D4.1_Guidelines for economic life cycle assessment of refurbishments, with special focus on step by step solutions

INTELLIGENT ENERGY – EUROPE II

Energy efficiency and renewable energy in buildings

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EuroPHit

[Improving the energy performance of step-by-step refurbishment and integration of renewable energies]

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Introduction

Buildings are constructed to provide shelter and comfort for people. A significant amount of capital is invested into improving living and working conditions and making them more pleasant. Higher sale prices and rents are paid for additional amenities. Investment in these amenities do not pay back directly to the investors – either they spend more money on these for themselves, or they will offer their property on the market and of achieving a higher price for improved quality measures. Usually, this is a risky investment with a good chance of a better return. Other added value can be the feeling of goodwill gained from investing in a better world; visible signs of this have a market value because a significant number of people appreciate it and are willing to pay a premium for