (if existing) or the valuer's expectations due to replicable argumentation or estimation.

VEA - expresses the valuer's estimated adjustment due to the probability of occurrence, uncertainty, etc. regarding the AAP.

The valuer can then apply the calculated WAF to the key valuation parameters (in this case the observable market rent per m² per month) in order to derive a numerical **"Valuation Parameter Adjustment" (VPA)**. An example how the explained adjustment can be applied in practice is illustrated in chapter 6.4.3.4 (Case Study 2).

Concluding, one might note that the calculated saving potential is not representative due to the fact that the energy consumption of the subject and the comparable buildings are influenced and dependent by the occupiers' behaviour of usage and therefore can differ from the actual energy consumption. While, this might be the case, one should also note that in accordance with renowned valuation standards, valuers always assume that the owner or occupiers of a property act, maintain and use a property in a proper manner (idea of "highest and best use"[182]).

Further one should understand that if data availability allows, it is advisable to **go beyond the pure energy cost** and **include the other relevant operating cost elements** such as costs relating to cleaning, inspection, maintenance, replacement etc. (see in detail chapter 6.4.2), to determining the AAP. Using an LCC approach one can derive the "Operating Cost Saving Potential" (OCSP) expressed along the lines of the approach described above:

$$OCSP = \frac{\sum_{i=1}\left(OC_{ref,i}\right) - \sum_{i=1}\left(OC_{sub,i}\right)}{r_M \times 12} \qquad (31)$$

where:

OC_{ref} operating cost element of a reference building (e.g. average of comparables)

OC_{sub} operating cost element of the subject property

i certain operation cost category (e.g. maintenance, cleaning, energy consumption etc.)

r_M observable market rent of comparable properties[€/m² p.m.]

Summarising the proposed approach consists of two parts: (see also Figure 29 on page 111).

[182] Cf. IVSC (2007), p.79

- First, the potential rent premium must be assessed by analysing operational cost differences between the subject and comparables. This is based on the assumption that lower operational costs can be transferred to higher rents - but only to a certain degree!
- The market conditions need to be assessed in order to derive the extent to which rents can be increased due to lower operational costs. The valuer can perform this in a structured and transparent way by applying the score-card developed in the frame of this project.

Valuers need easily applicable LCCA tools in order to calculate cost differences. Therfore, appendix A includes several examples of LCCA models applicable to the calculation of operational costs of buildings.

Other application possibilities of the WAPEC approach

Besides using the WAPEC to estimate adequate market rent, valuers could also adjust other key valuation parameters (main green value drivers as explained in chapter 6.4.3.1) such as the applied yield or other issues with a direct influence on value in a similar way (see Figure 36 and Figure 37).

However, the adjustment of the applied yield (see Figure 36) would be, critical because the method tends to produce overestimated results. Valuers must be aware that the maximum yield adjustments and gap between conventional building and green buildings (which encompass more aspects than just energy efficiency) might be as low as 50 to 75 basis points as stated by e.g. Bowman and Wills[183]. From another perspective, institutions such as the New Research Bank (California) report that they apply a 0.125 % discount rate and a higher loan to value ratio for green building developments.[184]Therefore one should only take an adoption into considerations if reliable evidence for yield adjustments is available.

[183] Cf. Bowman, R., Wills, J. (2008), p.28

[184] Cf. Valhouli, C.A. (2008), p.42

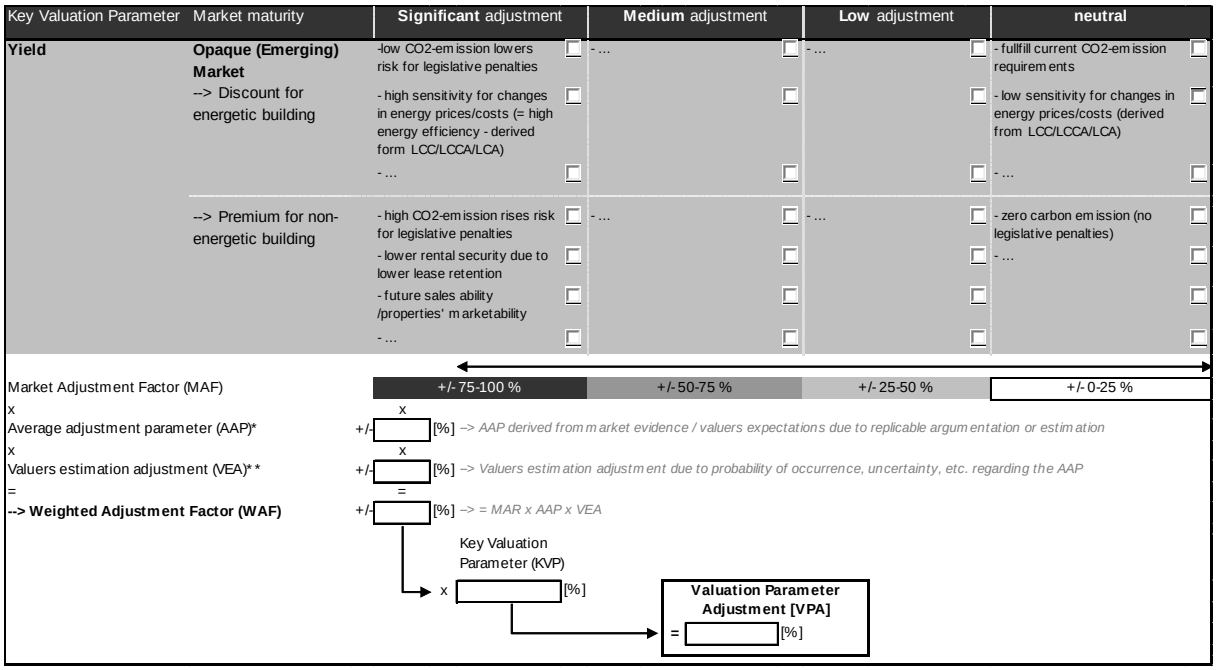


Figure 36: Example WAPEC for yield adjustment

Independent of the presented WAPEC-approach, de Francesco and Levy[185] consider applying a similar way to consider sustainability aspects within the applied yield that relies on the basis of advanced determination of the yield via the CAPM (Capital Asset Pricing Model). According to their intuition, in addition to the usual risk factors, (risk-free rate (r_f) and the market risk factor component expressed in the second term) there exists another risk factor associated with sustainability aspects ($\beta_s \times r_s$) as expressed in following equation.

$$yield = r_f + \beta_m \times (r_m - r_f) + (\beta_S \times r_s) \quad (31)$$

where:

r_f - risk-free rate

β_m - quantum for systematical risk of the specific property market

$(r_m - r_f)$ - market risk premium

$(\beta_S \times r_s)$ - additional risk factor associated with sustainability aspects

The illustrated risk factor for sustainability is comparable to the *WAF* as expressed in the WAPEC-approach, whereas *MAR* is equal to β_s and the *AAP* represents the r_s.

[185] Cf. de Francesco, A.J., Levy, D. (2008), pp.77

Another possible application of the WAPEC is related to direct energy efficiency investments which might be necessary because of specific building standards of a certain quality required by the market in order to achieve a certain rent. On the other hand, it is also possible that non-energy-efficient buildings could be threatened by tax penalties, etc. If this is the case, valuers have to estimate to what extent such aspects influence the market value of a property. Therefore, the WAPEC could be an appropriate way to estimate an adequate weighted adjustment factor (see Figure 37)

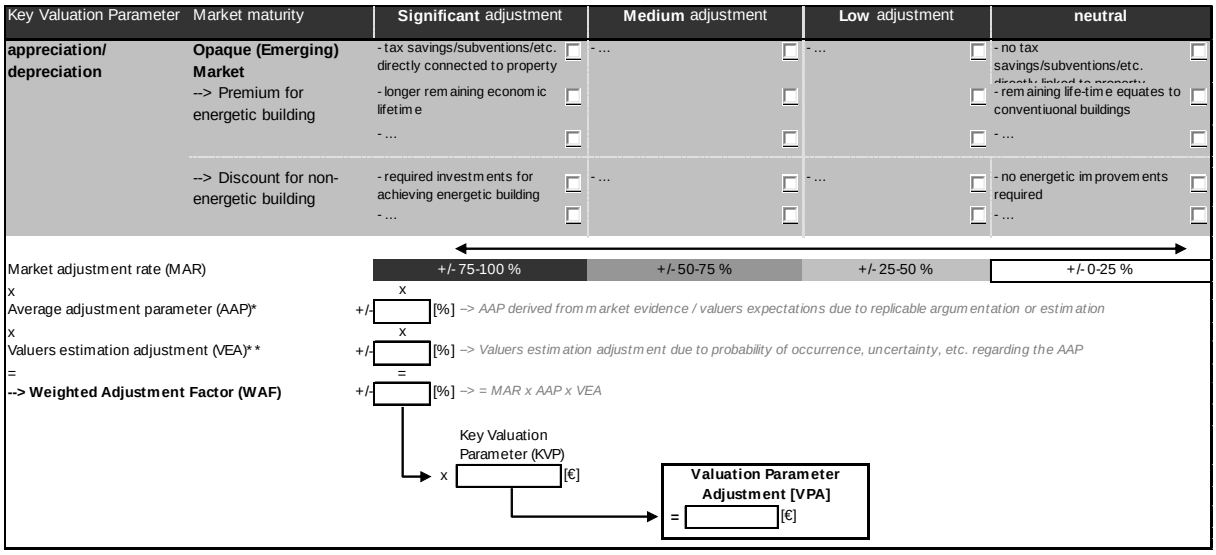


Figure 37: Example WAPEC for particular characteristics which directly influence value

Limits of the WAPEC approach

The WAPEC scoring is designed to calculate the differences in technical construction between the peer group and the subject property.

Hence the WAPEC table has certain limitations concerning its applicability. Consider the following example: The market has a strong demand for passive houses and regards them as a prestige object, resulting in an over demand of these buildings. Consequently, the cost value is below the market value. However, this implies that building a passive house on an undeveloped site is strictly cheaper than buying a house on the market. Yet, since the house as such is comparable and reproducible, this is counter intuitive and has no sound economic reasoning. Therefore, the higher market value cannot result from the fact that the customer is looking for a passive house but rather the fact that he is looking for a passive house at this *particular location*. Having uncovered this mechanism it is straightforward to obtain a market adjustment by monitoring recent sales.

6.4.3.3 Case Study 1 – Evidence from econometric analysis for the case of a developed market

6.4.3.3.1 Effect of energy performance for office buildings[186]

The following survey is an original study. It is based on empirical data of office buildings collected for benchmarking purposes by CREIS Real Estate Solutions. The CREIS database consists of various building attributes and service charges[187] (explanatory variables) as well as average rents per square meter. The following table describes the variables used for this study. The attributes and costs were collected on the basis of legal requirements (e.g. BetrKV, 2004; DIN 277, 2005; DIN 18960, 1999; DIN 31051, 2003 etc.), that make the results traceable and convertible.

As the data was originally collected by a questionnaire, the original data was changed into a dataset that one could be statistically investigate first. For this purpose, all the labels of categorical variables that were represented with alphabetic characters were transformed into numbers. Therefore, the dummy variable *elevator* (existence of an elevator), originally labelled yes-no was changed to 1-0. Covariates *air* and *quality* were also encoded by dummy variables. The variable describing the city where the building is located was also encoded by numbers in alphabetical order. Furthermore, there were two ordinal variables with three categories, each also labelled by characters: Air condition (*air*) and building quality (*quality*). The first variable describes whether a building is equipped with full air condition (i.e., if air condition comprises heating, cooling, humidification and dehumidification), partial air condition (compared to full air condition, at least one of the functions is not contained) or no air condition.

The original sample consists of 1578 observations, collected from 2000 to 2005 in 94 German cities. As the response variable was only collected from 2002 onwards and still not mandatory, the sample size was reduced to 532 observations in 57 cities. The following Table 14 describes the variables used in the regression.

[186] We thank Neumann und Partner GbR for the provision of the data used in this study.

[187] Service charges may be defined as the costs of area provision and management allocable to the tenant (see Jones Lang LaSalle, 2000 - 2005).

Variable	Description	Mean/ frequency	Std.-Dev.	Min	Max
rent_psqm	Average rent per sq.m. (NGF) per month	13.72	5.81	2.56	38.73
ngf	Netto Grundfläche (NGF), net floor space of all floors of a building	14,037.05	13,310.16	370.53	115,278.00
age	Age of the building, duration since the last redevelopment	14.37	13.39	0.00	113.00
quality	Quality of the building	1.17	0.59	0	2
quality_h	Dummy for high quality of the building	28%		0	1
quality_m	Dummy for medium quality of the building	62%		0	1
quality_l	Dummy for low quality of the building (reference)	11%		0	1
elev	Dummy for the existence of an elevator	99%		0	1
air	Air condition of the building	0.56	0.70	0	2
full_air	Dummy for full air condition	12%		0	1
part_air	Dummy for partial air condition	31%		0	1
no_air	Dummy for no air condition (reference)	56%		0	1
maint_psqm	maintenance costs per sq.m. per month	0.427	0.504	0.004	4.827
energy_psqm	energy costs (heating, electricity) per sq.m. per month	0.839	0.624	0.104	5.510
other_psqm	other service charges per sq.m. per month	1.700	0.667	0.316	4.373
year	Year of entry into the database	2,003.63	1.16	2,002.00	2,005.00
city_no	No of the city the building is located in			1	57

Table 14: Description of key variables used for regression

The variable quality needs to be further explained. Its categories “basic/low,” “fair/medium” and “high” depend on various items (see Table 15). One must mention that the description of this variable partly overlaps with other variables (elevator and air). This is likely to cause multicollinearity and therefore reduces the expressiveness and significance of these variables. Furthermore, one may recommend collecting each item of this variable separately, as that may lead to different effects on different cost categories. For example, a structured body shell may lead to higher heating energy consumption, while a curtain wall façade may have contrary effect. Since both express high qualities, the total effect of this category is blurred.

	Basic	Fair	High
Body Shell, Space Concept	Simple body shell structure, fixed space concept	Simple or structured body shell, flexible space concept	Structured body shell, flexible space concept
Façade	Perforated façade, ribbon windows, basic materials (e.g. plaster finish)	Ribbon windows, curtain wall façade, medium quality materials	Curtain wall façade, high-quality materials (e.g. glass)
Floor, Electricity supply	Solid floors, single sockets or dedo trunking	Dedo trunking or integrated floor ducts	Double-bottomed floors, hollow floors, ducts or floor containers
Ceiling, Lighting	Solid ceilings, suspended ceilings with integrated lights	Suspended ceilings with integrated high-quality lights	Suspended ceilings with direct as well as indirect lighting
Heating energy supply	Stationary heating, natural ventilation	Stationary heating, some air conditioning in special areas	Innovative heating system, partial or full air conditioning
Other equipment	Data transmission network, access control, smoke detectors	As before, in addition: lifts, emergency power generator	As before, in addition: central building control and video-based security systems

Table 15: Categories for building quality

Additionally, the variable *age* (difference between the year of data collection and year of construction/redevelopment) was introduced in order to make the effects of the age of the building comparable across the whole sample and get a "cross section view". If the building has been redeveloped, the year of redevelopment was used for the calculation of the age of the building, otherwise the year of construction. With respect to a possible time trend concerning the general cost level, dummies for the year of entry were introduced as control variables.

We first establish a theoretical ("deterministic") relationship for the regression analysis. Theoretical considerations tell us which functional form should be applied (a log- or semi-log specification, see above). This yields the model:

$$\ln(rent_psqm) = \beta_0 + \beta_1 quality_h + \beta_2 quality_m + \beta_3 elev + \beta_4 full_air + \beta_5 part_air + \beta_6 age + \sum_{i=7}^{10} \beta_i year_i + \sum_{j=11}^{31} \beta_j city_no_j + \beta_{32} \ln(ngf)) + \beta_{33} \ln(maint_psqm) + \beta_{34} \ln(energy_psqm) + \beta_{35} \ln(other_psqm) + \mathbf{u} \quad (32)$$

where all metric variables except *age* are transformed logarithmically. Furthermore, we control for a time effect (*year*) and the city the building is located in. Specifically, we generate dummy variables if more than 4 observations occur in the respective city.

The results of this linear regression analysis are presented in the following table (the dummy variable coefficients capturing locational heterogeneity are not shown in Table 16.

Linear Model

Number of obs	532
F(33, 498)	10.58
Prob > F	0.0000
R-squared	0.4121
Adj R-squared	0.3732
Root MSE	0.3115

logrent_psqm	Coef.	Std. Err.	t	P>|t|
_cons	2.615	0.210	12.43	0.000
logngf	-0.058	0.018	-3.19	0.002
age	-0.002	0.001	-2.09	0.038
logmaint_psqm	-0.020	0.018	-1.07	0.285
logenergy_psqm	**-0.095**	**0.035**	**-2.73**	**0.007**
logother_psqm	0.270	0.042	6.38	0.000
year_2003	0.044	0.043	1.03	0.304
year_2004	-0.023	0.041	-0.57	0.569
year_2005	-0.107	0.040	-2.67	0.008
quality_h	0.357	0.064	5.62	0.000
quality_m	0.125	0.053	2.34	0.019
elev	-0.142	0.145	-0.98	0.326
full_air	0.104	0.057	1.82	0.069
part_air	0.093	0.036	2.58	0.010

Table 16: Results of linear regression analysis

The F-statistics show that the model is highly significant. With an adjusted R^2 of 37 %, it gives a reasonable fit to the data. Furthermore, energy costs seem to have a significant effect on rents per square meter: *Ceteris paribus*, 100 % higher energy costs per square meter reduce rent per square meter by 9.5 %. This result holds on a 5 %-significance level.

However, although we have a rough idea of which functional form to apply in the hedonic regression model from theoretical considerations, it seems fruitful to apply the additive mixed

regression model AMM as described in Fahrmeir, et al.[188]. We use a semiparametric approach in order to deal with nonlinearity in regression parameters and a random city effect term to incorporate spatial heterogeneity as described in the last subsection.

Therefore, we estimate the model

$$\begin{aligned}\ln(rent_psqm) &= \beta_0 + \beta_1 quality_h + \beta_2 quality_m + \beta_3 elev + \beta_4 full_air \\ &+ \beta_5 part_air + \beta_6 age + \sum_{i=7}^{10} \beta_i year_i + \sum_{j=11}^{31} \beta_j city_no_j \\ &+ f(\ln(ngf)) + f(\ln(maint_psqm)) + f(\ln(energy_psqm)) + f(\ln(other_psqm)) + \mathbf{u}\end{aligned} \tag{33}$$

Taking a closer look at the semiparametric effect of energy costs per square meter, we find a rather pronounced nonlinearity. The following Figure 38 evaluates the effect of monthly energy costs per square meter at the sample mean rent per square meter (which is approximately 13.72 Euro). Interestingly, in the domain of 0.2 to 2 Euro per sqm, there seems to be a "zone of indifference", meaning that an increase in energy costs does not seem to have any effect on rents per sqm. However, as energy costs increase further, there is a noticeable effect on rents per square meter – a decrease from 14.0 Euro to 13.2 Euro per sqm (~5.8 % of the mean).

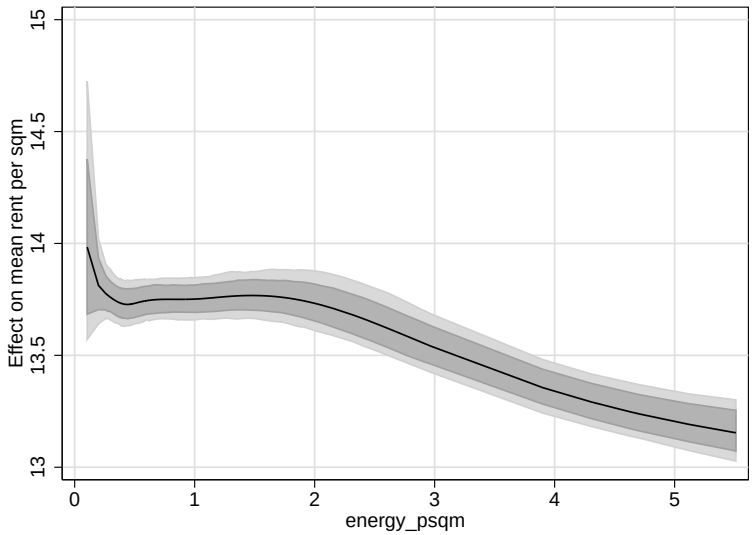


Figure 38: Effects of energy costs on monthly rent per sqm

Another possibly interesting question could be how the omission of the covariate energy costs would impact the estimates of the other covariates. As we know from the theoretical

[188] Cf. Fahrmeir, L., Kneib, T., Lang, S. (2004)

considerations above, we know that the bias is more pronounced the higher the omitted variable is correlated with the included variables. The correlation structure shows that energy per square meter is particularly correlated with the quality of the building and the existence of an air condition.

	Correlation with energy_psqm
quality_h	0.148
quality_m	-0.099
full_air	0.442
part_air	0.005

Table 17: Correlation of energy per square meter with buildings' quality

It turns out that an underspecified model (omitting energy costs) results in a different parameter estimation for quality and particularly for air condition. Specifically, the estimated parameter for medium quality decreases by 13 %. The estimated parameter for full air condition even decreases by 93 %.

varname	full model	omitted	difference
quality_h	0.307	0.315	3%
quality_m	0.134	0.117	-13%
full_air	0.069	0.005	-93%
part_air	0.051	0.042	-17%

Table 18: Effects of applying different models

Interpretation of presented regression results and link to property valuation

One m ust note regarding the above shown regression that there are three main critical aspects regarding the applied dataset. First of all, the stated impact of energy cost based changes is based on the agreed rent due to lease conditions and does not reflect the specific market rent, which is usually the basis for property valuation. Second, the regression is carried out on historical energy consumption and does not reveal the current energy demand. Furthermore, the stated energy costs represent historical costs and do not reflect the current prices for energy sources.

In fully transparent and developed markets (as defined previously) the quantified impact of energy cost on the achievable rent for a property could be directly integrated in a proper manner into property valuation. Otherwise valuers have to estimate the impact to appraise and evaluate possible effects (see methodology for opaque markets).

To give an impression of how valuers can integrate the above stated specific result of the regression analysis in an appropriate way (if a developed market is given) we created the following simplified example with subsequent assumptions:

Subject Property	
• Rentable Area	800 m²
• Energy demand	135 kWh/m².a
• Costs for energy	0.05 €/kWh
• Non-recoverable operating expenses	15000 € p.a.
• Equivalent Yield (incl. inflation, growth of energy costs, etc.)	6.00 %
• No special construction damage, significant maintenance demand.	
Peer Group (comps)	
Comp. 1:	
• Energy demand [kWh/m².a]	65 kWh/m².a
• Rent [€/m² p.m.]	13.5 €/m² p.m.
Comp. 2:	
• Energy demand [kWh/m².a]	50 kWh/m².a
• Rent [€/m² p.m.]	14.5 €/m² p.m.
Comp. 3:	
• Energy demand [kWh/m².a]	85 kWh/m².a
• Rent [€/m² p.m.]	13.0 €/m² p.m.

To show the direct market value impact of the stated correlation between energy costs (energy efficiency) and rent in the example is based on the assumption of the following aspects. In general one must assume that the degree of energy efficiency is derived by the difference between the energy demand of the subject property in contrast to the average energy demand of a peer group. The applied peer group exists only of comparable properties (comp 1, comp 2 and comp 3), which represent the same kind of property in similar location and have equivalent size measures, age etc., and just differ in their energy efficiency and demand respectively (assuming that there is a linear relationship between energy demand and energy costs). To simplify the following case study, one further assumes that the estimated non-linear rent reduction due to better energy efficiency (see results of regression analysis above) can be applied in a linear manner to the market rent and current energy prices.

Given this framework, valuers can calculate the rental impact by taking the results of the regression analysis as a basis to express a “rent adjustment factor” (RAF) as follows:

$$RAF = 0.095 \times \left(\frac{E_{peer} \times c_e - E_{subj} \times c_e}{E_{peer} \times c_e} \right) + 1 \qquad (34)$$

where:

E_{peer} - average energy demand of a peer group [kWh/m² a],

E_{subj} - energy demand of subject property [kWh/m² a],

c_e - costs for energy

Due to this, a RAF of <1 expresses a higher energy demand for the subject property in comparison to the average energy demand of the peer group (subject property is less energy-efficient than comparable properties). In contrary if the RAF is 0 or >1 the subject property achieves same or better energy efficiency than comparable properties. In the illustrated example the RAF exceeds a value of approximately 0.9 as it can be seen in Figure 39.

Parameters	Subject property	Average of peer	Comp 1	Comp 2	Comp 3
Observable rent	-	-	13.5 €/m² p.m.	14.0 €/m² p.m.	13.0 €/m² p.m.
Market rent	-	**13.5 €/m² p.m.**			
Energy demand	**135 kWh/m².a**	**67 kWh/m².a**	65 kWh/m².a	50 kWh/m².a	85 kWh/m².a
Cost of energy	0.05 €/kWh	0.05 €/kWh			
Energy costs	**0.56 €/m² p.m.**	**0.28 €/m² p.m.**			

$$RAF = 0.095 \left(\frac{E_{peer}\ c_e - E_{subj}\ c_e}{E_{peer}\ c_e} \right) + 1 = \left(\quad \right) = 0.9$$

Figure 39: Numerical example – estimation of RAF

One can apply the RAF derived in this manner directly to calculate the adjusted estimated rental value (ERV) and the potential gross income within the valuation calculations. Following Figure 40 illustrates a numerical example related to the previous explanations and show how the RAF is embedded.

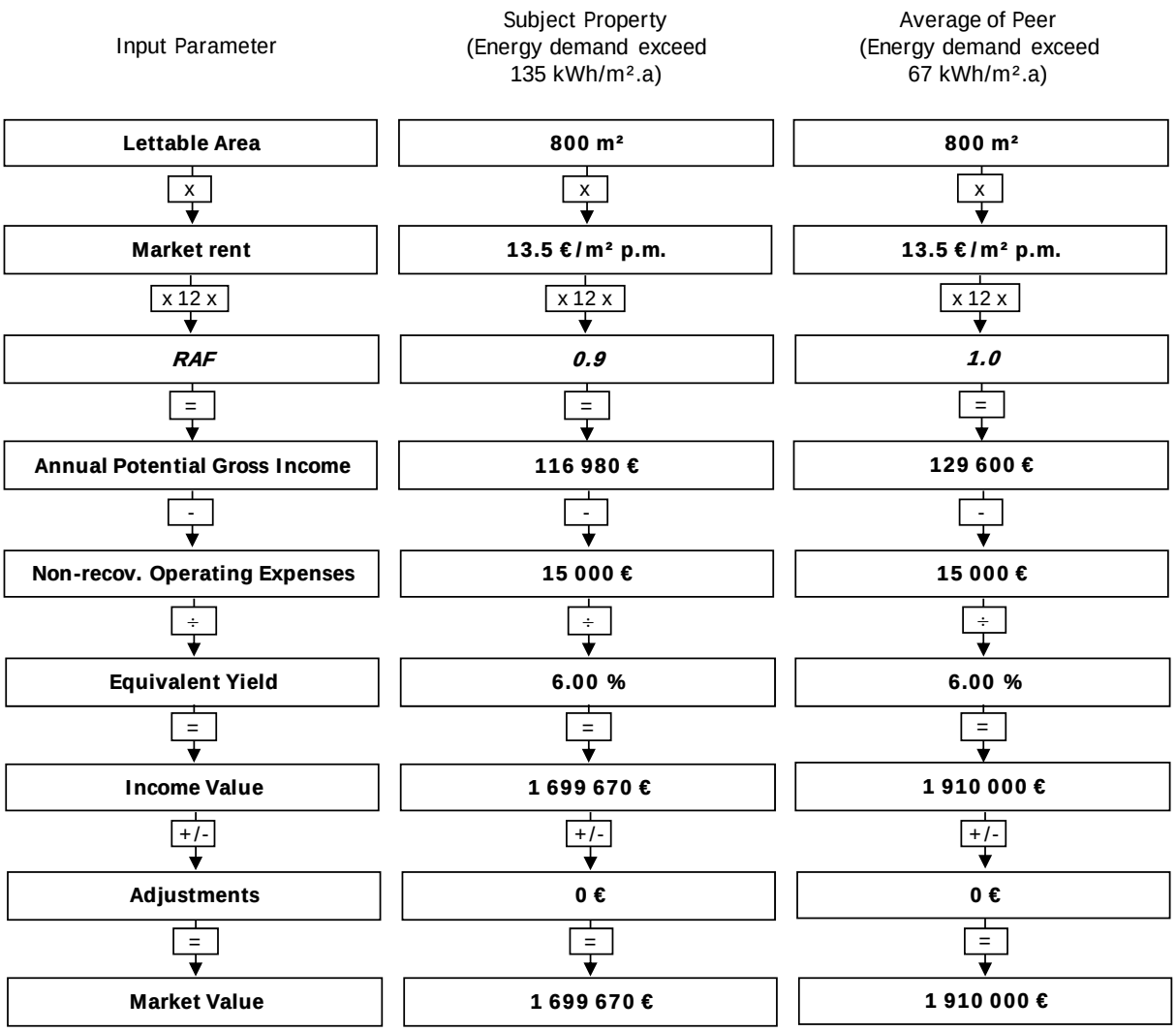


Figure 40: Numerical example – direct cap approach in developed markets

In conclusion, the exemplary calculation implicates just one possible quantified impact of energy-efficient buildings – namely on the achievable rent. Consequently one must carry out further regression analysis in order to quantify more valid impact factors which might be applied in a similar way as shown in the example above.

Therefore when summarising the results of the case study, one must mention that the rental effects on the basis of the results from the regression analysis are higher than the gap between the energy costs of the subject property and the reference building. This is due to the fact that the market data used implies a willingness to pay for energy-efficient buildings, which is higher than the energy cost saving potential. That means that in the observed market energy-efficient buildings are still a *unique selling proposition* (USP) and do not express the standard. Therefore they achieve higher rental premiums than a rational occupant might pay. Another

reason for this may be due to possible omitted variables as stated in chapter 6.4.3.2.1 as well as possible uncertainty within the used data base.

6.4.3.3.2 Residential real estate - omitted variable bias[189]

The considerations above showed us that the omission of a relevant covariate such as energy costs or energy efficiency result in biased estimates. However, in most studies concerning energy efficiency, if there are any, deal with commercial real estate and do not take residential property into account. Based on a study by Brunauer et al. (2009), we try to get an impression of how the omission of a relevant energy-specific covariate (e.g. "energy efficiency" as measured in the the buildings' specific demand of heat ($HWB_{BGF, Ref}$ per sqm).

As described in Steixner et al.[190], the buildings' annual demand is the amount of heat that must be provided to keep the temperature of the heated rooms at the required level (OIB, 2007) and applies to the heated gross floor area related to a standard climate (3400 degree days). The demand is categorized in energy efficiency classes: "A++" indicates a highly efficient building of no or a very low heat-consumption, respectively class "G" marks a very high heating energy demand of more than 250 KWh/m²a. The following Table 19 shows the 9 energy efficiency classes of the Austrian energy certification (OIB, 2007).

Klasse	$HWB_{BGF, Ref}$
A++	≤ 10 kWh/m²a
A+	≤ 15 kWh/m²a
A	≤ 25 kWh/m²a
B	≤ 50 kWh/m²a
C	≤ 100 kWh/m²a
D	≤ 150 kWh/m²a
E	≤ 200 kWh/m²a
F	≤ 250 kWh/m²a
G	> 250 kWh/m²a

Table 19: Categories of the Austrian EPC-energy efficiency classes

The data set used for this study covers 8767 rental flats in Vienna from the 1st of January 2004 to the 14th of February 2007. It includes offered rent (in Euro values per month incl. VAT and service charges, excl. heating and energy costs, which are usually paid by the tenant),

[189] We thank ERES NETconsulting-Immobilien.NET GmbH (www.immobilien.net), who act as a sponsor of this project, for the provision of the data used in this study.

[190] Cf. Steixner, D., Brunauer, W., Lang, S. (2007)

continuous variables such as floor size of the flat and indication of the time of letting, integer variables such as the floor in which the flat is located, its current condition (captured in 4 categories) and its year of construction (10 categories) as well as binary variables such as identifying whether the unit has a terrace, a balcony, a garage or a parking lot (see the following Table 20).

Variable	Description	Scale Type	Mean	Std.-Dev.	Min	Max
logrent_psqm	log of rent per sqm. of apartment [EUR per sqm.]	ratio	2.08	0.29	0.81	3.00
Area	floor size of the flat [sqm.]	ratio	85.06	38.67	24	200
Terr	existence of a terrace	binary	0.18	0.38	0	1
Balk	existence of a balcony	binary	0.14	0.34	0	1
Gar	existence of a garage	binary	0.14	0.34	0	1
Park	existence of parking lot	binary	0.03	0.17	0	1
Elev	existence of an elevator	binary	0.70	0.46	0	1
Noelev	no elevator in 3rd floor or higher (interaction variable)	binary	0.09	0.29	0	1
Cond	condition of the apartment	ordinal	2.18	0.53	1	4
Floor	number of floor the apartment is located in	ordinal	2.81	1.72	0	6
yearconst	year of construction	ordinal	1938	46.22	1815	2006
Distr	number of district	nominal			1	23
End	time index variable [days]	interval	07/12/2005	316	01/01/2004	14/02/2007

Table 20: Description of binary variables

While most studies examine the effects of these characteristics on total rents, Brunauer et al. (2009) follows Fahrmeir et al. (2004) and chooses to examine the effects on rents per sq. m. mainly for the following reasons:

First, using this specification we try to explain the structure of the supposedly decreasing marginal returns of additional floor size in detail. More specifically, we find substantially decreasing effects of additional floor size in our data.

Second, rent per sq. m. is especially interesting in the context of the Austrian rental law, which imposes upper limits for this ratio depending on dwelling and building characteristics. Therefore, the achievable rent per sq. m. is an important benchmark for policy makers as well as market participants on both the supply and demand side.

Brunauer et al. (2009) estimate a semiparametric model using P-splines (see above): Non-linear effects of continuous covariates as well as a smooth time trend are modelled non-parametrically through P-splines. Unobserved district-specific heterogeneity is modelled in two ways: first, by location specific intercepts with the postal code serving as a location

variable. Second, in order to permit spatial variation in the nonlinear price gradients, in a two-stage procedure they introduce multiplicative scaling factors for nonlinear covariates. While Brunauer et al. (2009) focus on the spatial aspects of hedonic price models, we try to describe the consequences of an omitted covariate for energy efficiency and therefore do not need to estimate a second stage.

For our purposes, we focus on two covariates in this study: the year the building was built (left panel of the following Figure 41) and the condition of the flat (right panel).

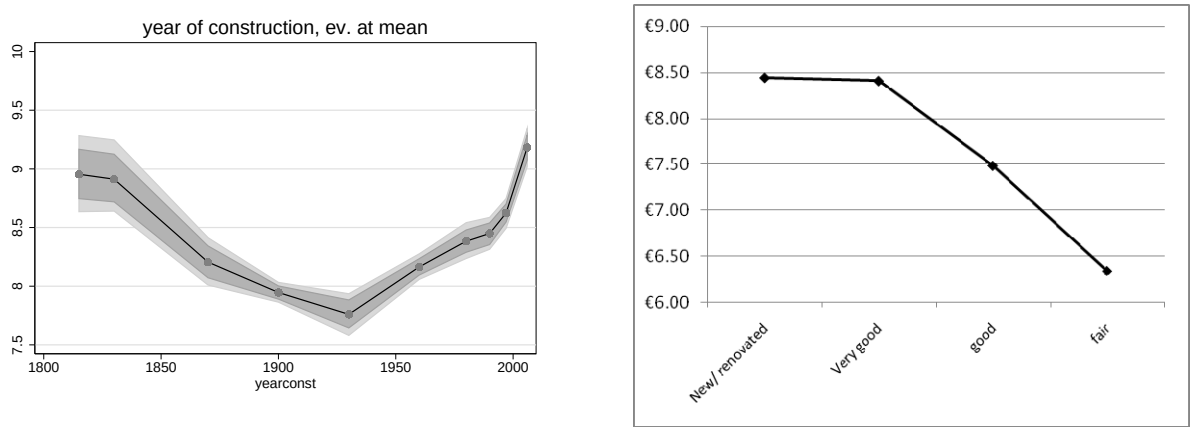


Figure 41: Effects of covariates year of construction and condition of the flat

Brunauer et al. (2009) explain the effect of the year of construction as follows: "…Furthermore, heating costs could also have an effect on rents per sq. m.: Recall that heating costs are not included in offered rents in our dataset. Therefore, the higher the heating costs of a flat, the lower the rent a tenant should be willing to pay for it. Buildings constructed before First World War tend to exhibit rather good thermal quality due to their massive structural design, while buildings constructed afterwards up to the 1960s are usually of a lower constructive quality. Additionally, energy-efficient building has become more and more popular during the last 15 years (e.g. due to an increasing amount of subsidies), which could also partly explain the strong increase of rents for relatively new buildings." Additionally, the effect of the condition of the flat may be strongly correlated with the energy efficiency of the building.

Hence, energy efficiency seems to be a relevant omitted variable, and it is therefore desirable to get an impression of the size of its effect on rents per sqm. We use the covariates *year of construction* and *condition* to construct the new explanatory variable for demand of heat, which we call *hwb*.

In order to construct this new variable, we figured out realistic numbers for hwb, which are shown in the following Table 21.

		cond							
		new/ renov.		very good		good		fair	
		low	*up*	*low*	*up*	*low*	*up*	*low*	*up*
year	**< 1890**	30	100	80	120	100	150	130	200
	1890-1913	30	100	80	170	100	200	150	250
	1914-1945	30	100	100	200	120	200	150	250
	1946-1975	30	100	100	200	120	200	150	250
	1976-1984	30	100	40	100	50	100	70	120
	1985-1994	30	80	50	80	60	80	70	100
	1995-2000	30	60	30	70	40	70	50	80
	2001-2007	20	50	30	60	30	60	40	70

Table 21: Demand of heat due to building condition and age

In Table 21, "low" defines the lower bound and "up" 98 % quantile of a $\chi^2(6)$ distribution of the demand of heat measured in kWh/m² p.a.[191]

This procedure resulted in the following correlation structure (see Table 22):

	Correlation with hwb	
condition	**new/ renov.**	-0.253
	very good	-0.253
	good	0.319
	fair	0.261
year	**< 1890**	-0.001
	1890-1913	0.383
	1914-1945	0.182
	1946-1975	0.406
	1976-1984	-0.168
	1985-1994	-0.230
	1995-2000	-0.483
	2001-2007	-0.433

Table 22: Correlation of buidlings' condition and year of construction with hwb

We then conducted a linear regression on the model

[191] We chose a $\chi^2(6)$ distribution because it is bounded to the left and randomly generates some "outliers" to the right. Furthermore, it has a positive skew, which is also what we expect of energy performance indicators.

$$\log(\text{rent_psqm}) = \beta_0 + \beta_1\text{park} + \beta_2\text{balc} + \beta_3\text{gar} + \beta_4\text{cond1} + \beta_5\text{cond3} + \beta_6\text{cond4} + \beta_7\text{terr} + \beta_8\text{elev} + \beta_9\text{noelev} + \beta_{10}\text{end} + \beta_{11}\text{area} + \beta_{12}\text{area}^2 + \beta_{13}\text{area}^3 + \sum_{i=14}^{19}\beta_i\text{year}_i + \sum_{j=20}^{42}\beta_j\text{distr}_j + \beta_{43}\ln(\text{hwb}) + \mathbf{u} \quad (35)$$

For simplicity, we display the results of this regression for only the covariates of interest in the following table, namely condition, year of construction and hwb (see Table 23).

	Omitted variable				**Included variable *hwb***				
logrent_psqm	Coef.	Std. Err.	t	P>t	logrent_psqm	Coef.	Std. Err.	t	P>t
year1	-0.035	0.014	-2.54	0.011	year1	-0.002	0.017	-0.09	0.927
year2	-0.106	0.007	-14.18	0.000	year2	-0.065	0.014	-4.51	0.000
year3	-0.138	0.014	-9.59	0.000	year3	-0.090	0.020	-4.42	0.000
year4	-0.074	0.009	-8.74	0.000	year4	-0.027	0.017	-1.60	0.110
year5	-0.047	0.013	-3.75	0.000	year5	-0.031	0.013	-2.36	0.018
year6	-0.043	0.011	-4.04	0.000	year6	-0.029	0.011	-2.57	0.010
cond1	0.014	0.011	1.24	0.216	cond1	-0.010	0.013	-0.75	0.456
cond3	-0.116	0.006	-18.69	0.000	cond3	-0.110	0.007	-16.81	0.000
cond4	-0.286	0.016	-17.63	0.000	cond4	-0.267	0.017	-15.50	0.000
					lnhwb	-0.043	0.013	-3.31	0.001

Table 23: Results of linear regression for year of construction, hwb and condition

The estimated parameter for ln(hwb) is -0.043, meaning that the elasticity of demand of heat is -4.3 %. This parameter is significant on a 5 % level. The effect on the estimated parameters is furthermore displayed in the following Figure 42.

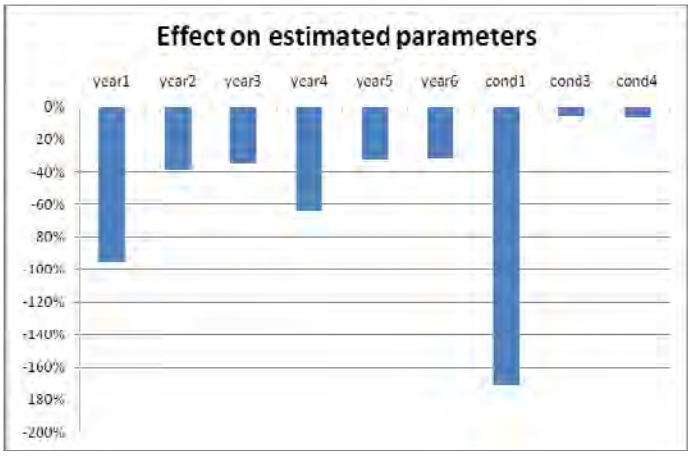


Figure 42: Effects on estimated parameters

Moreover, it would be interesting to estimate a nonparametric function for hwb. Therefore, we conducted a semiparametric regression on the model including the newly constructed covariate. The estimated function is displayed in the following Figure 43, for which we evaluated hwb at the mean of rents per sqm.

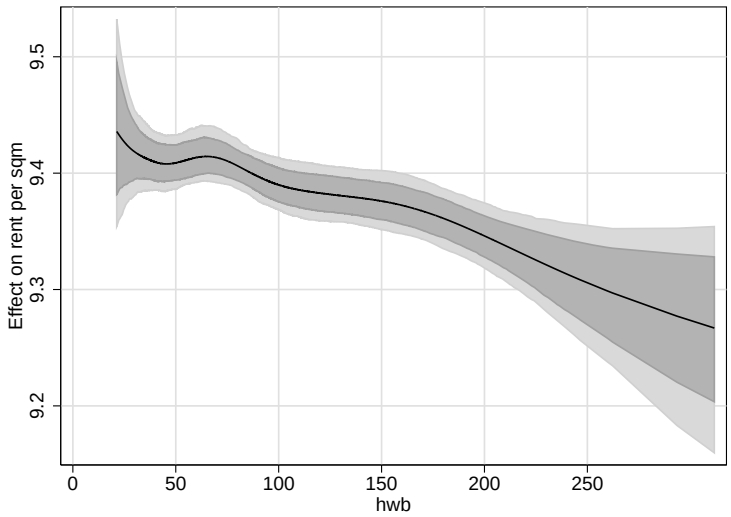


Figure 43: Effects of hwb on monthly rent per sqm

Final notes

In conclusion, one must mention that the illustrated results of the regression analysis under chapter 6.4.3.3.2 are hypothetical. The figures therefore just demonstrate and answer the question “what would happen, if...?“ on the basis of a theoretical scenario. Furthermore, the regression refers to a dataset that includes collected information from properties which where built a long time before governments and society started to pay attention to issues like energy efficiency and energy performance standards for properties, etc.

Referring to the results of the two regression analysis carried out under chapters 6.4.3.3.1 (German market data) and 6.4.3.3.2 (Austrian market data), one should further note the varying intensity of impact of a buildings’ energy efficiency. This observation implicates and strengthens the hypothesis that the markets’ willingness to pay for buildings’ energy performance varies between locations, market maturity (data availability), etc.

6.4.3.4 Case Study 2 – Basic makeshift for opaque markets

Based on the results stated in chapter 6.4.4.1.2, we created the following simplified example to demonstrate how such adjustments could be derived and handled in a practical way. In the following case the adjustment due to energy performance will be linked to the estimation of the applying market rent, as it is believed to be the most adequate adjustment parameter to integrate energy efficiency into property valuation.

Subject Property (Office)

- Rentable Area 800 m²
- No special construction damage, significant maintenance demand.
- Mainly use fuel oil as energy source
- Overall Energy demand 90 kWh/m².a
- Overall price for energy 0.10 €/kWh
- Non-recoverable operating expenses 8000 €
- Equivalent Yield (incl. inflation, growth of energy costs, etc.)6.00 %

Property Market situation

No profound evidence of direct impact of energy-efficient buildings on rents or property values is available, but markets' awareness for energy efficiency and the general sustainability topic gain momentum and importance.

Peer Group (comps office buildings)

Comparable properties mainly use renewable fuels as energy source (overall price for energy approx. 0.05 €/kWh).Comp. 1:

- Overall Energy demand [kWh/m².a] 50 kWh/m².a
- Rent [€/m² p.m.] 7,3 €/m² p.m.

Comp. 2:

- Overall Energy demand [kWh/m².a] 45 kWh/m².a
- Rent [€/m² p.m.] 7,5 €/m² p.m.

Comp. 3:

- Overall Energy demand [kWh/m².a] 60 kWh/m².a
- Rent [€/m² p.m.] 7,0 €/m² p.m.

The case study is carried out under following assumptions:

Due to the stated lack of evidence, property valuers must first evaluate the current property market situation in order to determine if and to what extent the market already recognises let alone cares about energy efficiency and energy-efficient buildings in general.

These investigations discovered that:

(1) the property market already recognised the importance of energy and resource efficient properties and started to take sustainability topics into account due to rising energy prices, etc.

(2) EPC's are mandatory, energy performance standards are introduced and property owners as well as tenants start to realise the relationship between EPC, energy efficiency and cost saving potentials.

The above stated market aspects lead valuers to evaluate the market maturity by applying the WAPEC-approach as illustrated in Figure 44:

Key Valuation Parameter	Market maturity	**Significant** adjustment	**Medium** adjustment	**Low** adjustment	**neutral**
Market rent	**Opaque (Emerging) Market** --> Premium for energetic building (primarilly in emerging market)	- high price elasticity ☐	- ... ☑	- ... ☐	-low price elasticity ☐
		- high awareness of tenants for sustainability and energy efficiency ☐	☑	☐	- tenants do not pay attention on sustainability and energy efficiency at all ☐
		- omnipresence of green building issues in the media ☐	☑	☐	- media does not recognise green buildings benefits at all ☐
		- high market sensitivity for operating expenses and energy costs (especially in gross rent-orientated property ... ☐	☑	☐	- majority of property market is not willing to pay rent premium for green buildings ☐
		- good general economic conditions ☐	☐	☐	- suffering economic situation ☐
		- ... ☐	☐	☐	- ... ☐
	-->Discount for non-energetic building (mainly in further developed markets)	- building does not achieve energy performance standards/codes ☐	- ... ☑	- ... ☐	- building achieve green building requirements ☐
		- market postulate green building standards/codes ☐	☑	☐	- market does not postulate green buildings ☐
		- high obsolescene and potential loss of occupier demand ☐	☐	☑	- no effect on occupier demand ☐
		- ... ☐	☐	☐	- ... ☐
Market adjustment rate (MAR)		+/- 75-100 %	+/- 50-75 %	+/- 25-50 %	+/- 0-25 %

Figure 44: Exemplary WAPEC for rent adjustment

As a result, the observed market already achieved a 60 % significant "medium" rating and therefore one can rate it with a market adjustment rate (MAR) of approx. 55 %.

Next, valuers have to estimate the maximum energy cost saving potential (ECSP) of the subject property in relation to a reference building (which illustrates an average from a peer group of comparable properties) in order to quantify the maximum rental impact (see Figure 45) of properties' energy efficiency expressed as the average adjustment parameter (AAP).

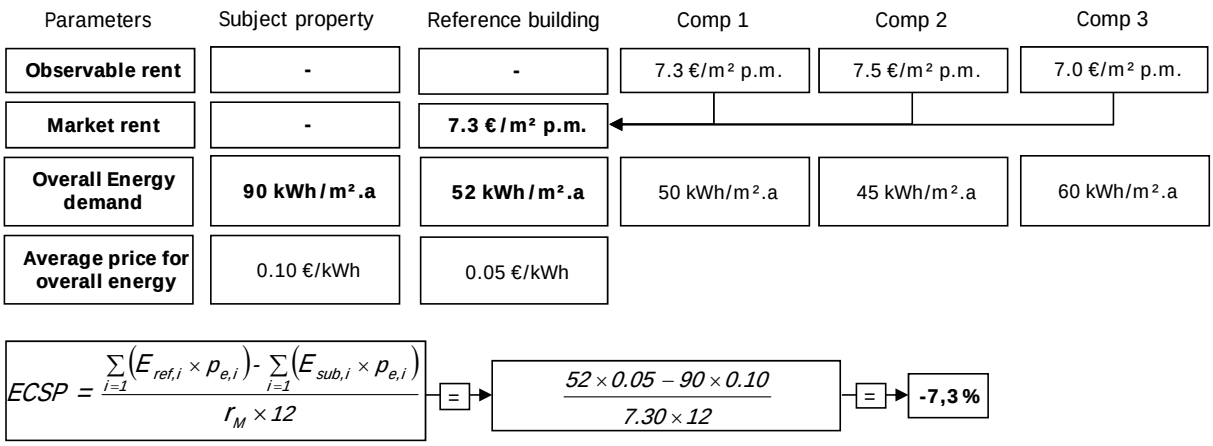


Figure 45: Numerical example – Estimation of CSP

To simplify the case study one assumed that the overall energy demand equals the sum of consumption of various energy sources ($\sum E_i$), and the average price for overall energy equals the average of the sum of the price for various energy sources ($p_{e,i}$). In this case study the subject property is less energy-efficient and its energy resources face higher prices.

On the basis of the estimated MAR and AAP (in the this case equals to *ECSP*), the valuer can calculate the weighted adjustment factor (WAF), which illustrates the specific adjustment of the observed key valuation parameter (KVP) – here the KVP is the market rent.

Following the displayed Equation (36) below the WAF exceed -4.0 % and lead to a VPA (valuation parameter adjustment) of approx. -0.30 €/m² p.m (Equation (37)).

$$WAF = MAR \times AAP \times VEA = 55\ \% \times (-7{,}3\ \%) \times 100\% = -4{,}0\ \% \quad (36)$$

$$VPA = WAF \times KVP = (-4{,}0\ \%) \times 7{,}30 = -0.30\ €/m^2\ p.m. \quad (37)$$

The estimated VPA then can be directly integrated as an adjustment parameter to derive the estimated rental value (ERV) as illustrated in Figure 46, on which the market value of the subject property is calculated (Figure 47).

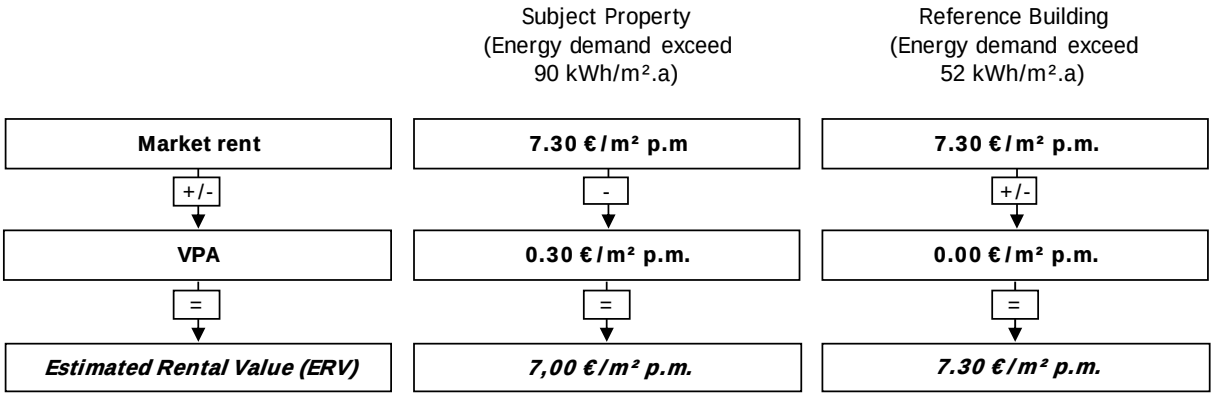


Figure 46: Application of the VPA to determine the ERV

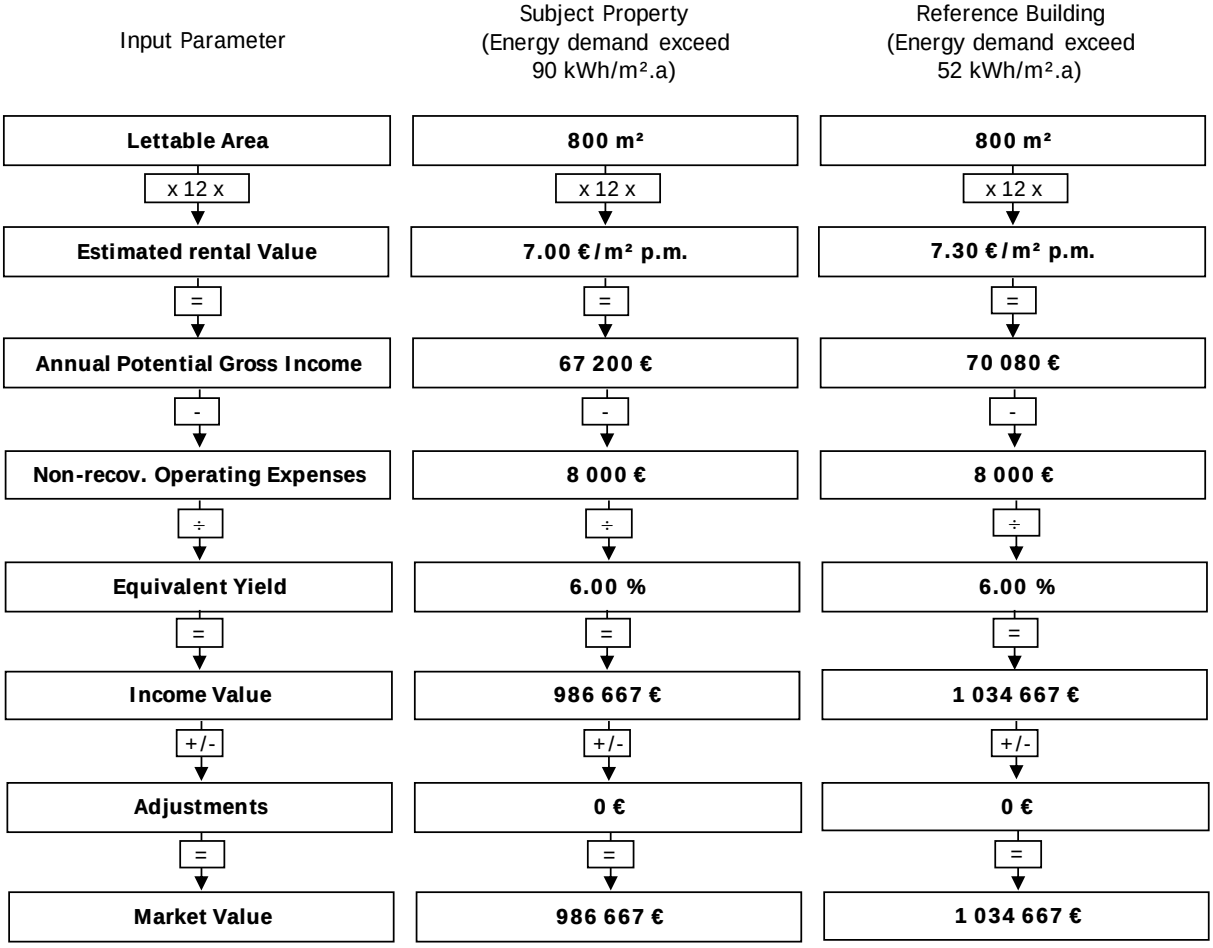


Figure 47: Market Value impact of non-energy-efficient buildings

6.4.4 Sales comparison Approach

Key Facts and Findings

Basic description of the methodologies

- The methodologies proposed to be used in the sales comparison approach are based on the idea that the Energy Saving Potential of a building (ESP) represents a feature to be taken into consideration in valuation procedures, The Energy Saving Potential is the difference between the annual energy demand presented in the EPC and a certain reference energy demand (the so-called “expected energy demand”).
- The proposed methodology considers the net present value of the ESP, adjusted in accordance to market trends, as a substitute for depreciations/appreciations due to low/high energy efficiency.

Short rationale for the proposed methodologies

- Previous works on finding a solution about the impact of energy policies on valuation procedures indicate that new methodologies that accept the energy efficiency level as significant in the real-estate market rely on the calculation of the modified operating costs.
- This kind of procedure is allowed in valuation methodologies as substitute for information on market preferences and may be used until more market data is available.

Expected impacts on property value

- The proposed methodologies underline extra-value resulting from reduced operating costs.
- The expected impact is recognition of owing highly energy-efficient buildings as a marketable benefit.

The sales comparison approach is based on the idea that identical houses should have identical prices. This approach uses transaction prices of highly comparable and recently sold or currently for sale properties. Firstly, the appraiser must investigate and analyze market data in order to extract quantitative information. Then, he has to estimate the degree of similarity or differences between the subject property and the comparable sales by considering various

elements of comparison. Finally, adjustments are applied to the sale price of each comparable property to derive the best-estimated value for the subject property.

6.4.4.1 Derivation/modification of basic approach for integration

The sales comparison approach is applicable if similar properties have recently been sold or are currently for sale in the subject property's market. It is highly recommended for valuation of condominiums, especially if they are owner-occupied. In the case of single family houses, it is recommended just for typical, standardized objects, like semidetached houses. For the valuation of multifamily-houses it should have just a supportive role.

6.4.4.1.1 Methodology for developed markets

In developed (i.e. transparent or with available databases) markets, appraisers are supposed to have access to a large database with information concerning transaction prices of property sales and rents, etc. Main real estate characteristics should be found in these databases for a wide range of buildings: age, location, number of floors, useful surface area, facilities, improvements, etc. By using statistical analysis tools, such as regression analysis, the valuer can analyse the influence of each factor and estimate market value for subject properties.

Identify differentiating criteria for sales comparison approach

The problem remains, how exactly should one perform real estate valuation that includes building energy efficiency information given the fact that a good valuation means well supported differentiating criteria. The subject is complex and it becomes even more so when a European/international methodology is needed, especially when the very concept of what a highly energy-efficient building means is different in each country.

Energy demand of buildings – especially the energy demand for heating – is to a certain extent correlated to the age of the buildings. Every country has well established appraisal methodologies for taking into consideration the age of the building in valuation process. Therefore a new appraisal methodology including the energy efficiency input must not interfere with the usual calculation of depreciations/appreciations due to the age of the building. In other words, the age and the energy efficiency must be independent inputs. This

principle is important in any valuation methodology, no matter how simple or complicated it is, or how developed or undeveloped the studied markets are.

Avoidance of redundancies and isolating of effects is a complicated task

In terms of energy efficiency, age intervenes with the energy codes valid for constructions at the time of building erection. One may calculate the design energy demand by considering the energy demand indicator included in the construction codes valid at the time of building completion with the useful area of the building and climate conditions. The difference between the current energy demand/consumption and the design value is associated with age deteriorations as well as subsequent energy efficiency investments (if any). In order to exclude age as a comparison criterion, the average energy demand/consumption of buildings of similar type, size, and age (when data is available) may be subtracted from the current energy demand/consumption of the investigated building to point out energy efficiency deviation from an average case. Thus, one may calculate the depreciations/appreciations of value produced strictly by differences in energy efficiency separate from depreciations/appreciations of the building's value produced by age. If the subject property and the comparables were constructed within the same construction codes, the age of the building and the ESP are independent inputs, so they can be used in studies based on linear regression analysis. The choice of the statistical technique depends significantly on the relationship between inputs. For instance, the classic least squares method (OLS) requires independence of input variables (Montgomery et al, 1994).

Energy demand as main criteria

The methodology presented here is based on the idea that the difference, named Energy Saving Potential (ESP), between the energy demand of the studied building (E_{demand}), presented in the EPC and a reference value for energy demand, the so-called "expected energy demand ($E_{expected}$)," represents a feature to be taken into consideration in valuation procedures (Popescu et al., 2009). One can use this idea in sophisticated methods such as statistical analysis using data from developed markets or in the simple direct sales comparison approach using several buildings, as is the current practice in opaque markets.

For each type *"j"* of energy demand (i.e. gas, electricity, district heating, solar etc), the ESP of a building is

$$\left(ESP\right)_j = \left(E_{demand} - E_{RES}\right)_j - \left(E_{expected}\right)_j \tag{38}$$

where:

ESP specific annual energy saving potential [kWh/m².year];

E_{demand} specific annual energy demand [kWh/m².year];

E_{RES} specific annual energy produced by renewable energy sources (RES) which do not cause running energy cost (e.g. solar-thermal energy) [kWh/m².year];

$E_{expected}$ specific annual expected energy demand (demand in a certain reference case [kWh/m².year];

A positive ESP indicates a low energy efficiency; by contrast, a negative ESP evidences a superior energy performance.

The calculation of the specific annual expected energy demand for a building is based on certain reference figures. These references can be either extracted from the EPC or from prescription in the building codes.

Convert energy savings into present value

Similar to the methodology proposed for the income approach, that of the comparison approach is based on the calculation of the modified operating costs. Although this may or may not fully reflect the willingness to pay more for a better energy performance, the procedure is allowed in valuation methodologies as a substitute for information on market preferences and therefore may be used until more market data is available.

The methodology presented here considers that the net present value of the total costs of ESP during a chosen time-interval generates depreciations/appreciations due to energy efficiency:

$$NPV_{ESP} = \sum_{j=1}^{J}\left[ESP_j \cdot (C_E)_j\right] \cdot \left(\frac{(1+i)^T - 1}{(1+i)^T \cdot i}\right) \quad (39)$$

where:

NPF_{ESP} net present value of costs of Energy Saving Potential [EUR]

$(C_E)_j$ energy tariff for each type “j” of energy (e.g., thermal, electricity, gas) EUR/kWh];

T remaining economic lifetime of property [years]

i all risk yield (derived from property market)

The issue of setting a “correct” price for the different energy carriers is crucial. In principle, one can use current prices as well as expected prices, depending on whether there is an assumption that energy price increases would outreach average price increases. A more

detailed description on how the calculate energy costs based on energy performance figures given in the EPC is included in chapter 6.4.2.1.

In order to find the premium/discount of value for energy efficiency, one can apply a market adjustment in accordance with the willingness to pay for energy performance. Therefore one might calculate value of ESP with the following equation:

$$V_{ESP} = A \cdot NPV_{ESP} \quad (40)$$

where A is a market adjustment for the willingness to pay for energy efficiency. The coefficient A is considered to be 0-25 % for low awareness among tenants of sustainability and energy efficiency, 25-75 % for medium awareness and 75-100 % for high awareness. Alternatively, one could also use the score-card methodology proposed under chapter 6.4.3.2.2

The value added due to better energy efficiency may be very different from the net present value of the total costs of ESP if the chosen time interval is wrong. The time interval N must reflect the willingness to wait for payback of value added due to higher energy efficiency. Finding the “right” time interval is the crucial point of this methodology. It is also the most vulnerable because it is based on the experience and judgement of the valuer. According to RICS’s study, “Green Value, Green buildings, growing assets,” a “rapid payback resulting from lower operating costs is increasingly recognized as the most marketable benefit of building green” (Davies R., 2005).

The expected energy demand as reference value

As a general rule, the proposed methodology requires that the comparables must be constructed within same construction standards/codes as the subject property that they are of the same type and are located in the same area. In this case, one might calculate the ESP of each building using equation (38), and the corresponding depreciations/appreciations of comparables may be calculated using equation (40).

Futher, one may consider two options when defining the expected energy demand for the building.

The first option is to consider the expected energy demand of each building is that extracted from the EPC for each type of energy. The problem is that if differences between the expected energy demands of comparables are important, the proposed methodology calculates depreciations/appreciations for them, which is hazardous.

The second option is to consider that the expected energy demand is equal to the average expected energy demands for m reference cases (E_{ref})

$$\left(E_{expected}\right)_j = \left(\frac{1}{m}\sum_{i=1}^{m} E_{ref\ i}\right)_j \quad (41)$$

In general, reference cases are buildings constructed within the same construction codes as the subject property and the comparables. This method is adequate for developed markets that can offer data regarding the expected energy demands of sufficient buildings.

The expected energy demand for a building ($E_{expected}$) is based on the reference rates extracted from the EPC or from construction codes. The reference energy demands and the reference building are concepts issued from the Energy Performance of Buildings Directive, which stipulates that "the energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building." In practice, each European country uses different approaches for the definition of references. The EPC's of some countries include reference rates for each building, others for a peer group of buildings. One must adapt the proposed methodology according the specific country's approach when presenting references. In the following, we present several examples of different country approaches and how to deal with them for the proposed sales comparison approach. Further information on country approaches can be found in the country reports on the site of EDBD Buildings Platform (http://www.buildingsplatform.org/cms/).

Proposed application for the case of England and Wales

The EPC from England and Wales is two label certificate with two scales: one for the energy demand of the studied building and one for the potential energy demand if all cost effective measures were installed.

The residential building certificate is accompanied by a report, which includes cost-effective recommendations to improve the energy ratings. Indicative paybacks are listed for each improvement. In the case of domestic properties, indicative paybacks are categorized as lower cost - typically up to £500 and higher cost - typically over £500.

The non-domestic EPC also provides two benchmarks. Cost effective recommendations for non-domestic properties are categorized as: short term - payback less than three years, medium term - payback between three and seven years and long term - payback more than seven years. Other recommendations are based on the assessor's knowledge.

Proposed application for the case of Romania

The Romanian EPC has two energy marks (on a scale from 20 to 100) and two energy scale levels (in the range from A to G): for the studied building and for the so-called reference building. The reference building is a fictive construction that corresponds to the building in question regarding geometry, orientation, and terms of use, however all the building envelope elements and installations correspond to the current legal standards regarding energy features. The studied building may be superior, equal or inferior to the reference building in terms of different energy demands.

Proposed application for the case of Austria

The Austrian EPC does not contain reference values but rather a system of requirements implemented for all kinds of buildings (except historical buildings).

The valuer can easily calculate the maximum permitted net heating demand per year m² denoted $HWB_{BGF,WG,max,Ref}$, depending on the geometry (characteristic length lc) of the building because all the necessary data, volume and area of the building can be found in the EPC or are known by the appraiser from the property documents of the building. This valuer can then serve as reference value and as basis for the calculation of the so-called "expected energy demand" for the proposed sales comparison approach.

The maximum net heating demand per year and m^2 for residential buildings (new construction and major renovations) is presented in Table 24.

New (up to 31.12.2009)	$HWB_{BGF,WG,max,Ref}$ = 26 * (1 + 2.0/l_c) [kWh/m^2year]	But not above 78.0 [kWh/m^2year]
New (after 1.01.2010)	$HWB_{BGF,WG,max,Ref}$ = 19 * (1 + 2.5/l_c) [kWh/m^2year]	But not above 66.5 [kWh/m^2year]
Major renovation (up to 31.12.2009)	$HWB_{BGF,WG,max,Ref}$ = 34 * (1 + 2.0/l_c) [kWh/m^2year]	But not above 102.0 [kWh/m^2year]
Major renovation (after 1.01.2010)	$HWB_{BGF,WG,max,Ref}$ = 25 * (1 + 2.5/l_c) [kWh/m^2year]	But not above 87.5 [kWh/m^2year]

Table 24: Permitted annual heating demand for residential buildings

The upper limit for net heating demand for non-residential buildings (new construction and major renovations) is presented in Table 26.

New (up to 31.12.2009)	$HWB_{BGF,WG,max,Ref}$ = 9* (1 + 2.0/l_c) [kWh/m^{2}year]	But not above 27.0 [kWh/m^{2}year]
New (after 1.01.2010)	$HWB_{BGF,WG,max,Ref}$ = 6.5 * (1 + 2.5/l_c) [kWh/m^{2}year]	But not above 22.75 [kWh/m^{2}year]
Major renovation (up to 31.12.2009)	$HWB_{BGF,WG,max,Ref}$ = 11 * (1 + 2.0/l_c) [kWh/m^{2}year]	But not above 33.0 [kWh/m^{2}year]
Major renovation (after 1.01.2010)	$HWB_{BGF,WG,max,Ref}$ = 8.5* (1 + 2.5/l_c) [kWh/m^{2}year]	But not above 30.0 [kWh/m^{2}year]

Table 25: Permitted annual heating demand for residential buildings

Proposed application for the case of Germany

The German EPC is calculated according to EnEv2007 and it considers reference rates for heating+hot water and for lighting+cooling.

For residential buildings, a fixed scale of reference values of energy for heating and preparation of warm water is presented in the EPC (Figure 40).

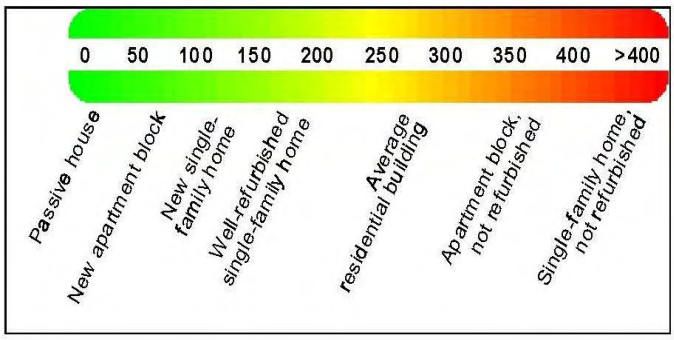


Figure 48: M Scale of reference values (heating and hot-water) for residential buildings from Germany.

According to DIN V 18599, the energy demand of the reference-building for air- conditioning and lighting has not fixed limits for the primary energy demand. It refers to a fictive reference construction that corresponds to the building in question regarding geometry, orientation and terms of use.

The reference values for non-residential buildings take into account the individual terms of use and define the maximum value of the scale. The German Federal Ministry of Transport, Building and Urban Development has introduced two official announcements about simplified data recording simultaneously to the EnEV 2007. The announcement applying to

non-residential buildings also contains the reference values for different/mixed uses. A few examples of heating/hot water and electricity reference values for metered consumption of non-residential buildings are shown in Table 27.

Building use (examples)	Reference value heating/hot water	Reference value electricity
	kWh per m^2 and year	
Office buildings, heated	135	55
Office buildings, air conditioned	190	155
Hotels (medium class)	120	95
Restaurants	320	135
Cinemas	150	75
Shops, non food small	210	70
Shops, food, small	160	90
Department-stores, air conditioned	85	150
Hospitals, large (> 1000 hospital beds)	230	100

Table 26: Examples of results for non-residential buildings (metered consumption)

6.4.4.1.2 Methodology for opaque markets

The calculated value of a building using the direct sales comparison approach is derived by comparing the property being appraised to other properties, applying appropriate units of comparison and finally making adjustments to the sale prices of the comparables based on the criteria of comparison. The sales comparison approach needs comparable buildings for its calculations of the market value of the subject property being valued.

Opaque markets are characterized by a reduced number of comparables. The main problem in using the sales comparison approach is that it is very difficult to find comparables that have an EPC and/or are energy efficient. Undeveloped markets usually have a reduced number of EPC. This represents a certain limit on the proposed methodology.

Moreover, the proposed methodology requires that the subject property and the comparables are built within the same construction codes, no matter if the markets are transparent or opaque. This requirement further limits the choice of comparables, which might generate additional problems.

For opaque markets, the first option, considering for each type of energy that the expected energy demand of each building is that extracted from the EPC, seems to be the only one possible. An alternative would be for one to consider that the expected energy demand to be used in equation (38) is equal to the average reference rates of comparables.

If the market is semitransparent, a reasonable number of cases are available and the second option, considering that the expected energy demand is equal to the average expected energy demands for m references cases (E_{ref}) may be used according to Equation (41). Since a

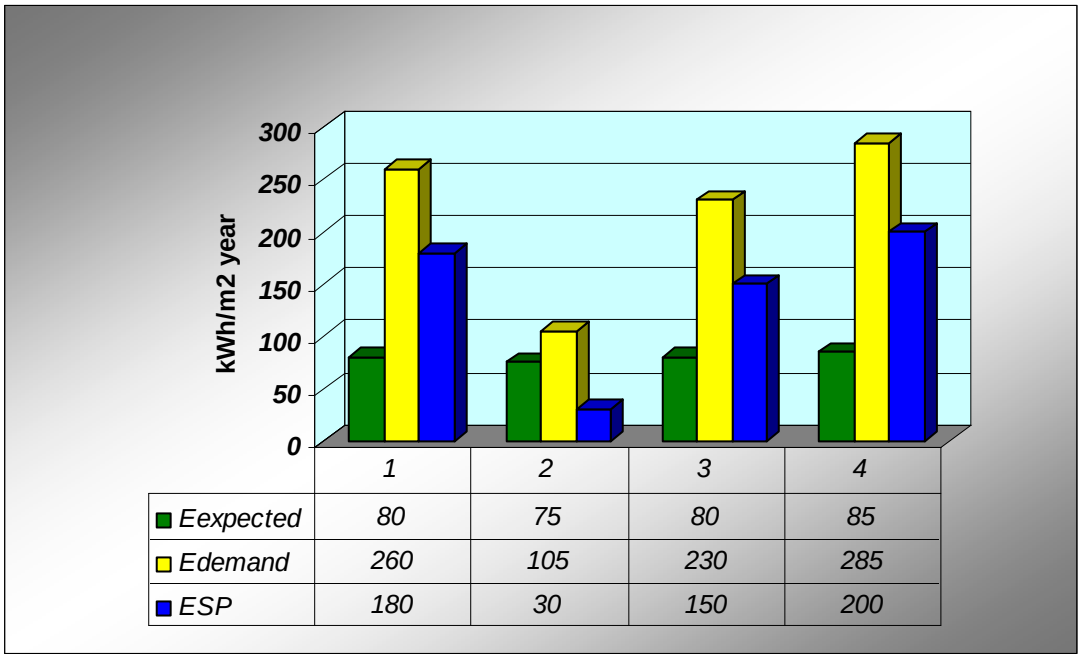
reasonable number of cases are available, one may use the second option, considering that the expected energy demand is equal to the average expected energy demands for m references cases (E_{ref}) may be used in Equation (41),

6.4.4.2 Case Study

During a valuation process in a less developed market, adjustments of value are set by corrections between the subject property and comparable properties. In the following contains an example that shows how appreciations/depreciations due to ESP for heating are calculated.
It is a case study from Romania, which EPC contains information about the annual heating energy demand of the studied building and about the annual heating energy demand of a reference building. The annual expected energy demand is considered to be the heating energy demand for the reference building, E_{ref}, extracted from the EPC.
The **subject property denoted 1** is a block of flats, built in 1981, which have undergone only running maintenance since that year. Walls are made of bricks with reinforced-concrete frames. There is no thermal insulation in the walls and the windows are double-glazed with thermal insulated p.v.c. frames. The space heating energy demand is 260 kWh/m^2year. The space heating energy demand of the reference building is 80 kWh/m^2year.
The **comparable denoted as building 2** is an apartment situated inside a building, the envelope of which was thermally insulated. The level of energy efficiency for the reference building was not reached because heating installations were not changed and the general maintenance is poor. The cost of the rehabilitation was EUR 11,500. The space heating energy demand is 105kWh/m2year. The space heating energy demand of the reference building is 75 kWh/m^2year.
The **comparable denoted as building 3** is an apartment that has no thermal insulation on the opaque external walls, but the windows are triple-glazed with energy-efficient PVC frames; in addition, an individual performing heating system was installed. Further, 1,200 EUR were spent replacing old wooden windows with the modern ones. The new heating system installation cost EUR 1,500. The space heating energy demand of building 3 is 230 kWh/m^2year. The space heating energy demand of the reference building is 80 kWh/m^2year.
The apartment from building 4 did not suffer any improvement since it was built. There is no insulation in the walls, windows are double-glazing with wooden frames and the heating radiators are old. The space heating energy demand of is 285 kWh/m^2year. The space heating energy demand of the reference building is 85 kWh/m^2year.

No renewable energy sources are used in any of the buildings included in the analysis.

Figure 41 presents the heating annual energy demands (E_{demand}), the heating annual expected energy demands ($E_{expected}$) and the Energy Potential Savings (ESP) for heating in the following cases: subject property denoted 1, comparables denoted 2, 3, 4.



	1	2	3	4
Eexpected	80	75	80	85
Edemand	260	105	230	285
ESP	180	30	150	200

Figure 49: Values of the Edemand, Eexpected and ESP for heating. Case study.

Figure 41 points out that comparables 2 and 3 are more energy efficient than the subject property, since the ESP of buildings 2 and 3 is lower while comparable 4 has a lower energy efficiency since the ESP of building 4 is higher compared to the subject property.

Part of a Romanian appraisal report with the proposed methodology implemented is presented in Table 28. The analysis assumes the thermal energy tariff of 0.107 EUR/kWh, the economic life of the building is 50 years, the yield is 7 % and the correction for the willingness to pay is 0.75 [see eq. (39)].

Details regarding the calculation of corrections generated by the energy efficiency are presented in Table 29. Differences between the V_{ESP} of each comparable building (i) and the V_{ESP} of the subject property are taken into consideration as corrections. Corrections are needed to derive how much the value of the comparable would be if it were similar to the subject property.

Comparison elements	**Subject property**	**Comparable assets**		
	Building 1	**Building 2**	**Building 3**	**Building 4**
Price (*EUR*)		*105000*	*110000*	*112000*
Useful are (*mp*)	77.63	77	80	78
Correction (EUR)		+859	-3259	-531
Adjusted price (*EUR)*		*105859*	*106741*	*111469*
Property rights	**Full**	Integral	Integral	integral
Correction *(EUR)*	0	0	0	0
Adjusted price (EUR)		*105859*	*106741*	*111469*
Conditions of financing	Market	Market	Market	Market
Correction *(EUR)*		0	0	0
Adjusted price (EUR)		*105859*	*106741*	*111469*
Market conditions	04. 2009	03. 2009	03. 2009	03. 2009
Correction (EUR)		0	0	0
Adjusted price (EUR)		*105859*	*106741*	*111469*
Age (year of construction)	1981	1976	1977	1984
Correction *(EUR)*		+5610	+4569	-3511
Adjusted price (EUR)		*111469*	*111310*	*107958*
Floor/ height conditions	2/10	3/8	6/7	4/7
Correction (EUR)		+2117	+7472	+5573
Adjusted price (EUR)		*113586*	*118782*	*113531*
Location	same	same	same	same
Correction (EUR)		0	0	0
Adjusted price (EUR)		*113586*	*118782*	*113531*
Indoor design investments				
Correction *(EUR)*		-400	-200	-400
Adjusted price (EUR)		*113186*	*118582*	*113131*
ESP [kWh/m².year]	180	30	150	200
NPV_{ESP} **[EUR/m²]**	213	31	161	249
Correction (EUR)		-10579	-3004	2116
Adjusted price (EUR)		102607	115578	115247
Selected compared value	**115247 EUR**			

Table 27: Market value calculated by sales comparison approach.

The following calculation was used in the valuation of energy efficiency presented in Table 29.

	Subject property Building 1	Comparable assets		
		Building 2	Building 3	Building 4
E_{ref} /E_{demand} for heating [kWh/m².year]	80/260	75/105	80/230	85/285
$ESP = (E_{demand}) - (E_{expected})$ **[kWh/m².year]**	180	30	150	200
T [years]	22	17	18	25
$\left(\frac{(1+i)^T - 1}{(1+i)^T \cdot i}\right)$	11.06	9.76	10.06	11.65
NPV_{ESP} **[EUR/m²]**	213.04	31.34	161.45	249.39
V_{ESP} [EUR/m²]	159.78	23.50	121.09	187.04
$Correction = (V_{ESP\,comp} - V_{ESP\,subject}) \cdot S_{subject}$		**-10579**	**-3004**	**2116**

Table 28: Detailed calculation of depreciations/appreciations due to ESP for heating.

6.4.5 Cost Approach

Key Facts and Findings

- The cost approach is driven by two main effects. The technical effect and the market effect. The technical effect contains the technical characteristics and the cost related implications of these parameters. The latter effect comprises the market effect and thus the demand side. This parameter does not include any costs and adjusts for the willingness to pay.
- The technical effect is reflected by the replacement costs, which are market driven themselves, and/or adjustments (other value affecting characteristics). The adjustments based on the market effect, however, are based on market evidence.
- The following process for integration can be constituted:

- **Technical effect**: The quantification is the same for “developed” and “undeveloped” markets. Therefore, it must be clear which type of construction leads to a good energy efficiency level. A higher quality usually leads to higher costs. E.g. a building with a thermal insulation has higher replacement costs than a building with the same features without thermal insulation.
- **Market effect**: The quantification is different for “developed” and “undeveloped” markets.

  (1) Developed market: One must derive the ratio between the market value (the real transaction price) and the calculated cost value from past transactions. If both values are known, there are two ways to calculate the adjustment – a) Simple linear regression, and b) Compare same buildings

  (2) Undeveloped (opaque) market: One might use a scoring model in order to quantify the market effect related to energy efficiency in the opaque market. The scoring model is a tool to get a feeling how important energy efficiency in the observed market is. Furthermore the tool helps to quantify the effect.

Of all three main approaches, the cost approach is the least frequently used because the cost approach is not able to reflect the market in most cases.[192] Nevertheless, many countries still use it as an accepted valuation approach. The cost approach uses the replacement costs of the property being valued. [193] The market value is the sum of the land value and the total replacement costs of a new building reduced by the accrued depreciation. Cost related approaches are applicable if there are no comparable values and it is used in markets where market actions can not be observed. [194] Therefore this method is particularly applied to the appraisal of special purpose properties or financial statements. In general, the cost approach is used for properties where the costs play the dominant role. The basic concept of the cost approach is shown in Figure 50.

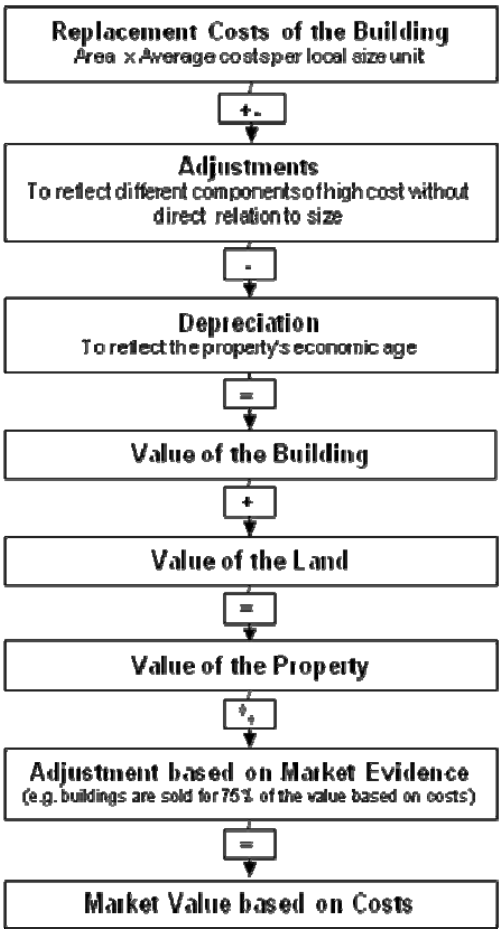


Figure 50: General Cost Approach

[192] Cf. Leopoldsberger, G. Thomas, M., Walbröhl, V. (2007), p. 520

[193] Cf. EVS (2007) p. 36

[194] Cf. Bienert, S., Reinberg, M. (2007) p. 477

The cost approach's use is not used equally distributed across Europe. In some countries it is used more often (e.g. Austria and Germany) but in others it is rarely used (like United Kingdom or Romania).

The purpose of the cost approach within specific countries is summarized in Table 29: the application of the cost related approach.

Austria	Germany	Norway	Romania	United Kingdom
Single houses Semidetached houses Owner occupied factory buildings or warehouses	Same like Austria	Reference value for residential and commercial real estate	Rarely used Only for properties which are not normally bought or sold	Owner occupied properties Properties which are not normally bought or sold

Table 29: The Application of the cost related approach

Generally the cost related approach does not dominate valuation as strongly as the income approaches. Table 29 shows that the procedure discussed in this chapter is particularly used to value owner occupied properties. Especially in Austria and Germany the approach is mainly used for one-family houses. The method of the cost related approach is quite the same for all countries. The difference lies in the amount of the construction costs. However these not only vary between nations, figures also show a considerable variation between regional districts within one country. But the construction costs are not the only ones that are different. The market perceptions from single characteristics differ between regional areas as well. Hence it is impossible to model consistently quantified adjustments for all countries. Therefore this report will show the structure behind integrating the effects of energy performance certificates. While the integration developed will be the same in all countries, the quantification of these effects will be different for each country.

In the cost approach one can classify the main value drivers into two categories – the technical effects and the market effects. These two effects represent the adjustments that are necessary in order to match construction costs and the actual value of the building. As seen in an economic context: the technical parameter provides the supply side i.e. it represents the object and its specific characterizations, which are offered at the market. Therefore the market parameter focuses on the demand side where the focus lies in the analysis of the demand structure and its implication on the value of the building.

The cost approach is based on the replacement costs, i.e. the technical aspects are the focus of the valuation. In fact, these costs refer to the construction costs of the object at the point in

time the valuation is undertaken, reflecting current economic and technical aspects.[195] The technical adjustment parameter can be defined based on this specification. This parameter contains the technical characteristics as a whole. As described above this might also be interpreted as the supply side. The quantification results from the cost side. The technical parameter is obtained by comparing the actual building and a theoretical implementation of e.g. a thermal improvement.

The second effect comprises the market effect and contains the demand side. This parameter does not include any costs and only considers the market. This parameter takes in account the issue of the diverging "technical value" and the market value. How high is the willingness to pay e.g. for a house with an excellent thermal insulation? In other words the market parameter reflects the demand e.g. for a house in Austria with an EPC of Level A++ compared to Level D, but equal construction costs and size.

The main question is how these parameters might be integrated into the cost approach? The integration of technical parameters can be done more easily. All technical effects may be calculated and integrated through the additional costs resulting from the higher quality of the material used to erect the building. For example, the additional cost of excellent thermal insulation may be calculated and thus lead to higher replacement costs for the building. This consideration of high-quality components is already common practice in property valuation. Therefore a valuer can use the EPC as an indication for higher replacement costs.

The market effect provides a direct connection to the demand side of the market. The main issue here is to what extent the energy efficiency of LCC optimized houses will be honored by the market. The consumer (renter/buyer) generates the willingness to pay for special features that are reflected in the market prices. However, one must consider this effect with the aid of an adjustment based on market evidence. The market effect cannot be generally quantified as the quantification is individual for each single region.

In order to get an idea as to which effects influence the valuation it is important to know what the main green value drivers are. Therefore the first step for the valuer is to identify them before the allocation of technical or market effects is carried out.

6.4.5.1 Main green value drivers

In order to generate a quantification of the 'green' influence, it is essential to identify the main green value drivers related to the cost approach. Table 30 gives an overview of the main value

[195] Cf. Funk, M., Koessler, C., Stocker, G. (2007) p. 270

drivers identified within the cost related approach. The classification follows as it was explained in previous chapter and classified by:

(1) Public benefit

(2) Intangible benefits

(3) Tangible benefits

Green feature	Green impact	Theoretical linkage: added value to owner?	Evidence of market impact	Recommendation for adjustment
Energy efficiency				
Energy efficiency	**Public benefits**	·Only if tax savings / subventions etc. directly connected to the property. Public benefits which leads to reduce the building costs.	If applicable easy to assess.	**Replacement costs** (if clear regulation shows positive effect compared to Peers. BUT penalties for non-green might be more relevant in the future)
	Intangible benefits for user (Improved occupant productivity, lower churn, Higher well be etc.	·Higher accoutrements – higher well be. ·Generally increased willingness to pay higher value must be tested. ·Green building as a marketing activity ·Longer economic life. ·Higher marketability leads to faster sale	Rare market evidence and difficult to isolate.	**Replacement costs** (higher accoutrements leads to higher costs) **Adjustment based on market**
	Tangible benefits for user Lower energy costs (for the user)	·Lower energy cost because of higher quality ·Higher marketability for "prestige"?	Pure cost cutting effect will have an impact in the valuation The market effect is not clear – must be carried out. „Prestige" probably just a first mover bonus that will disappear soon	**Replacement costs** (higher quality leads to higher costs) **A higher marketability – Adjustment based on market** **(In the cost approach is no direct link to income!)**
	Tangible benefits for user Maintenance costs	·Both way (higher and lower) might be the case depending on the technical level of the building		**Replacement costs** **Adjustment (for value affecting characteristics)** **Adjustment based on market**

Table 30: Main green value drivers

Table 30 intends to give a general overview of the main value drivers of the cost approach. The next chapters will explain a detailed classification of the effects and the possibility of such effects respective integration into the cost approach.

6.4.5.2 Derivation/modification of basic approach for integration

While modifying the basic approach one must keep the following statement in mind. Upgrading a property to the highest thermal standard technically feasible and subtracting the value before the renovation does not reflect the gain in value since no investor/owner would look at the situation this way.[196] Cost to upgrade does not necessarily equal value. This fact

[196] Cf. Davis Langdon (2009): Upgrade to good medium standard as a most likely szenario.

shows the need for the valuer to separately integrate the technical effect and the market effect. The modification must contain both effects to get the actual market value.

The cost approach offers four theoretical options when integrating the effects of the energy certification:

(1) Replacement costs

(2) Adjustments (other value affecting characteristics)

(3) Deprecation

(3) Adjustment based on market evidence

Upon closer examination there are actually two possibilities that one must examine, the technical aspects (replacement costs and adjustments and other value affecting characteristics) and the market aspect (Adjustment based on market evidence).

However there could also be a third method of integration: the depreciation. Valuers might favor the inclusion of depreciation in the sense that the deprecation contains not only the technical aspects of the building, but also the remaining economic lifetime. From this point of view it might be possible for the valuer to integrate the influence out of the market. E.g. one might assume that buildings of a certain poor thermal quality will not be marketable in the future. This fact would result in a reduction of the remaining economic lifetime. This situation might occur if energy efficiency is bad, i.e. generate very high energy costs, which may lead to a high vacancy rate and the remaining economic lifetime drop to *de facto* zero.[197] Currently there is no way of quantifying the influence on the remaining economic lifetime with respect to the EPC.

Therefore the inclusion in this parameter is not preferred at the moment.

While at the first glance another way of integrating energy efficiency might be calculating the future gains when compared to the higher costs of energy investments. However, the calculation of energy savings and transfer to e.g. a present value does not agree with the cost approach. By definition the cost approach only regards cost and therefore neglects possible future gains. Hence by application the valuer accpts this systematic implicitly and must not combine it with others. Future gains discounted to a present value are the hallmark of income related approaches.

The valuer can integrate the market effect in a better and more comprehensible way by using adjustments based on market evidence. From the technical side an integration into deprecation

[197] Cf. Kleiber, W., Simon, J. (2007), p.1850

due to properties' age seems not to be a reasonable possibility either. While thermal renovation improves the overall quality of a building, not every renovation necessarily improves the thermal quality. Even if a building is refurbished, the energy efficiency has no effect on the remaining economic lifetime. One should not confuse cause and effect. A building in good condition with high quality thermal component can have a positive effect on the fictive age of the building and consequently on the efficiency level, but not vice versa. Therefore the valuer can better integrate the market- and technical effect within other positions in the valuation approach. However one should be cautious concerning possible redundancies. In a valuation process redundancies are not allowed. This means that a single effect can only be considered once; so the splitting into market and technical effect is far more important. Both effects can be seen as a single effect that must be considered separately. Similarly, both effects need a statement in the valuation report for their application.

The valuer can integrate the technical effect into the replacement costs and/or adjustments (other value affecting characteristics). The integration depends on the construction parameters. If a certain design construction is included in the level of quality of standardized replacement costs, the integration of this design is already ensured through the use of this parameter. Only constructions that are not included in the level of quality must be adjusted for by the valuer(through other value affecting characteristics). As far as the market effect is concerned, there is only one clear possibility for integration: adjustment based on market evidence. The following Table 31 reviews the integration of the market and technical effects into the cost related approach.

Effect	Linkage	Green impact	Perception of energy	Example
Energy efficiency				
Technical Effect	Replacement costs	Construction (like DIN 276-1 300 Bauwerk – Baukonstruktion)	•insulation of façade, •Insulation roof, •Insulation floor •insulation glass window	Insulation of s facade leads to higher replacement costs
		structural engineering(like DIN 276-1 400 Bauwerk – Technische Anlagen)	•heating system (generation, allocation, heating area) •Ventilation system (ventilation plants, partial air condition, air condition)	air condition leads to higher replacement costs
	Adjustments (for value affecting characteristics)	If the effect, which leads to the good energy performance of the building, is not included in the replacement cost, then this technical effect has to be regard in the adjustments.		
Market Effect	Adjustment based on market	No direct link to building activity – market's perception	•oil price •public opinions in local newspapers •availability of energy in the region •market structure •etc..	If the oil price a rising, the sensitivity for energy efficiency raises as well.

Table 31: Integration of technical and market effects

Table 31 shows only the general possibility. A common solution for the cost approach for all countries or regions is impossible because of the different characteristics of the regional and national property markets.

In this context, the valuer must differentiate between developed and undeveloped/emerging markets. This differntiation leads to two different procedures to integrate the energy certification into the cost approach. The developed market in this context is characterized as a very transparent market, where market data - and in particular market data about the "green value" of energy-efficient properties - are available. In this scenario, the appraiser only requires the right data and experience to integrate this information into the valuation process. In contrast, undeveloped markets have little to no market data regarding the quantifiable value of a "green building." In this case it is much more difficult for the valuer to integrate information into the cost approach. The huge difference between the developed and the undeveloped market with regards to the cost approach is the quantification of the market effect sincethe procedure to quantify the technical effect for both markets is nearly the same. Therefore this report will give a detailed description in the following sections.

6.4.5.3 Methodology for developed markets

A market is regarded as developed if sophisticated data on energy efficiency buildings' attributes is available to the valuer. It is easier to quantify the market effect of energy-efficient buildings which provides easy access to the information that the valuer can be use for valuation. In general this information is available in two types. The easiest and more comfortable may be described as the situation, where the country's information about the adjustment of the market effect are published. The quantification information is current and available for the appraiser to integrate it into the valuation with the aid of the cost approach. The second possibility might be the situation wherein the data are available in "raw form." Such data include the transaction price, the calculated cost value, the EPC and the characteristics of the property. This implies that the valuer must calculate the adjustment based on market evidence. The following chapters explain the two ways of calculating adjustments further.. Figure 51 demonstrates the process of integration in developed markets.

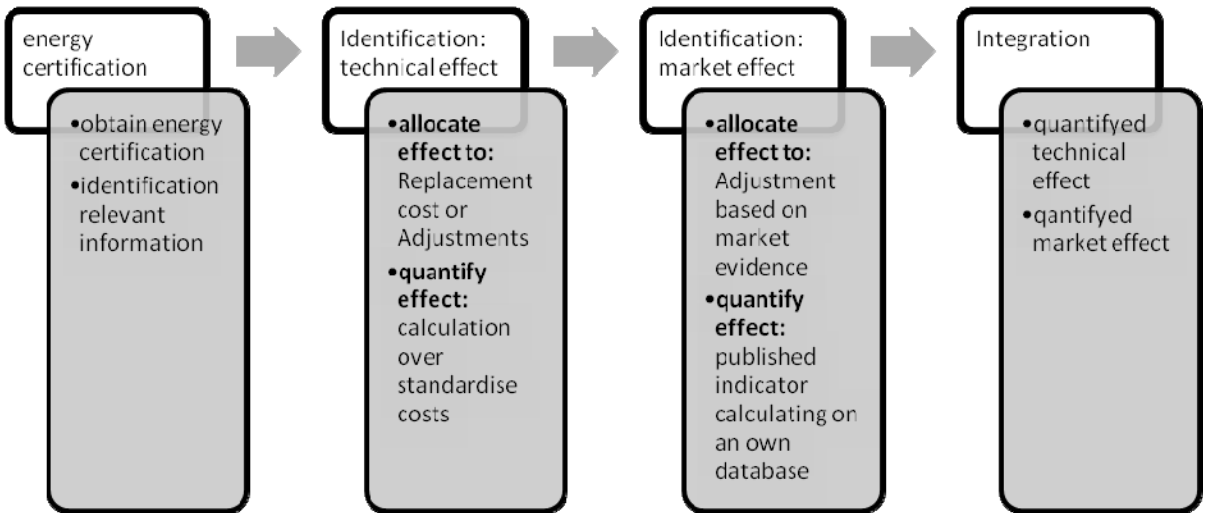


Figure 51: Process of integration in developed markets (Cost Approach)

The first step to obtain the relevant information is to acquire the energy certification and analyze it. Each country has a specific energy certification, hence the information from the energy certifications are different. However, all EPCs have one thing in common. One can use them as an indicator for as to how efficient or inefficient the energy consumption of a building is. If the building has a good energy certification the valuer needs to analyze why. It needs to be clear what type of construction leads to a high level of energy efficiency. The

valuer can then split this type of building configuration in order to evalute the effect of construction (insulation of façade) and the effect of structural engineering (solar heating system).

In Germany e.g. the replacement costs (NHK or BKI) are split into construction (300 Bauwerk – Baukonstruktion) and structural engineering (400 Bauwerk – Technische Anlagen) accordingly to the standards of DIN 276. These two types of costs are listed in detail in the DIN 276-1.[198] If an effect leads to a posative energy performance is not included in this list, the valuer must account for the technical effect in the adjustments. Furthermore, it is possible that the equipment was overpriced and/or such equipment might not be necessary to reach a specific level of energy efficiency. Consider a house with an efficient heating technology and a facade with a thermal insulation, both categories may lead to a higher level of thermal efficiency, for example, from medium to high quality. This in turn influences the costs, which are higher for the high quality compared to the medium quality. After this step, the valuer should integrate all technical effects connected to this issue into the valuation process where the resulting value of the property is based on costs. Because of the different local characteristics a specific quantification seems not meaningful.

The recently published study by CBRE shows that in 2009 the additional costs associated with the development of a low-energy building compared to a basic house raise the construction costs by approximately 2 % to 3 %. The construction of a greener and even more energy-efficient building designed to achieve higher standards of accreditation is likely to add between 5 % and 7.5 % to the construction costs. The development of a zero-carbon building (even higher than levels of BREEAM and LEED accreditation) adds a construction cost premium of around 12.5 %[199]. The costs of developing a green building, relative to those of a conventional one, ranges between 2 % and 7 % depending on the level of accreditation.[200] The study by Kats 2003 based on 33 office and school buildings suggests only 0.6 % higher costs for LEED certification, 2.1 % for silver, 1.8 % for gold and 6.5 % for platinum certification.[201] The survey by Miller, Spivey and Florance 2008 shows a table of extra costs for LEED certifications by region of the USA.[202]

[198] Cf. DIN 276-1 (1993), pp.5

[199] Cf. CBRE (2009), p.3

[200] Cf. CBRE (2009), p.14

[201] Cf. Kats, G., et al, (2003), p.15

[202] Cf. Miller, N., Spivey, J., Florence, A. (2008), p.12

Market	Platinum	Gold	Silver
UCSB Ave.	7.8%	2.7%	1.0%
San Francisco	7.8%	2.7%	1.0%
Merced	10.3%	5.3%	3.7%
Denver	7.6%	2.8%	1.2%
Boston	8.8%	4.2%	2.6%
Houston	9.1%	6.3%	1.7%

Table 32: Extra costs to go green vary by region[203]

One may notice on closer examination that a huge difference exists between the different American cities used in the survey. One factor affecting the cost to go green is the effects of the mandates and incentives provided by local governments, utilities, other non-profit organisations, trusts and foundations. If a city such as San Francisco requires gold certification by 2012 on office projects larger than 50.000 square feet, the marginal costs of achieving LEED certification up to the gold level becomes zero since there will be no alternative.[204]

This aspect and the fact that these studies have been conducted outside Europe, leads to the opinion, that these quantifications should be used carefully. In addition these studies do not only take the energy efficiency into account, they are focusing on a broader range of green building aspects. Due to the aforementioned, one should not apply these figures completely for the purposes discussed in this analysis.

It is essential that the valuer examine European studies to get an overview of the quantification of energy efficiency. There are only a few that are applicable in this context. Belz and Egger (2000)[205] gives a general overview for different studies combining energy efficiency and construction costs. They quote a study from Germany (1994) finding that low energy consumption houses (Niedrigenergiehaus: energy indicator heat demand (HWB) < 50kWh/m²/a) have about 4 % higher construction costs than normal buildings. However, the study pointed out that there is a high margin of deviation, what means that there is a huge potential to build cheaper. Belz and Egger (2000) also analyzed a study from Switzerland (2000) that came to the conclusion that houses with a lower heat demanded energy indicator (lower amount of heat demanded energy consumed per unit) (HWB) of 45 kWh/m²/a have

[203] Cf. Miller, N., Spivey, J., Florence, A. (2008), p.12

[204] Cf. Miller, N., Spivey, J., Florence, A. (2008), p.10

[205] Cf. Belz, F., Egger, D. (2000), pp.6

about 9 % higher investment costs. This study also noticed a high volatility in cost, which varied between 4 % and 13 %. All studies conclude that primary additional thermal insulation, building services and windows with higher insulation are the main cost drivers.[206] A Study from Austria [207] found 7 % higher costs for upgrading from a Niedrigenergiehaus (heat demanded energy indicator (consumed per unit) (HWB) < 50 kWh/m²/a) to a passive house standard for social residential buildings. This study also included the costs of living space ventilation.

One can derive another example of the quantification of energy efficiency from the previously mentioned BKI costs. The subsequent example shows an easy way to quantify the technical effect. One can obtain higher energy efficiency with better thermal insulation. In particular, the thermal insulation affects the properties of the façade. The BKI costs describe this cost type as 330 external wall. The following table shows the costs for single respectively double houses. In addition, the costs for category 420 (heat generation) are also listed.

Type of single/ double house	cost type	from [€/m² BGF]	to [€/m² BGF]	Mean [€/m² BGF]
low with cellar	330 external wall	141,29	252,84	186,44
medium with cellar	330 external wall	195,21	427,28	280,25
medium with no cellar	330 external wall	234,36	483,21	336,96
high with cellar	330 external wall	263,44	398,95	323,95
high with no cellar	330 external wall	346,92	470,34	406,35
passive house	330 external wall	337,56	568,89	433,75
low with cellar	420 heat generation	39	64	50
medium with cellar	420 heat generation	48	117	72
medium with no cellar	420 heat generation	54	115	73
high with cellar	420 heat generation	78	110	90
high with no cellar	420 heat generation	79	158	129
passive house	420 heat generation	22	72	45

Table 33: BKI – cost categorys 300/400[208]

The Table 33 shows that there are relatively huge differences between the types of houses. One can better observe this effect in the following Figure 52, where the x-axis shows the type of houses and the y-axis gives the information about the costs.

[206] Cf. Belz, F., Egger, D. (2000), p.8

[207] Cf. Schöberl, H., et al, (2004), p. 153

[208] Cf. BKI (2008)

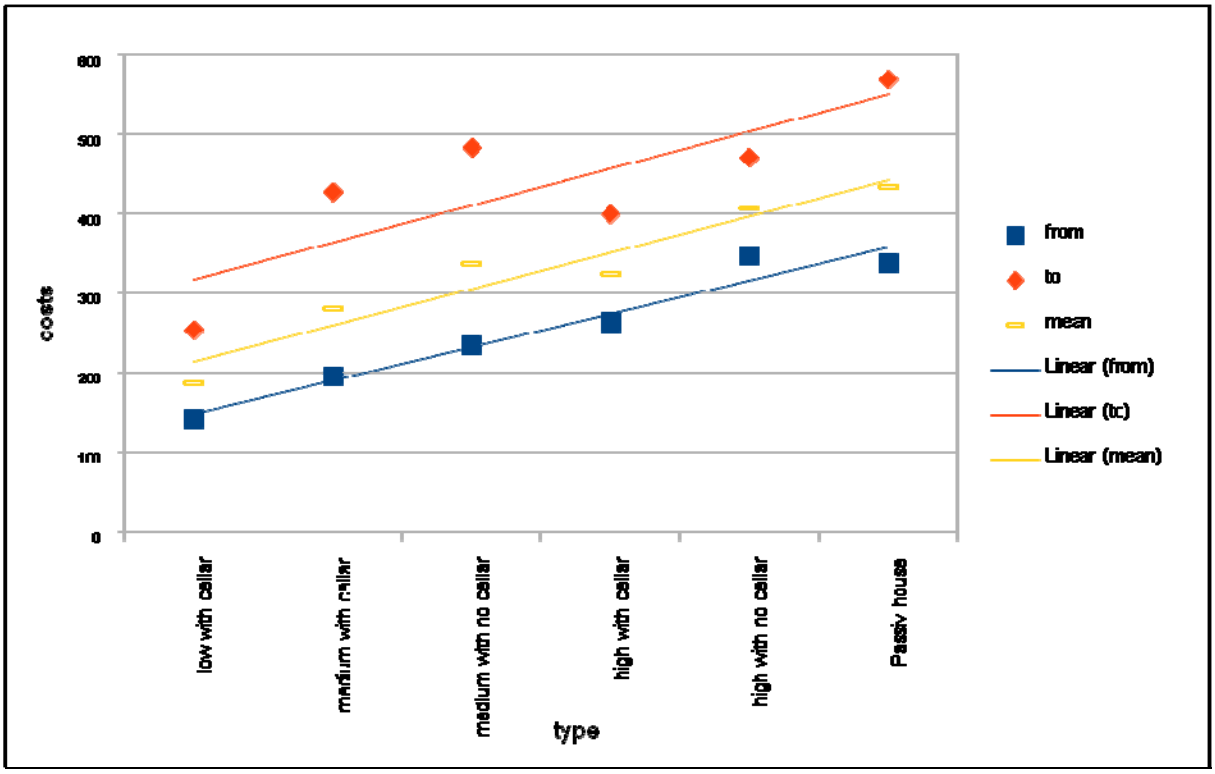


Figure 52: BKI – cost category in connection to property type (costs in €/m² BGF)

Table 33 and Figure 52 show the highest, lowest costs and the mean of the cost type 330 (external wall). One can also track the additional costs for better external wall constructio to the cost type 300, and thus 300+400, which are the basis of the BKI. However, cost types 300+400 are not representative of the complete construction costs. Categories like coverage of the area or ancillary construction costs are missing.

Of course the adjustment factor is highly dependent on the basis used. The calculated adjustment factor over the 300 category is higher than the factor based on 300+400 that, by definition, must be higher than 300.

Consider the following example. Two identical buildings in the single houses with a low quality thermal quality category that only differ in the thermal insulation. (one building's properties for the external wall are like single houses with medium quality) This difference leads to 5 % higher costs compared to the cost type 300+400. The factor based on cost type 300 might be 9 % in this case. In an extreme case of a low quality house where the external wall has the properties like a passive house, this might lead to approximately 15 % higher costs compared to the cost type 300+400.

Again we must emphasize that there is a huge deviation between lowest and highest costs. These results match the findings of the studies from Belz and Egger (2000). The following Figure 53 gives a small conclusion of the calculation of the additional costs.

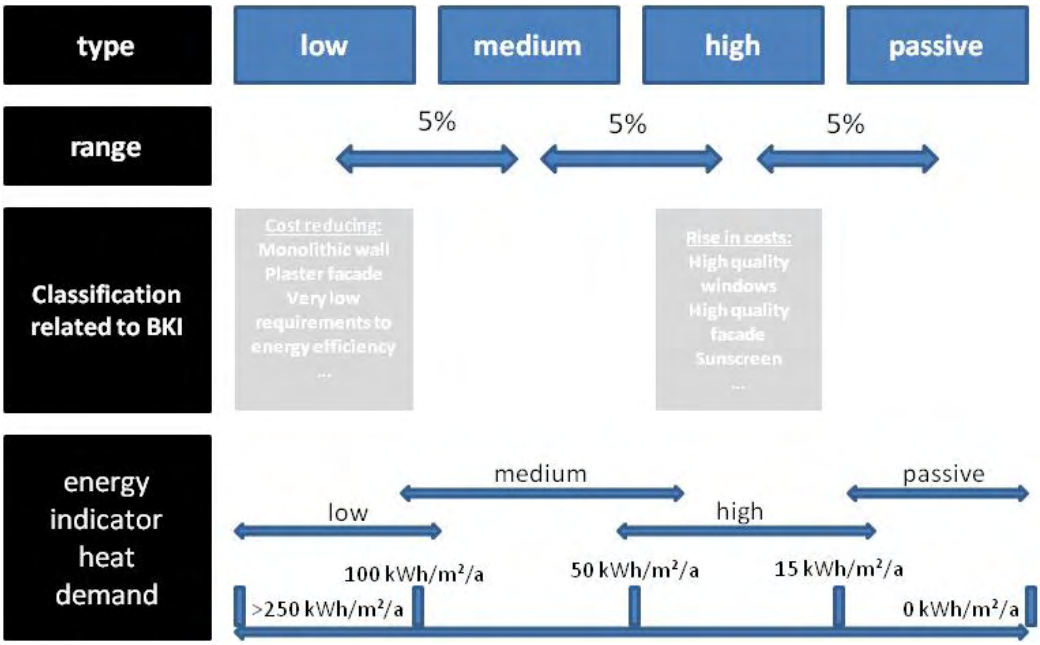


Figure 53: BKI – Quantification of energy efficiency

The previous classification is only a very rough approximation and cannot be directly included into the valuation process. Rather than delivering a basis for valuation, this only serves as an indicator for past construction costs. These adjustments must not be included if the energy efficiency is included at other levels in the valuation process. Adjustments are only necessary if discrepancies within the different levels exist. This could be the case where the quality of the wall deviates from the quality of the rest of the buildings. Such a situation explicitly leads to the need of an adjustment of the BKI values. However, this method is restricted to the previous mentioned cases only. <tt is advisable to calculate replacement costs following the standardized methods of the BKI or NHK since energy efficiency is already included in these categories.

Often enough, however, the cost of a property often does not equate to the willingness to pay of the consumer so one must also consider the market aspects. A valuer should perform the adjustment based on market evidence. Such a quantification of market evidence could come from current regional publications or calculations with available data. The probability that current regional adjustments based on market evidence are published is very low. If there is a good database for market evidence on green or energy-efficient buildings is available, the valuer can calculate market effect.

In general, the calculation of adjustments based on market evidence is one of the most difficult tasks in the valuation process. It hinges on the the local property market's current situation and the ability for the valuer to identify the ratio between the real market value and the calculated cost value.[209] The ability for the valer to calculate adjustments based on market evidence is not a problem specific to the context of energy efficiency, it is also a general problem for valuation a a whole. The literature gives two types of calculations based on the same idea. For both calculations the valuer must know the real market value and the cost value. However, it is a huge challenge to identify both pieces of information. One can obtain the market value from the contracts, but the cost value in a valuation report.. If a valuer prepares many reports, the valuer has both values. However, if valuer does not have any information about the local market, he has to obtain information from other valuers.

The first approach depends on an easy linear regression model where the cost value and market value are set in relation to each other.

$$Y = \beta_0 + \beta_1 * X + \varepsilon \tag{48}$$

Y contains the market value; x is the cost value and ε is the error term, which contains all factors not explainable. The prime reason for performing this regression is the parameter β_1, which can be interpreted as the adjustment.[210] If β_1 has a value above one, the cost value is lower than the market value. In contrast, a value lower than one means that the cost value is higher than the market value. This means that the market is not willing to pay the full calculated cost value. If the parameter β_0 and β_1 are known the market value can be calculated by adopting the cost value (X). The calculation of the market value ($\hat{Y}$) follows like this:

$$\hat{Y} = \beta_0 + \beta_1 * X \tag{49}$$

The second method to calculate the market premium is more common. The method, which follows Kleiber[211] and the market premium respectively, adjustement can be calculated as follows.

$$\text{Adjustment based on market}_{\text{(real value)}} = \text{market value} - \text{cost value} \tag{50}$$

[209] Cf. Simon, J., et al.. (2004), p.467

[210] Cf. Simon, J., et al.. (2004), p.473

[211] Cf. Kleiber, W., Simon, J. (2007), p.1911

Consequently, one must derive the market adjustment from the local property market. However, the market must contain ample available data that statisfy multiple requirements. The valuer has to know the cost value and the market value from past comparable transactions to calculate the adjustment for the local property market. Therefore the valuer must be able to obtain not only the values of past transactions but the valuer must also pay have access to other relevant characteristics. If there are enough transactions, the valuer can calculate the adjustment factor like this:[212]

$$\text{Adjustment factor} = \frac{\text{market value (market price)}}{\text{cost value}} \tag{51}$$

In a transparent market such as Germany the valuer can obtain these indicators from the so-called German committee of valuation experts, the Gutachterausschüssen. One must then calculate an adjustment factor for each transaction. If there are enough observations, the mean can be calculated and the adjustment used. If the adjustment factor is bigger than one, the market value is higher than the cost value. This investment is less than the intrinsic value of the object. If the adjustment factor is lower than one, the intrinsic value is higher and the market reflects lower value than the costs. One should note that the the market factor is calculated from past transactions and has no direct connection to future prospects. The market value can now be calculated by the cost value multiplied by the adjustment factor.

$$\text{Market value} = \text{cost value} * \text{adjustment factor} \tag{52}$$

The adjustment factor refers to the building and the land so there is no way of distinguishing between the two. This case clarifies that the adjustment factor is one entity and It is impossible to distinguish different effects. Therefore, a clear classification for the diverse effects is not possible. By taking this into accout it is vital to regard the rule of conformity of the system. In general this involves two facets:[213]

(1) Conformity of the valuation approach

(2) Identical input parameters

When using factors that were empirically derived, the method of derivation has to be the same as the one in the current valuation approach. Hence, to calculate the cost value of the object, the valuation approach must be completely identical to the valuation process used to calculate

[212] Cf. Kleiber, W., Simon, J. (2007), p.1912

[213] Cf. Kleiber, W., Simon, J. (2007), p.1912

the adjustment factor. However, the method is not the only aspect that must remain the smae. The input parameters must also be nearly the same in order to get consistent results . The market factors of the cost value are primary dependent of:[214]

(1) Sort of the building

(2) Age of the building and depreciation type

(3) Level of the cost value

(4) Status of the country

(5) Characteristic of the building

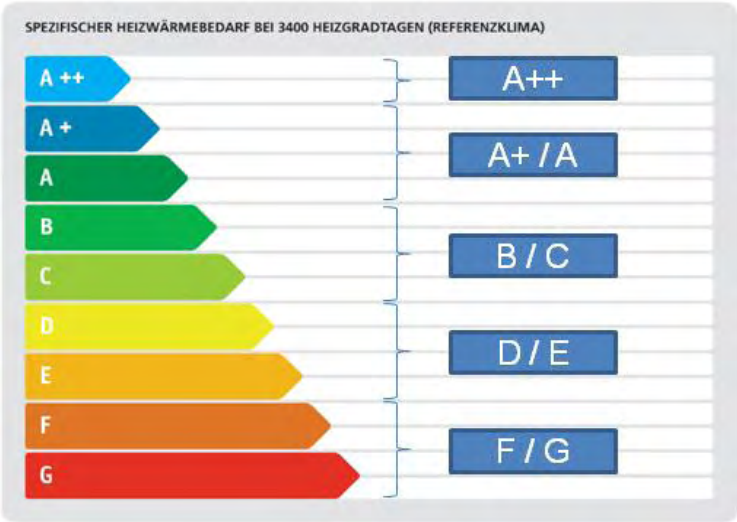


Figure 54: Possible classification of Austrian energy certification

In order to isolate the market effect, the valuer may onlycompare buildings with the same characteristics for the same reason. It might be more easy for a valuer to collect and categorize the buildings in the right way with the help of a description sheet such as the following.

[214] Cf. Kleiber, W., Simon, J. (2007), p.1913

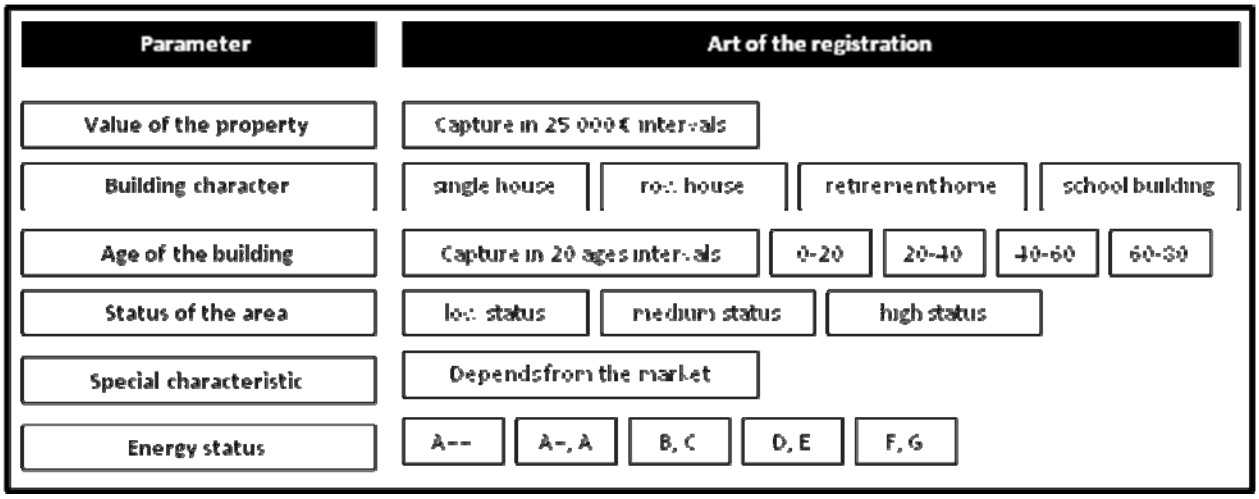


Figure 55: Process of integration in developed markets

This process guarantees that identical parameters are compared and that the market effect from the energy side can be identified.

However, one should emphasize that the technical effect should be identified and calculated first. The valuer should also check if the costs are integrated in the standardized replacement costs or not. If the additional costs are not integrated they have to be integrated by adjustments (other value affecting characteristics). The next step is more difficult than the quantification of the technical effects. There are two possibilities to obtain quantified market effect. If there are market adjustments available from the advisory committee (Gutachterausschuss) the systematic for calculating adjustments has to be disclosed. If the system is equal to the own valuation the adjustment can be adopted directly. If there are no adjustments available from advisory committees, the valuer must calculate the adjustments. This can only be done if representative data exists. One can calculate the adjustments via the method described above. In this context it must be mentioned that this can be only established in developed respectively transparent markets.. So a solution must also be developed for undeveloped respectively emerging markets.

6.4.5.4 Approach for “undeveloped/emerging markets”

On one hand, the label developed market describes a market where limited data concerning green/energy-efficient buildings available (e.g. Germany, Austria, etc.) and on the other hand, there are markets that in general have limited availability of property market data (e.g. Emerging markets like Romania, SEE-countries, etc.). For the emerging markets, data

availability is difficult in general let alone specific problem of valuing energy-efficient buildings. In principle, however, the approach for both cases is the same.

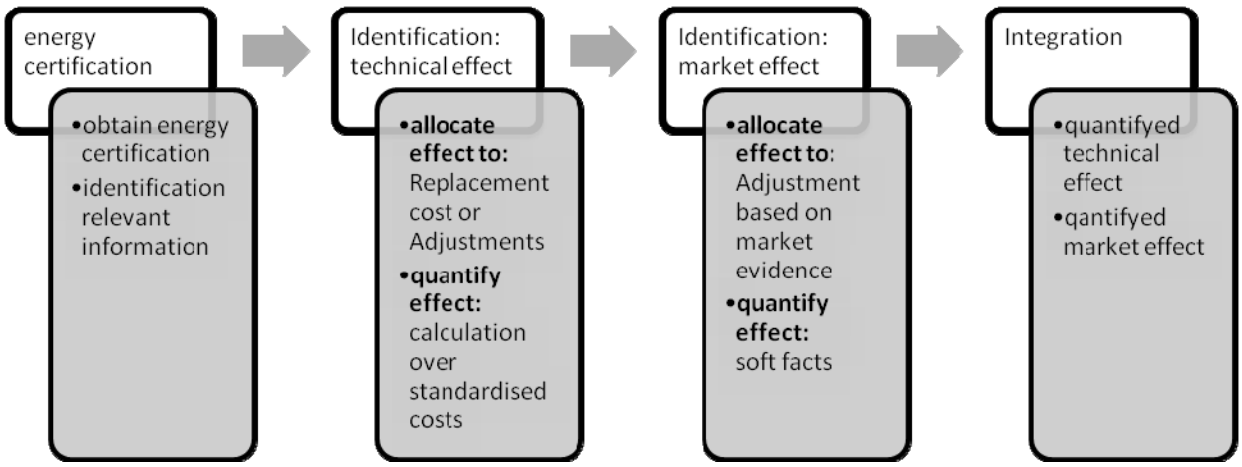


Figure 56: Process of integration in undeveloped markets

The first and second steps are the same as in the approach for "developed markets." In this sense, analyzing the energy certification and identification of the technical effect does not and cannot differ from the work previously mentioned. If there are no standardized replacement costs like the NHK or BKI in Germany, the valuer can adjust the costs with country specific factors. For example, the BKI from Germany can be used for Austria if they are adjusted with a published local factor.[215] So the NHK from Germany can be used for the Austrian market and therefore must be adapted with the published factor for Austria. In extreme cases it might be necessary for the valuer to obtain offers from local developers and construction companies. The huge difference between the two markets lays in how the value r identifies of the market effect. Because there is no market data available, the valuer cannot obtain a direct quantification. One must derive the market effect from so called "soft facts". The valuer should use these soft facts as an instrument to get an overview as to how green buildings are observed in the market. Examples of soft fact that a valuer could use might include: oil price, public opinions in local newspapers, availability of energy in the region, market structure etc. Since the price of heating oil and pellets or other heating resources move in correspondence to the oil price. If the oil price is high, heating costs are high as well. Therefore, the public gets

[215] BKI, (2008)

more sensitive to the energy topic. Some analyses show that consumers react to rising energy costs with a rise in overall cost awareness.[216] Time period also plays a huge role, especially concerning the price of oil. In the short run, however, falling oil prices may inhibit the adoption of green buildings by reducing the absolute scale of the achievable cost saving. So if the oil price is low the demand for energy-efficient buildings will also be low.[217] A study from Tayler Wessing shows that consumers are increasingly adopting a more holistic, long-term approach to the costs of a building. In the long run, a good energy certification has a higher impact on the willingness to pay.[218]

A valuer can use local newspapers as another indicator of the relevance of energy-efficient. If the newspapers publish a lot about topics like energy, energy certification, green buildings, etc., one can interpret this to mean that public interest lays in green/energy-efficient buildings. For integrating green factors into property valuation, the appraiser needs a high knowledge about the market structure. If the local market is dominated by high demand, the energy efficiency may not be as important as in a market where a huge supply exists. In an offer driven market, sellers can use the energy certification as a marketing instrument to increase the marketability. However, in areas where the energy sector is central, cheap and independent from the international market, energy efficiency is not a huge topic among consumers. One such example might include rural areas that organize their heating system centrally with their forest industry.

Indicator	effect	Sensitive of energy certification
Oil price	Oil price rising up	↑
Public opinion	Many articles about energy - green	↑
Market structure	Offer-driven market	↑
	Demand-driven market	↓

Table 34: Indicators to quantify markets awareness for energy efficiency

A clear quantification of the market effect is very difficult in undeveloped markets. The valuer must observe and audit all previously mentioned aspects critically. In addition to these aspects, valuers should obtain the opinions of local market actors like real estate agents,

[216] IZ, (2008), p.11

[217] Eddington, C., Berman, D., Hitchcock, D., et al. (2009), p.14

[218] Barnett, K., Fitzpatrick, D., Garthwaite, H., et al. (2009), p.31

developers or real estate administrators. Table 36 can only be used to get a feeling for market structure.

One possible and appropriate way for a valuer to quantifying the market effect in an opaque market focusing on energy efficiency might be through the use of a scoring model. For that reason a so-called "weighted adjustment for valuation parameter effecting characteristics" (WAPEC) was established by IMMOVALUE as a first indicator for property valuers, which is also used in a different way in the income approach.

The idea for this scoring model is based on the additional costs between reference buildings in the market and the valuated building. The remainder is the basis for the calculation. This value is referred to as AAP. This amount is then multiplied by the *"market adjustment rate"* (MAR), which can be seen as quantification for the markets' attention and resulting from the willingness to pay for energy-efficient buildings. In other words the AAP is weighted by the MAR. Hence the adjustment is the product of MAR times AAP.

Key Valuation Parameter	Market maturity	**Significant** adjustment	**Medium** adjustment	**Low** adjustment	**neutral**
Additional costs	**Opaque (Emerging) Market** --> Discount for energetic building	-low price elasticity - tenants do not pay attention on sustainability and energy efficiency at all			-high price elasticity - high awareness of users for sustainability and energy efficiency
	--> Premium for non-energetic building	- media does not recognise green buildings benefits at .. - majority of property market is not willing to pay higher costs for green buildings			- omnipresence of green building issues in the media - market postulate green buildings standards/codes
		- suffering economic situation - ...			- good general economic conditions - ...
Market adjustment rate (MAR)		+/- 75 - 100 %	+/- 25 - 75 %	+/- 0 - 25 %	+/- 0 %
x		x			
Average adjustment parameter (AAP)*		+/- [€]	--> *AAP derived from remaining amount between reference buildings and valuation building*		
x		x			
Valuers estimation adjustment (VEA)**		+/- [%]	--> *Valuers estimation adjustment due to probability of occurrence, uncertainty, etc. regarding the AAP*		
=		=			
--> Weighted Adjustment Factor (WAF)		+/- [€]	--> *= MAR x AAP x VEA*		

Adjustment based on Market Evidence
= [€]

Figure 57: Example of WAPEC for Adjustment based on market evidence

At the maximum the adjustment equals the AAP and zero at a minimum. One must use thefollowing approach when using the scoring model:

(1) Identify the market situation with WAPEC (MAR)

(2) Identify typical market rating in relation to energy efficiency (reference buildings)

(3) Compare rating between reference buildings and valuated object

(4) Calculate costs (remaining amount) between reference buildings and valuation building (AAP)

(5) Multiply the remaining amount (AAP) with the market adjustment rate (MAR) and Valuers estimation adjustment (VEA).

(6) Use the WAF (in €) as adjustment based on Market evidence

A word of warning, if the valuated building has a higher level of energy efficiency than the reference buildings and energy efficiency does not play a role in the market, this method leads to a discount. However the method will also lead to a discount if the valued building has a lower level of energy efficiency than the reference buildings and energy efficiency plays a role in the market.

The following chapter features two case studies that further explain the previous contentions with the aid of valuation examples. The first case shows two different types of houses.

The **first house is a passive house and the second a low thermal quality level house**. The technical effect is directly integrated into the replacement costs. In the **second case the buildings have the same characteristics except for the energy efficiency**. In this case the replacement costs are the same, but the building with the higher energy efficiency features a higher premium. The first case study shows the calculation of an adjustment based on market evidence in a transparent market. In the second case study shows an adjustment based on market evidence derived from an undeveloped market.

6.4.5.5 Case Study 1 – Basic makeshift for transparent markets

In this case, there is available information about cost value and transaction prices of current transactions. The calculation assumes that the characteristics of the buildings (e.g. size, location, etc.) with the exception of energy efficiency levels, are the same. Therefore we impose a *ceteris paribus* condition with an exception for this one key characteristic so thet the adjustment factors for the two buildings can be calculated like this:

Cost value + value of land	Transaction prices	HWB	Adjustment factor	same properties like valuation object
420.000	336.000	10	0,80	Yes
390.000	331.500	15	0,85	Yes
360.000	306.000	10	0,85	Yes
310.000	279.000	8	0,90	Yes
Average Adjustment factor			0,85	

Table 35: Calculation adjustment factor – type of house: passive

Cost value + value of land	Transaction prices	HWB	Adjustment factor	same properties like valuation object
280.000	280.000	180	1,00	Yes
250.000	225.000	200	0,90	Yes
290.000	275.500	160	0,95	Yes
270.000	256.500	170	0,95	Yes
Average Adjustment factor			0,95	

Table 36: Calculation adjustment factor – type of house: low energy efficiency

In this case, the adjustment factor for the passive house is higher than for a non-energy-efficient building. This indicates a lower willingness to pay for energy efficiency. The costs for a passive house are too high and not honoured by the market in the full height.

Case 1: Different type of houses (passive/low)		
Generel Information		
energy indicator heat demand	10 kWh/m².a	180 kWh/m².a
year of construction	2006	2006
Remaining economic lifetime	77 years	77 years
Total area in local size unit (BGF)	180 m²	180m²
Price per m² (Area = 600m²)	200 €/m²	200 €/m²
Type/level	passive standard	Low thermal quality standard
Assumptions valuation		
Replacement costs (new) in €/m² BGF		
Cost type 300+400	1140 €/m²	710 €/m²
Ancillary construction costs (%)	30%	28%
Calculation		
Replacement costs (new) of the building	266 760 €	163 584 €
Further adjustments	none	none
Depreciation factor	77/80 = 0.96	77/80 = 0.96
Value of building in €	256 089 €	157 041 €
Value of Land in €	120 000 €	120 00 €

Value of property in € based on costs	376 089 €	277 041 €
Adjustment based on market evidence (factor)	0.85 (see calculation adjustment factor)	0.95 (see calculation adjustment factor)
Market Value	319 676 € ~ 320 000 €	263 189 € ~ 263 000 €

Table 37: Case 1: Different type of houses (passive/low)

Case 1 shows that the whole technical effect is already integrated in the replacement costs. Therefore no further adjustment needs to be done by the valuer concerning the technical effect. However, the market effect does differ between the two buildings. In this case the market does not honor the passive house in a sense that the value is lower than the costs. This leads to an adjustment factor of 0.85. In contrast the low thermal quality standard house has an adjustment factor of only 0.95. In this case the market value between a passive house and a low standard house is € 57 000.

6.4.5.6 Case Study 2 – Basic makeshifts for opaque markets

Contradictory to a transparent market, there is no detailed information on energy efficiency or EPC available in case two. Due to the lack of evidence, appraisers first have to evaluate the current property market situation to determine if, and to which extend, the market already recognizes and cares about energy efficient buildings in general.

According to these investigations the valuer found that:

(1) The property market and media already recognised the importance of energy and resource efficient properties and started to establish a broad sense for sustainability agendas due to rising energy prices, etc.

(2) The reference buildings that the market accepts have an energy indicator heat demand of 50 kWh/m².a.

The above stated market aspects lead valuers to evaluate the market maturity by applying the WAPEC-approach as illustrated in Figure 58:

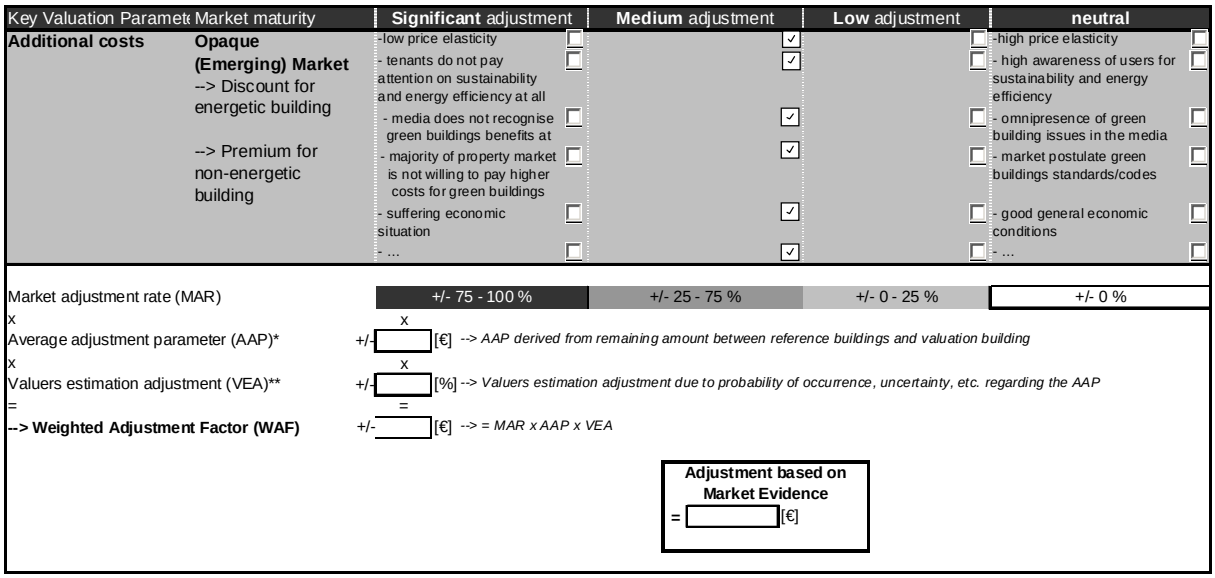


Figure 58: Case 2: Example of WAPEC for Adjustment based on market evidence

As result the observed market achieves a "medium" rating and therefore can be rated with a market adjustment rate (MAR) of approx. 50 %. In the second step, the valuer pointed out that reference buildings accepted in the market have an energy indicator heat demand of 50 kWh/m².a. Next, the valuer must calculate the the costs (remaining amount AAP)between reference buildings and the valuation building. The bases for the calculation in this example are the replacement costs (cost type 300+400). In this case, we assume the replacement costs at 710 EUR/sqm. We assume 5 % higher replacement costs toupgrade a 50 kWh/m² house to a 10 kWh/m².a object (object 1). Furthermore, for the second object we assume 10 % higher replacement costs in order to upgrade a 180 kWh/m².a house (object 2) to a 50 kWh/m².a object. One must then multiüply the remaining amount (AAP) with the market adjustment rate (MAR) and the valuers estimation adjustment (VEA). After this process the valuer gets:

Valuation object	Reference object	AAP	MAR	VEA
10 kWh/m²	50 kWh/m²	€ 6,400 (5%x 710x180)	0,50	0,8
Adjustment based on market evidence (MAR x APP x VEA) - € 2560				

Table 38: Case 1: Adjustment for valuation object 1

Valuation object	Reference object	AAP	MAR	VEA
180 kWh/m²	50 kWh/m²	€ 12,800 (10%x 710x180)	0,50	0,8
Adjustment based on market evidence (MAR x APP x VEA) - € 5120				

Table 39: Case 1: Adjustment for valuation object 2

The results of this calculations show that for the 10 kWh/m² building there is a discount of € 2,560. So the market does not honor a level of energy efficiency as high as the costs to reach that level are. In contrast, the 180 kWh/m².a building gets a discount of € 5,120.

Case 2: Same type of houses (low/low) but different energy efficiency		
General Information		
EPC – market sense:	The reference buildings which are accepted in the market have an energy indicator heat demand of 50 kWh/m².	
energy indicator heat demand	10 kWh/m².a	180 kWh/m².a
year of construction	2006	2006
Remaining economic lifetime	77 years	77 years
Total area in local size unit (BGF)	180 m²	180 m²
Price per m² (Area = 600m²)	200 €/m²	200 €/m²
Type/level	Low standard	Low standard
Assumptions valuation		
Replacement costs (new) in €/m² BGF		
Cost type 300+400	710 €/m²	710 €/m²

Ancillary construction costs (%)	28%	28%
Calculation		
Replacement costs (new) of the building	163 584 €	163 584 €
Further adjustments	15% (of cost type 300+400) = 19170 € (106,5 €/m²)	none
Depreciation factor	77/80 = 0.96	77/80 = 0.96
Value of building in €	175 444 €	157 041 €
Value of Land in €	120 000 €	120 000 €
Value of property in € based on costs	295 444 €	277 041 €
Adjustment based on market evidence (factor)	- 2560 € (see calculation)	- 5120 € (see calculation)
Market Value	292 884 € ~293 000 €	282 161 € ~282 000 €

Table 40: Case 2: Same type of houses (low/low)

Case 2 shows two identical buildings that only differ in energy efficiency. Both buildings have the same replacement costs for their standard level. The building with the higher energy efficiency had an adjustment of 15 % applied for the cost category 300+400. This is because it costs approximately 15 % more to obtain a 10 kWh/m² standard house from a 180 kWh/m² object. This integration covers the entire technical aspect. In this case, the market honors the energy efficiency less than the costs. The energy efficient house has been discounted by 2,560 EUR. This is due to the fact that the market does not honor energy efficiency as one might expect for 10 kWh/m².a. In contrast, the 180 kWh/m².a house has lower energy efficiency than the market asks for. Since the market equilibrium lies at 50 kWh/m².a the discount is at 5,120 EUR instead of 12,800 EUR. Therefore a further improvement of the building shell down to 10 kWh/m².a would not be valuable.

7 Roadmap for Implementation (deliverable D5.3)

7.1 General Circumstances and requirements for implementation

As was mentioned previously, the degree of success when implementing green or energy efficiency aspects into current property valuation practices depends mostly on the awareness and willingness to pay for such attributes and ultimately on the empirical evidence the property market provides. That means that if the market does not pay attention to energy performance attributes as well as realise the advantages to such attributes, it is hard to provoke the related changes in property valuation practice. Therefore one of the fundamental requirements for the implementation of any new aspect and approach is the markets' sensitivity to such aspects. This awareness must exist in order to realize the aforementioned changes.

This paradigm shift in the property markets towards sustainability and energy efficient products can be attributed to rising omnipresence of climate change and related debates in the public media as well as the fact that governments, industry and key decision makers have already started to establish incentives (government aid for sustainable developments), mandatory regulations (e.g. EPBD, building quality standards), intercontinental agreements and commitments (e.g. Kyoto-Protocol), research programs, etc. to propagate the importance of properties' sustainability and energy efficiency.

Therefore it is important that valuers key integrate national and international organisations responsible for property valuation guidance and standards in order to achieve a broader acceptance of the property valuation society. It should be obvious, due to the fact that the majority of European national valuation standards refer to the RICS (Red Book) or TEGoVA Valuation Standards (EVS), that the valuation should include such organisations in the establishment of new valuation methodologies or the adaption of the international recognised methodologies. Whereas standards such as RICS or EVS just publish descriptive guidance notes for property valuation, a few national standards e.g. the Austrian valuation law and regulations (LBG, ÖNORM) or the upcoming German valuation ordinance (ImmoWertV 2009) go beyond the descriptive and encompass methodological explanations. Hence this report illustrates both – a descriptive guidance for the integration of energy efficiency/sustainable features (see Chapter 6.3) and an investigation of possible valuation adjustment methodologies (see Chapter 6.4).

7.2 Main obstacles for integration into property valuation standards

Valuers must solve three main critical obstacles (see Figure 47), in addition to the already mentioned implementation requirements in order to increase the acceptance and achieve an implementation of different established property valuation adjustment methods. , have to be solved.

Critical Obstacles	Action	Useful Tools	Solution
Practical Application	Testing of applicabiltiy and reliability of established approach	• Performing Pilot Projects	• Receive comprehensive evidence and rational constituted results • Quantifying and integrating analysis and results to improve applicability
Property Market Acceptance	Review Process	• Enforcement of Expert Surveys • Evaluation by valuation experts	• Incorporation of survey results • Organising expert advisory meetings • Consideration of feedback and improvement guidance to receive best practice
General Popularity and Recognition	Communication and Dissemination	• Integration of national and international key valuation organisations • Communication activities to key valuation companies and experts • Information for valuation customers • Information of broader public	• Co-operation with key valuation organisations (RICS, TEGoVA) • Organising valuation expert meetings • Participation at trade fairs, conferences, etc. • Publishing press releases, scientific papers and articles

Figure 59: Critical Obstacles for Implementation into Valuation Standards

First of all it is important that the established adjustments of the valuation approaches are feasible, reliable and applicable so that that can be easily handled and applied by property valuers. If the methodology is not simple the chance that the valuer could create misleading reports is high. Thus it is necessary that the approaches are tested and applied in pilot projects like the Swiss ESI-Valuation (see Chapter 5.1.2.2.1) and not remain solely as a theoretical concepts. In addition, it is important to quantify, analyse and integrate the results of performed pilot projects to improve the applicability in order to produce the best approach. If an applicable and reliable approach is on-hand, a good basis exists to reach a high acceptance within the property markets and the valuation society.

To gather and bundle other views and ideas for an integration of energy efficiency and performance aspects as well as LCCA into property valuation, an review by valuation professionals and energy experts of the created methodologies and carrying out pilot projects

are recommended and seem to be useful to avoid a misleading development of valuation approaches, which might not be accepted by the valuers' society. Furthermore, the review process also offers feedback and improvement suggestions, which may be necessary to satisfy valuers' interest.

Further, lack of popularity and public recognition might serve as another obstacle that could act as a barrier to implementation despite basic consensus and observable acceptance. To counteract such risks and pitfalls intensive communication and dissemination activities are required to spread information and advert to the established approaches. This communication will be the most effective if it is established via various co-ordinated communication levels and channels. Dissemination should be done on an individual basis (e.g. participation of individuals at conferences and trade fairs, publication of papers, etc.) and throughout bundled channels (i.e. RICS network, national associations, etc.). Furthermore, co-operations with educational institutions might be an appropriate way to distribute the approaches to a broad majority of valuers and property market participants.

7.3 If the above mentioned obstacles are kept in mind avoided as much as possible, there is a realistic opportunity to receive qualitative feedback, improvement ideas, and broader acceptance of the approaches. Selected roadmap for transformation and implementation

To succeed in the overall aim of establishing adequate and practical methodologies for encompassing energy efficiency and LCCA issues into property valuation practice, it is important to have a clear focus how to tackle the possible obstacles as explained. Therefore a helpful tool may be to create an implementation roadmap to prevent and reduce such barriers.

Taking the given obstacles into account, the roadmap for transformation and implementation of the created approaches into national and European-wide standards was established to follow the subsequent progress (see Figure 51). The roadmap consists of three parts, which cover the three main implementation obstacles that have to be terminated by explicit application of adequate tasks and actions. These are in particular (1) the testing and evaluating of pilot projects in a comprehensive way, (2) the enforcement of a review process by key valuation experts, and (3) selective communication and dissemination activities.

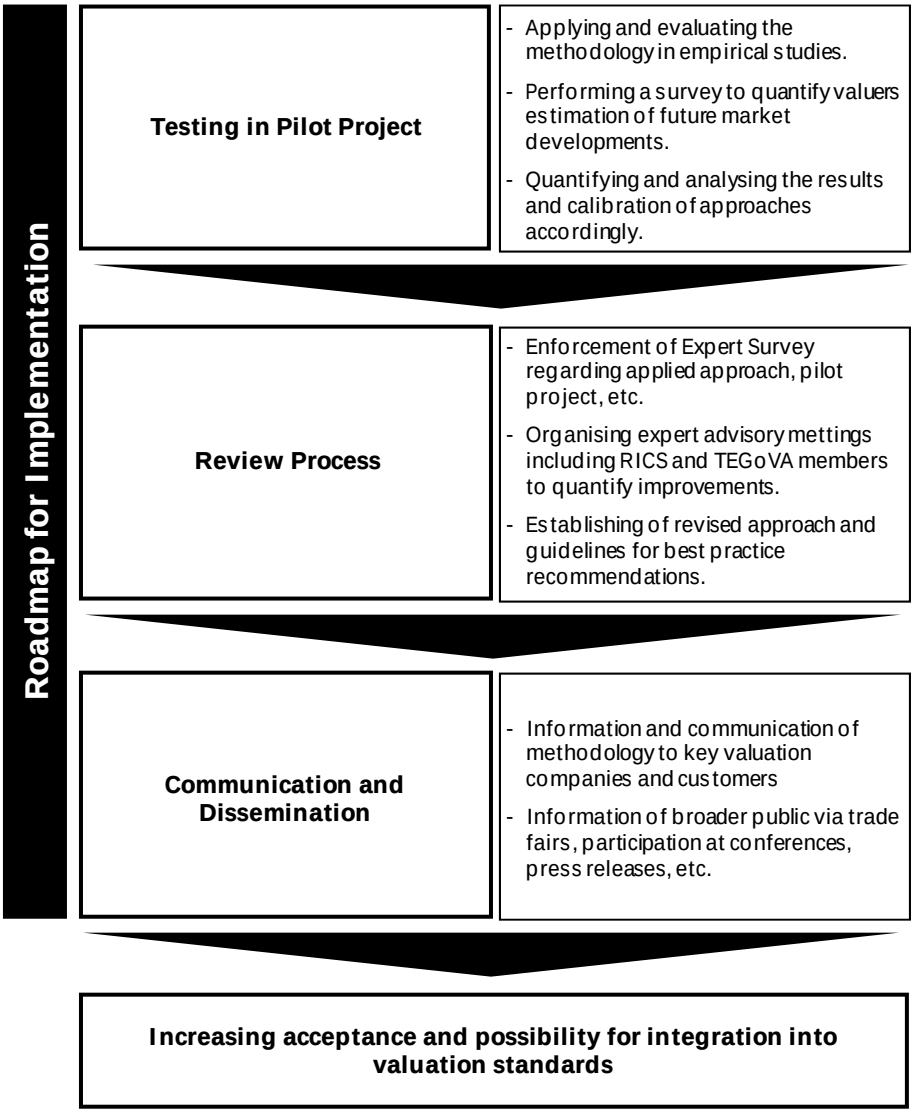


Figure 60: Roadmap for Implementation into Valuation Standards

Action I – Testing of Pilot Projects

To assure a practical and applicable alternative valuation approach, a testing and evaluating of pilot projects is necessary to quantify the results and consequences when applying the established valuation approaches. In addition an electronic expert survey will be enforced and distributed to valuation experts to quantify the current assessment of buildings energy efficiency and LCCA aspects within property valuation practice, and the expert's estimation of the futures sensitivity of the property market for sustainability and green building issues.

The results and outcomes of the pilot project and expert survey afterwards will be used to adjust the developed approach to calibrate and improve its applicability.

Action II – Review Process

A comprehensive review of the developed approach and corresponding pilot projects by mainly property valuation experts from different professional communities (e.g. valuation companies, valuers' association, etc.) will be organized in order to improve and better communicate the drafted approach.

The aim of this review process is to receive recommendations for technical improvements and information about critical aspects which might embarrass the implementation into valuation practice and standards. Furthermore this expert review should gain the acknowledgement and acceptance of the property valuation society regarding the developed approach and should lead to derived guidelines and best practice recommendations for national and international valuation standards.

To assure a structured procedure a common questionnaire serving a general structure for the expert feedback will be prepared. On the basis of the feedback received a conclusion will be drawn from the theoretical models/approaches and the tested pilot project, which will be evaluated by an expert advisory committee in a further step. The committee therefore will discuss the results and conclusions in context of the national and international impacts on the real estate markets. Outcomes and results of this consultancy will be integrated into a finalized report, which will be the basis for guidelines and best practice recommendations for national, RICS and TEGoVA valuation standards.

Action III – Communication and Dissemination

To spread out the tested and review established methodologies, and achieve that these approaches are seen as important inputs to running standardization processes, communication and dissemination activities will be targeted to important pressure groups in real estate valuation practice and business (e.g. professional associations, valuation companies, etc.). This will be mainly established via different communication and distribution channels as stated subsequently:

publication of results, surveys and reports on the official website of the IMMOVALUE project,

participation and dissemination at relevant trade fairs, conferences, seminars, etc.,

contribution of papers at professional real estate journals, and

information of broader public via different media such as press releases and newsletters (since e.g. EPC concerns the public due to mandatory regulations).

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V. Appendix A : Examples of LCCA models for the calculation of operational cost of buildings

The following section presents two examples of LCCA models that have already seen practical use several times and fulfil - at least partly - the following necessary requirementsfor an application of LCCA in property management:

- The LCCA must be conducted in a simple and quick way;
- The LCCA should deliver results with a limited set of necessary data and even with data lacks (through the use of default data);
- Cull the impact of users within the LCCA calculation
- The LCCA calculates on the basis technical building characteristics (thus filtering out the influence of building users and the quality of operational management on operational cost)
- The LCCA includes all relevant operational cost which are depending on the quality of the building itself.

The first model presented is the **Norwegian LCC calculator**, which can support the analysis of the most important cost drivers of a building in an LCC perspective.
The second model is an **Austrian tool** developed by the consulting companies M.O.O.CON and e7. It has been originally developed for a better consideration of Life Cycle Costs (LCC) during the planning phases of buildings. But as refers the application in property valuation and the important role of cost differences between sustainable buildings and conventional ones the tool is also a useful for the calculation of reliable and consolidated operational costs.

a) Norwegian LCC calculator: Main cost drivers in an LCC perspective

The task carried out in valuation is the estimation of the fair market value of an object. The main focus of the ImmoValue project is the correspondence between energy performance (as measured by Energy Certificates) and property value. However, other facts are also important in valuation. One such factor isthe physical condition of the property.

One approach might be to first estimate the fair price for an object based on its size, location and purpose – and then to adjust this value based on specific "deviations" from the normal. If there are specific properties of a building that deviate in a negative way from what is normal, such as a bad roof that needs to be replaced can be a reason to lower the estimated value of a property. The reason that in an LCC perspective the needed replacement of the roof will have to be sooner in time than the reference, and this lowers the estimated value.

In order for valuation professionals to identify and take into account these kinds of cost drivers they need a little bit of information. First of all they need to know what to look for, what kind of components can have major LCC-costs relations, if the technical conditions are not favorable? Secondly, they need to know the approximate replacement- and maintenance cost of these components.

The Norwegian State Housing Bank (NSHB) has financed a software based LCC calculator (see appendix). It was created by *SINTEF Building and Infrastructure* and *Multiconsult*, and uses Service Life Planning values from SINTEF and maintenance/replacement costs from Multiconsult. These estimates are used in this text to indicate how a checklist for surveyors, based on LCC cost drivers, can be prepared.

Notice that the estimates used in this text should be seen as an example of what type of information when crating this kind of checklists. More components and further details are necessary for a tool to be comprehensive, and the estimates and critical factors will differ between geographical locations.

In the following text the LCC calculator is first explained, then two examples shown with focus on first roofing and then windows.

The LCC Spreadsheet

In the following pages we have a short presentation of the LCC spreadsheet. The spreadsheet itself is in Norwegian.

Since we are interested in valuation we will examine some important properties regarding the technical quality of a building.

For each building component the estimated "Residual Service Life" (time before the component should be replaced, which means new costs) will be a function of the seven following aspects of the component.

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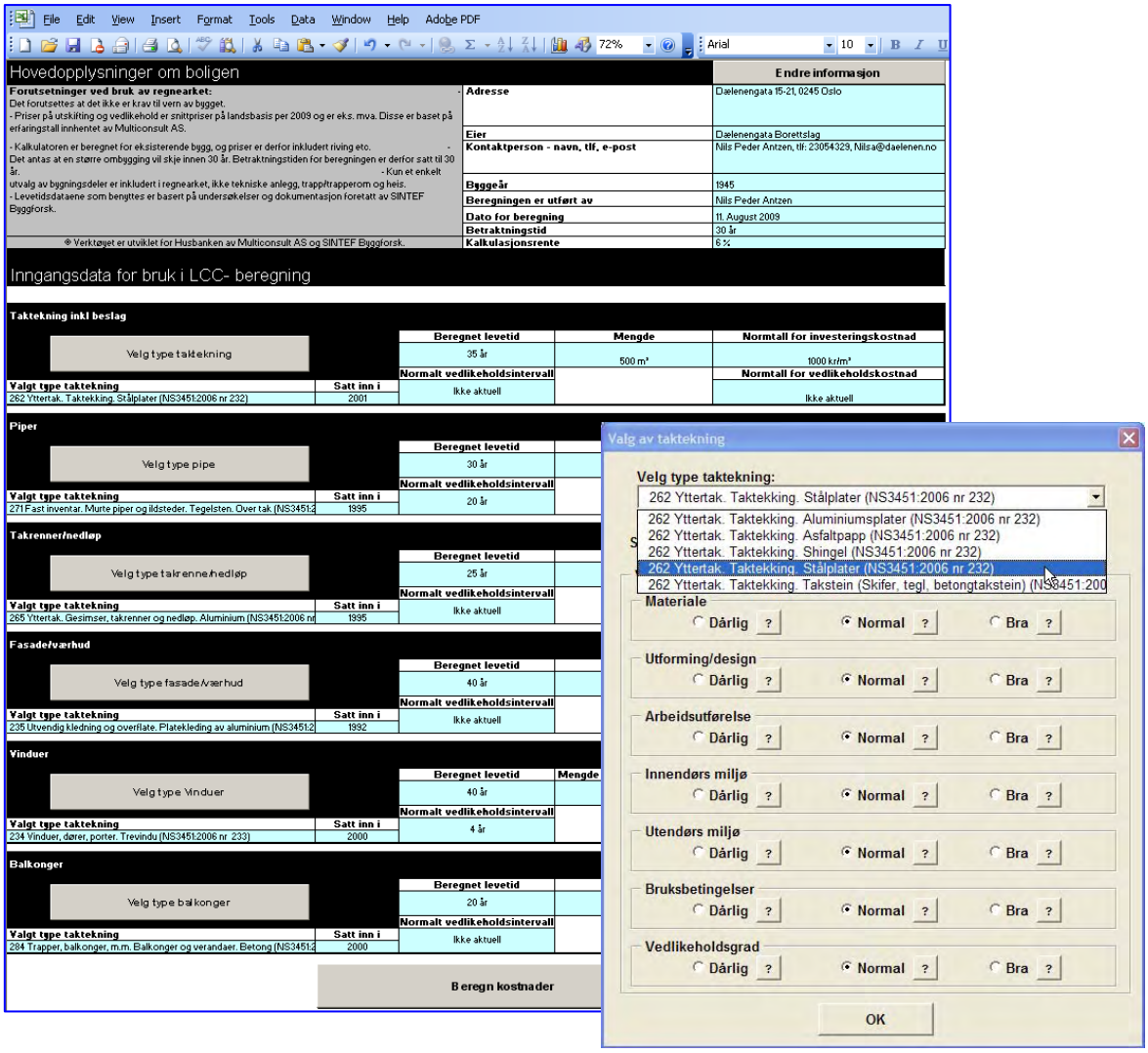
a. Material
b. Design
c. Craftsmanship
d. Indoor climate/environment
e. Outdoor climate/environment
f. Restrictions in use
g. Maintenance standard

These criteria are evaluated in

- Bad,
- Normal
- Good

Below is a screenshot of the data entry screen of the LCC calculator.

Behind each question mark is a description of the properties and why this (material choice etc.) is



considered bad, normal or good.

The main external building parts and components in the system are:

- Roofing
- Chimney (above the roof)
- Gutter/drainpipe
- Fasade
- Windows
- Balcony

In the following we will examine two building components to see how their residual service life (RSL) depends on the critical factors. In order to make the presentation simple only one critical factor will be changed for each of them.

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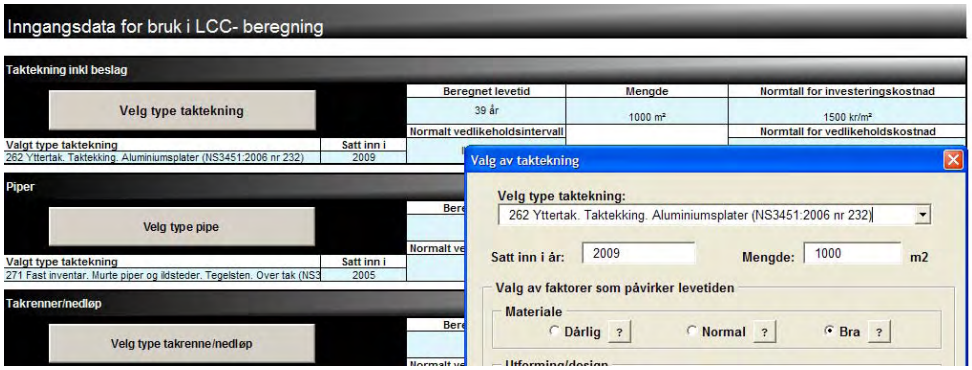
Roofing. Steel plates (NS3451:2006 nr 232)

1000 m2

Norwegian climate, Oslo.

Critical factor			Estim. life	Maintain. Interv.	Replacem. cost (NOK) per unit	Maint. Cost (NOK) per unit
Corrosion, poor fixing. Moisture/water damage in the underlay						
Specifications	**Specification**	**Factor:1.2 (Good)**	**39**	**Na**	**Na**	**Na**
Overflatebehandling, stivhet (tykkelse), innfestningsmateriale, underlag	Heat treated steel plate with organic coating (plastic coating or paint). Good material stiffness. Attachment of stainless steel screws with rubber gasket. Underlying Ceiling. Use of non-salt-treated materials.					
Specifications	**Specification**	**Factor*: 1.0 Normal**	**35**	**Na**	**Na**	**Na**
	Heat treated steel plate with organic coating or paint. Anti corrosion treatment. Satisfactory / normal material stiffness. Screw-fastening with rubber gasket. Ceiling.					
Specifications	**Specification**	**Factor*: 0.8 Bad**	**35**	**Na**	**Na**	**Na**
	Steel plates of steel that rusts slowly (Cortes), hot galvanized plates with PVF2 thin layer coating. Poor plate stiffness. Random fixing terms. material and type (blind rivets, nails). No ceiling.					

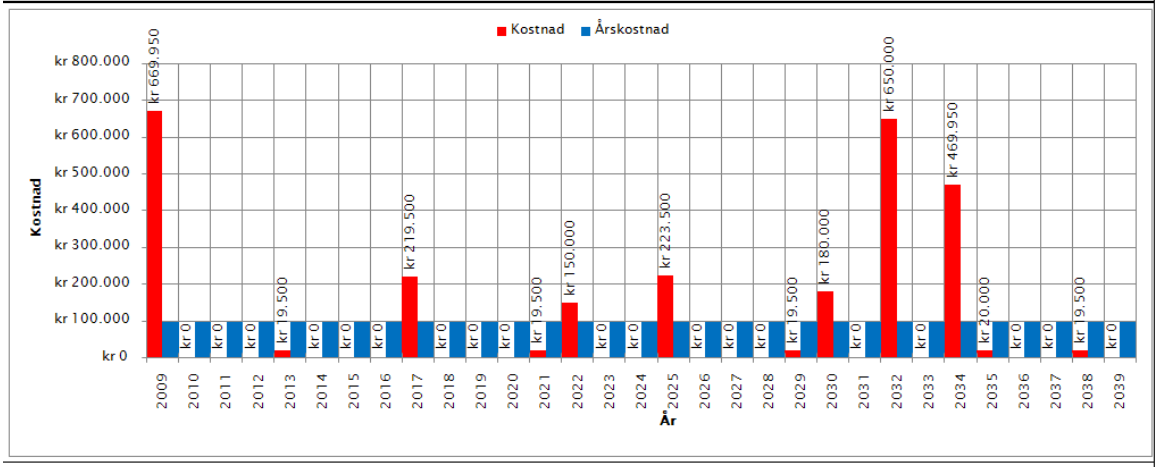


With the value “Good” (1.2) and the values for the other building elements placed at ”normal” (1.0) the following summary report is produced:

Oppsummering

Adresse	Dælenengata 15-21, 0245 Oslo
Eier	Dælenengata borettslag
Kontaktperson - navn, tlf, e-post	Nils Peder Antzen, tlf: 23054329, Nilsa@daelenen.no
Byggeår	1945
Beregningen er utført av	Nils Peder Antzen
Dato for beregning	19. Oktober 2009
Betraktningstid	30 år
Kalkulasjonsrente	6 %

	Bygningskomponent	Levetidskostnad		Årskostnad	
Taktekning inkl beslag	262 Yttertak. Taktekking. Aluminiumsplater (NS3451:2006 nr 232)	kr	-	kr	-
Piper	271 Fast inventar. Murte piper og ildsteder. Tegelsten. Over tak (NS3451:2006 nr 265))	kr	5.971	kr	434
Takrenner/nedløp	265 Yttertak. Gesimser, takrenner og nedløp. Plastbelagt forsinket stål (NS3451:2006 nr 236	kr	555.404	kr	40.350
Fasade/værhud	235 Utvendig kledning og overflate. Trepanel (NS3451:2006 nr 231)	kr	574.380	kr	41.728
Vinduer	234 Vinduer, dører, porter. Trevindu (NS3451:2006 nr 233)	kr	131.718	kr	9.569
Balkonger	284 Trapper, balkonger, m.m. Balkonger og verandaer. Tre (NS3451:2006 nr 262)	kr	70.326	kr	5.109
SUM		kr	1.337.799	kr	97.190



Skriv ut oppsummering | Forhåndsvisning | Endre inputdata

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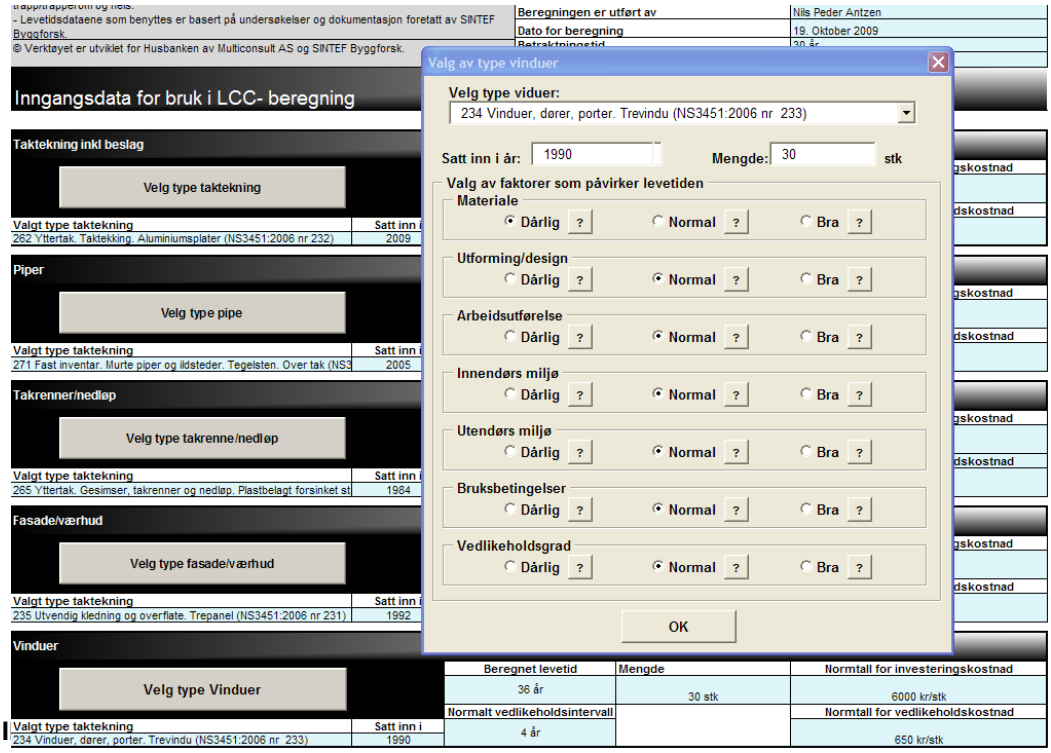
Another building part as an example -- a wooden window

Windows, doors, gates. Wooden window (Norwegian Standard NS3451:2006 no 233)

Window (manufacturer: NorDan).

30 units

Critical factor			Estim. life	Maintain. Interv.	Replacem. cost (NOK) per unit	Maint. Cost (NOK) per unit
Avflassing, råteskader, defekte hengsler/beslag						
Specifications	**Valuation/ Specification**	**Factor:1.2 (Good)**	**44**	**4**	**6000**	**650**
	Pressure treated spruce / pine. No cutting of wood finishing after treatment. External aluminum cover.					
Specifications	**Valuation/ Specification**	**Factor: 1.0 Normal**	**40**	**4**	**6000**	**650**
	Pressure treated spruce / pine.					
Specifications	**Valuation/ Specification**	**Factor: 0.8 Bad**	**36**	**4**	**6000**	**650**
	Spruce / pine without pressure treatment, or unknown/undocumented.					



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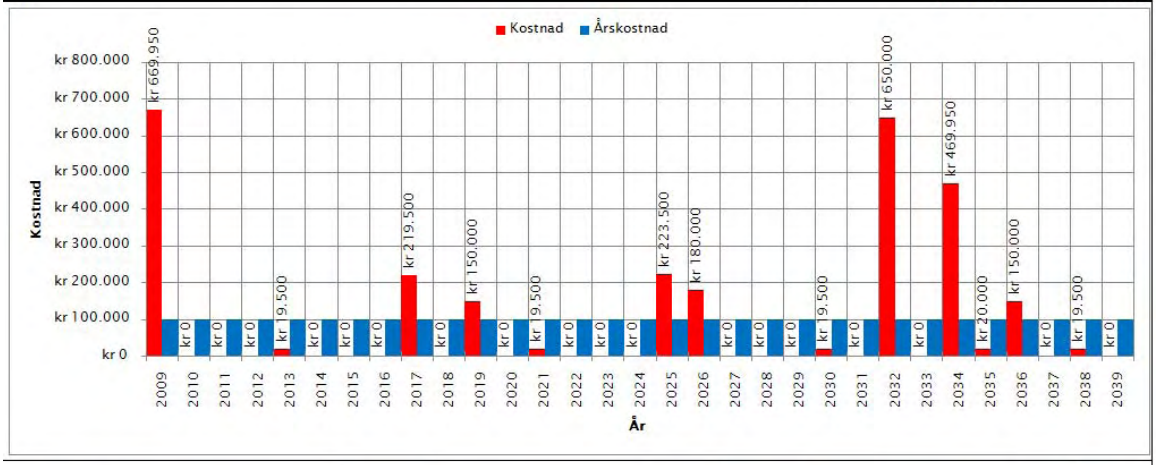
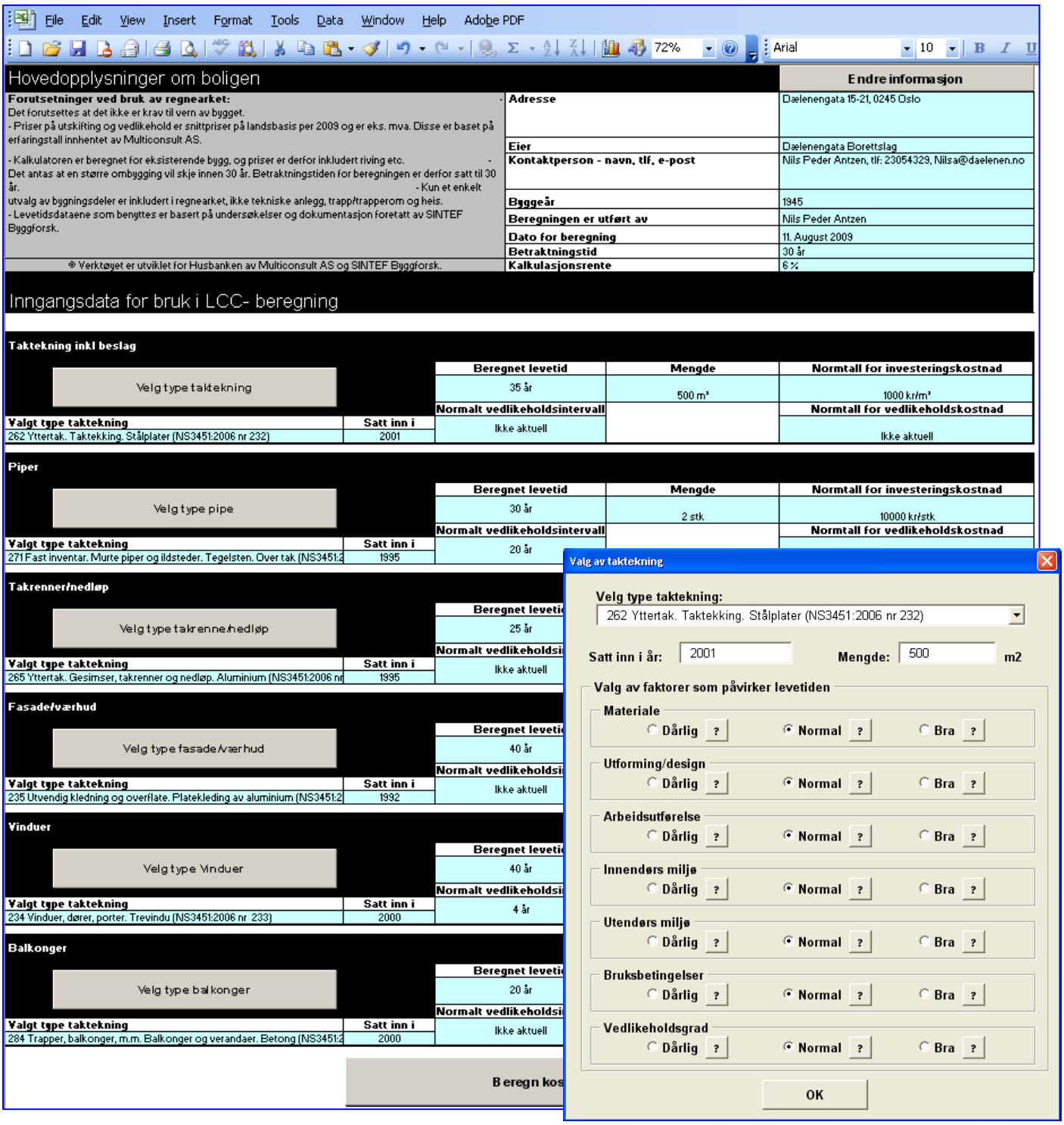
	Bygningskomponent	Levetidskostnad ?		Årskostnad ?	
Taktekning inkl beslag	262 Yttertak. Taktekking. Aluminiumsplater (NS3451:2006 nr 232)	kr	-	kr	-
Piper	271 Fast inventar. Murte piper og ildsteder. Tegelsten. Over tak (NS3451:2006 nr 265))	kr	5.971	kr	434
Takrenner/nedløp	265 Yttertak. Gesimser, takrenner og nedløp. Plastbelagt forsinket stål (NS3451:2006 nr 236	kr	555.404	kr	40.350
Fasade/værhud	235 Utvendig kledning og overflate. Trepanel (NS3451:2006 nr 231)	kr	574.380	kr	41.728
Vinduer	234 Vinduer, dører, porter. Trevindu (NS3451:2006 nr 233)	kr	145.271	kr	10.554
Balkonger	284 Trapper, balkonger, m.m. Balkonger og verandaer. Tre (NS3451:2006 nr 262)	kr	114.864	kr	8.345
SUM		kr	1.395.891	kr	101.410



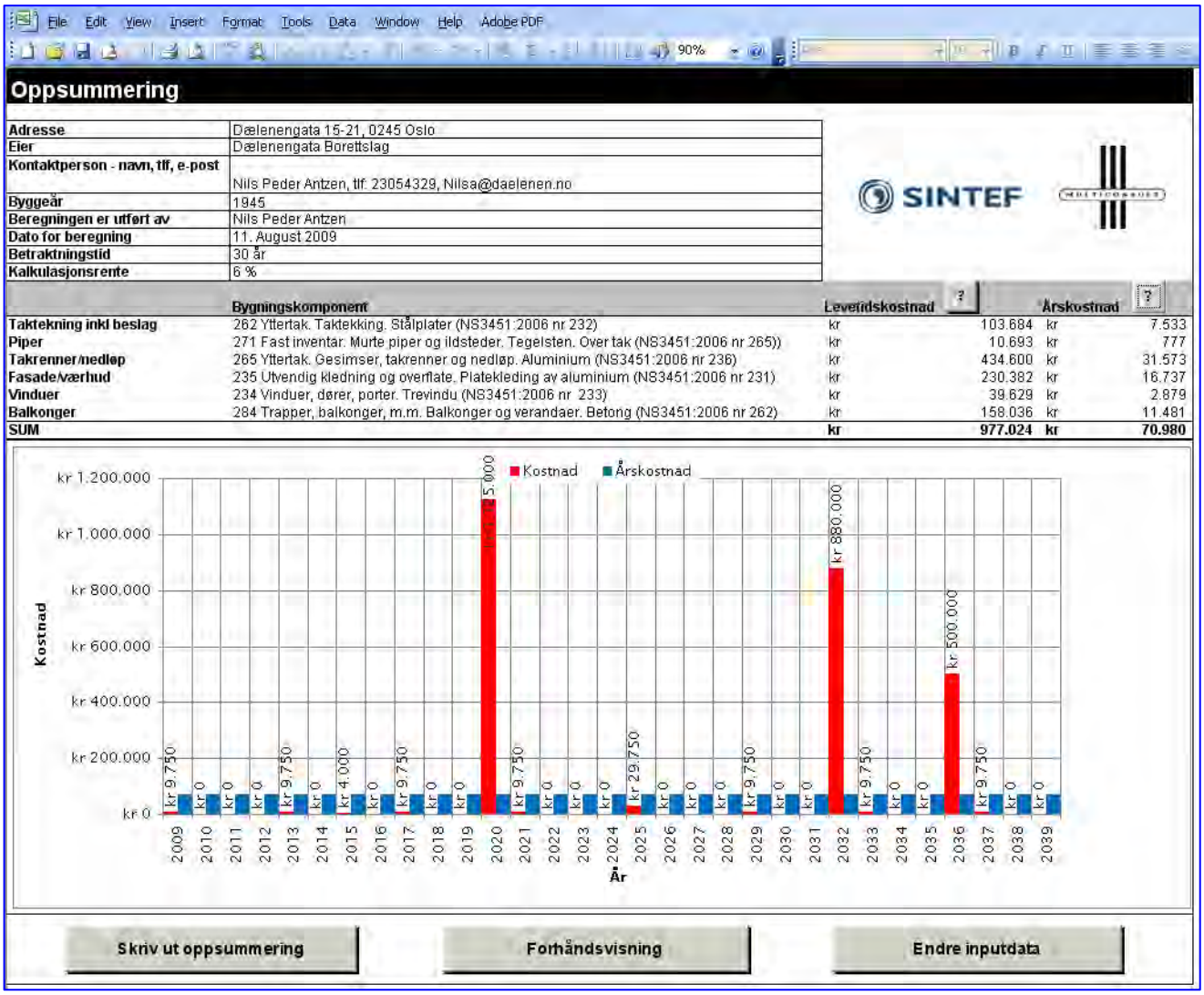
Skriv ut oppsummering | Forhåndsvisning | Endre inputdata

For better illustration: Screenshots from the Norwegian LCC calculator

Screenshot showing entry of information. Data entry is finalized when the button “Beregn kostnader” (English: “Calculate costs”) is pushed.



Overview including a graph showing the results of the calculations



”Behind” the user interface where values can be chosen and changes made exists a matrix containing all the basic data, descriptions, values, etch. This one is not shown to the user, but can be opened for qualified users so that they can add their own numbers based on their experience.

b) Austrian LCCA tool of e7 and M.O.O.CON

Consideration of Life Cycle Costs (LCC) during the planning phases of buildings is insufficient. The the focus of clients for whom a building is being built most often remains on the initial investment costs. On the other hand, available software tools are complex and the data needed to use them properly is vague during the early design phase – the phase where cost minimising can be most efficient. Thus, on the basis of various existing Life Cycle Cost tools, a method and tool has been developed so that detailed forecasts of expected Life Cycle Costs can be made during early planning phases.

Methodological Structure

In order to combine the advantage of the fast cost estimation of the top-down method with the advantage of the accuracy of the bottom-up method it was necessary to take on a new approach.
At the same time, the decision-making process in the planning phase was incorporated into the method with great detail. In general, decisions are made mainly at the strategic and system levels during the phase before the construction of a building [15.]

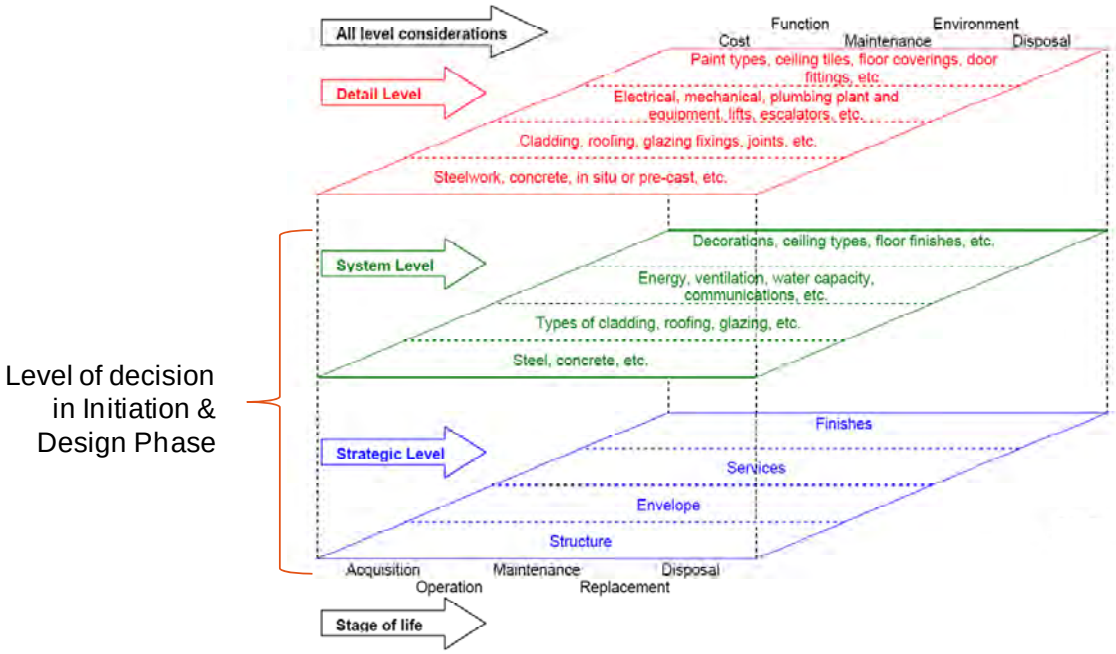


Figure 2: Levels in the decision-making process (Source: Life Cycle Costs in Construction [15])

The goal of the newly developed method was to model the building in such a way that LCC could already be calculated in the early planning phases. Even, at a point of time when no design for the

building is yet available. To this end both tools for generating the space allocation program and volume program for the building, as well as data for construction costs and operating costs are necessary on an aggregated level. This allows for entries to be made at the beginning of planning. In addition, an energy calculation tool should illustrate the interdependency between the building design, the facade, and the building equipment system. In this way, no additional calculation tool is needed. The method and the tools should be designed so that LCC analysis can be carried out well into the detailed design phase, i.e. when preparing detailed information for construction.

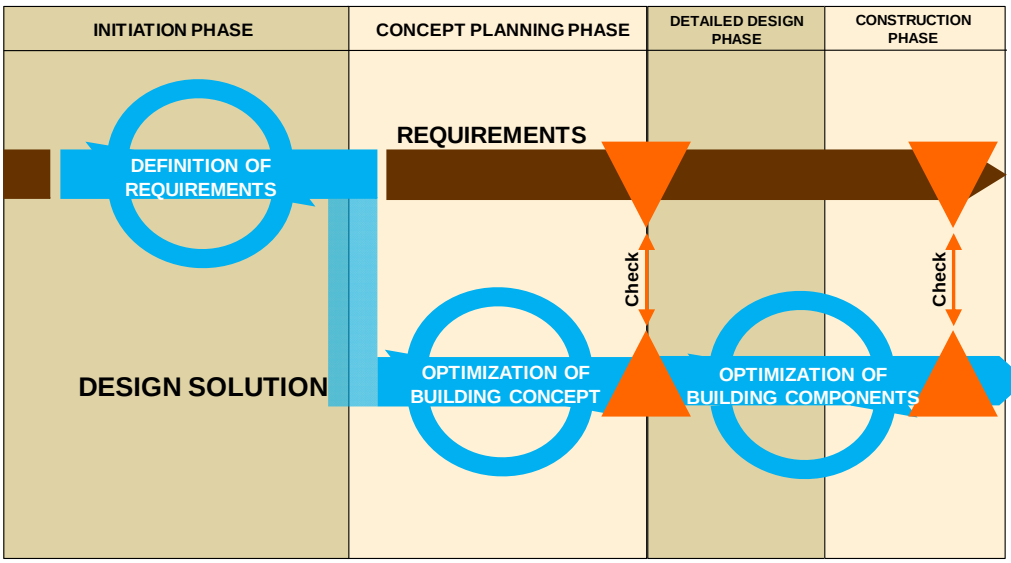


Figure 3: Areas of application of the LCC tool from initiation through to the detailed design phase (Source: original illustration)

Option 1: General building data via virtual building model

Avirtual building model was developed for the purpose of modelling the subject property. This virtual building model is based on the experience of the company M.O.O.CON acquired as part of their client consulting on office buildings. Based on the requirements of the client's brief, the virtual building model can calculate the approximate volume and surface area of the building at a time where no design drafts for the building have been put forward. Apart from the calculation of volume and surface area this tool can also optimize usable floor space. Optimising the use of floor space is a powerful lever for the reduction of construction and operating costs. Through the reduction of conditioned volume, energy costs can also be reduced.

In this process office spaces and other special areas in the building are combined in different design variations into floors and building cores and the gross floor space is calculated. Thus, it is possible to optimize the floor space even at this point of time, which in turn leads to lower follow-up costs (see figure below).

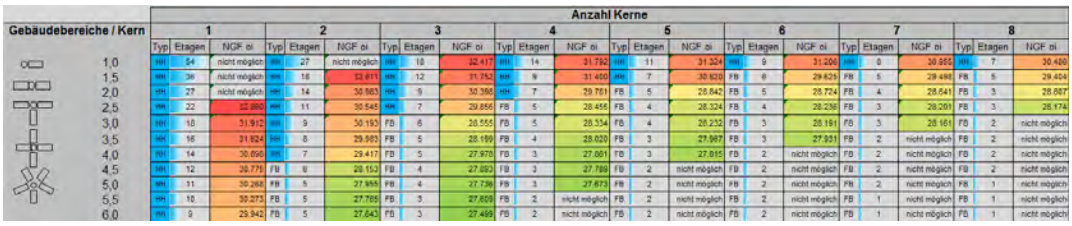


Figure 4: Output of floor space values per building sector and number of cores. (Source: M.O.O.CON)

Option 2: General building data by using architectural concept

With the introduction of an architectural concept, the data in the virtual building model is changed in accordance with the significant geometrical dimensions (essential building area data, facade, building orientation). Therefore the existing data can be optimally used with minimal additional effort related to data entry.

Relevant areas in office buildings in the decision making process

Concerning the building, the impact of the various usage areas on cost is investigated. Here the focus is to outline the effect of special areas on cost when compared with main usage “office” spaces. The primary utilization of an office building, as the names suggest, is for office and administrative use. The main usage areas are complimented by decentralized spaces such as staircases, elevators, restrooms, as well as centralized special usage areas such as conference rooms, the lobby, cafeteria(s), storage areas or carports. The essential system decisions are made based on the main usage which also generates the main source of costs. Consequently, the building elements for the main usage areas (“office” spaces) need to be provided at a different level of detail than for the special usage areas.

Based on cost analysis, buildings elements were defined at different levels of detail. Depending on the influence of the usage, aggregation of the building elements was carried out at a different level. For the main usage area, “office”, cost relevant issues are compiled at the level of elements (as defined by Austrian Standard ÖNÖRM B 1801-1[16]), for less cost relevant issues or building elements in less cost relevant usage areas at the level of cost ranges (as defined by ÖNORM B 1801-1).

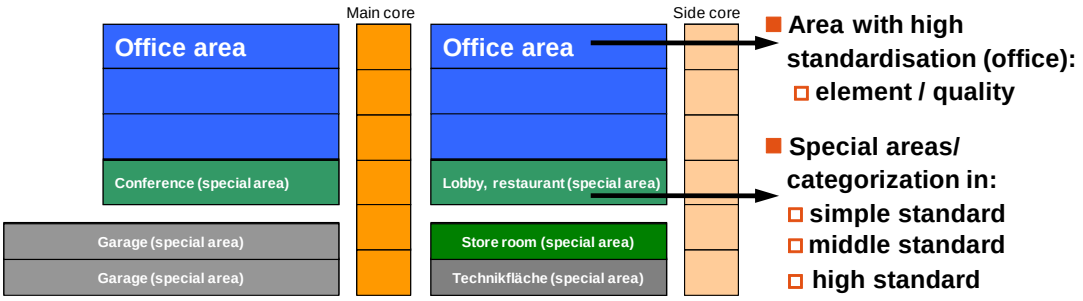


Figure 5: Structure of costs for the main usage “office” space and special usage space (Source: original illustration)

The building elements were consequently compiled from bottom-up aggregated items for the relevant cost drivers in the office areas (i.e. type of floor, type of heating system). For less relevant costs ranges and usages in special areas, they were bottom-up aggregated and tested against top-down benchmarks, as a certain imprecision can be tolerated. Thus the number of elements and consequently the amount of data entry is reduced significantly.

Calculation costs for defined building elements

Different sources were referred to for an estimate of the investment cost. These sources included the experiences of the large Austrian construction company *Allgemeine Baugesellschaft - A. Porr Aktiengesellschaft,* and the analysis of their AVA software as well as the experiences of the large Austrian building equipment supplier *Axima Gebäudetechnik GmbH* and the engineering office *Allplan GmbH.* For an assessment of the operating costs the database of *Axima Gebäudetechnik GmbH,* the largest building management company in Austria, was analysed. These figures were integrated into a database that was specially developed for this method.

In order to ascertain the total cost of the elements comprehensive building data is necessary. This can be gathered based on the virtual building model or the architectural concept. As with the aggregation of the building elements, it was also necessary to keep the amount of required data to a minimum for the calculation of comprehensive building data.

Calculation of Life Cycle Costs

Again the results of the analysis of the cost drivers were referred to and an attempt was made to incorporate only a few significant parameters from the plans. All other data should be calculated by algorithms based on these entries. The algorithms are derived from planning regulations for office buildings, fire safety regulations, work space regulations and years of experience of various projects of M.O.O.CON. The significant parameters for the efficient use of space such as width and structure of building could be easily entered and changed. The data entry is done through a space allocation and function program used by M.O.O.CON in the initiation phase. Common measurements of architectural plans provided at this time are used as a basis during the early planning phases.

Building elements could be defined and associated with investment and operating costs based on the structure of the usage area as well as significant system decisions, which contribute to the comfort of the interior (acoustics, visual comfort). For a usage area such as a cafeteria, this meant the definition of different building elements for different standards at a level of costs ranges (such as “high quality cafeteria”). For the office areas building elements for flooring, floor construction, office partitions, hallway dividing walls, noise insulation, etc. were defined. (e.g. office area, flooring, carpeting, high quality). For the building itself, building elements such as facade, HVAC and many more had to be

defined.
Based on the virtual building model of selected building elements and user specified comfort guidelines, it is now possible to calculate energy consumption based on the calculation for the energy certificate complemented by several significant factors such as: the influence of thermal mass, different usage areas, the taking into account of daylight, the actual energy consumption of different utilities like lighting, cooling, heating and ventilation.

Thanks to years of experience of the employees of *e7 Energie Markt Analyse GmbH* very realistic energy usage scenarios could be compiled. Through the programming of a software interface the entry of the virtual building model and of the building elements could be directly linked to the energy cost calculation, making any additional step unnecessary. The linking of the building elements to the use of energy calculation allows for an additional correlation between building design and heating and cooling load of the building's central equipment system. Heating and cooling loads are calculated through the entry of the buildings volume and facade design. These loads are indicators for the selection of the dimension of the building equipment systems for heating and cooling. An improved insulation of the facade contributes directly to lower investment and operating costs of the building equipment systems. The chosen method of calculating the energy costs also allows for the selection of alternative energy systems such as heat pumps, photo-voltaic and thermal solar systems.
Based on investment and operating costs provided on a per-element basis (originating from the building elements) as well as building specific calculated energy costs it is now possible to calculate LCC using the net present value method or the method of complete financial plans.
By changing significant parameters (inflation, construction cost index, energy cost index, depreciation period and financing options, etc.) their effect can be simulated. Sensitivity analysis can be done by changing the entered value for calculations. Cost parameter of the building can be varied in Excel allowing for a risk analysis of individual parameters to be carried out.

Realization of a LCC Software tool

The different elements are connected to form a complete, functioning tool in the form of software that was developed by Alpha Carinae KEG in Austria. An array of factors influences the relationships and recognizes the impact of hi-tech, large, complex system components on one another. These interdependencies were derived on the basis of expert interviews with those providing the data. The software user interface incorporates the use of several Excel tools and a costs database.

Figure 6: User interface of the LCC tool (Source: original illustration)

The set-up and follow-up costs of the aggregated building elements are deposited in a database that can be used and maintained independently from the LCC software.

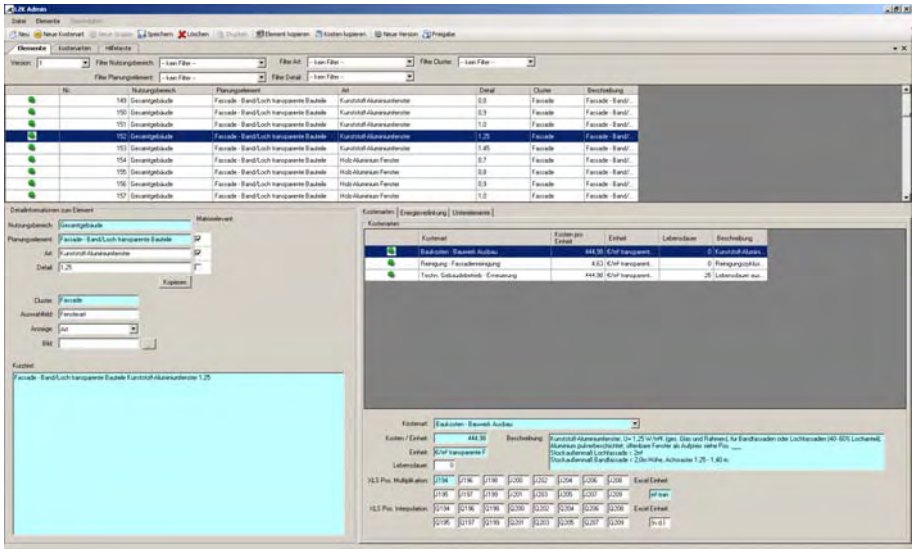


Figure 7: User interface of the costs database (Source: original illustration)

The software provides results with different degrees of aggregation so that, depending on the required aspect of optimization, all of the data is available for viewing in various well-sorted overviews and illustrated with graphics.

Significant expenditures are:

- Construction costs (total/ by cost areas/ by building elements)
- Operational costs (total/ by type of costs/ by building elements and cost catagories)
- Gross floor area (total/ by utilization areas/ by space)
- Energy consumption (total/ by causer (cooling, heating, lighting, work equipment, other)
- A graph of LCC

It is possible to compare different variants with each other; specific values of other projects can be taken up for comparison as well.

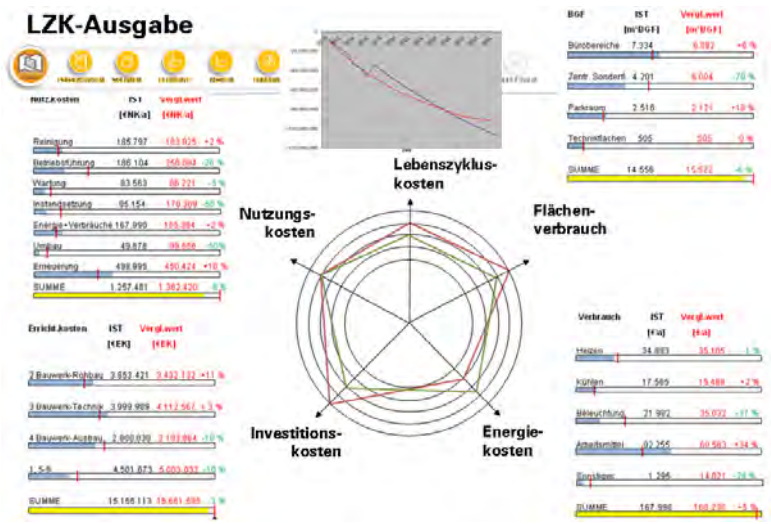


Figure 8: Aggregated output of the LCC Tool (Source: original illustration)

Results

In the final test phases investment cost and operating cost data, derived from completed and operating buildings, were compared with corresponding results generated by the tool. Through this data it was possible to test the programmed algorithms and the cost estimates and make any necessary change.

After the testing phase was complete, it was possible to confirm, that the chosen approach lead to extremely short data entry times. At the same time the cost reliability achievable in this early planning phase remained within the margins of +/- 10 to +/- 20% for all simulated projects.

Thus, it could be shown that with sufficient knowledge of significant cost drivers the simulation effort can be minimised without compromising on data reliability.

Future Prospects

After first applications of the method where results with high cost reliability for existing buildings were achieved, it is now implemented for the planning of new office buildings.

Nevertheless, there are also other possible areas of application where the developed LCC method could be implemented: renovation of office buildings, other categories of buildings such as schools, nursing homes, or residential buildings. In addition, other indicators will be incorporated into the tool: the rating of ecological materials, comfort, etc. The method and the software will be gradually expanded over the next years, so that a complete sustainability assessment will be possible in the early

planning phases with minimal effort.

VI. Appendix B

Acknowledgement

We would like to thank the European Commission (the executive agency for competitiveness and innovations – eaci), RICS (The Royal Institution of Chartered Surveyors), gif (Gesellschaft für Immobilienwirtschaftliche Forschung e.V.), Federal Ministry of Agriculture, Forestry, Environment and Water Management of the Republic of Austria (BMLFUW) as well as the Federal Ministry of Economy, Family and Youth of the Republic of Austria (BMWA), for sponsorship and funding the and the IMMOVALUE-project in general.

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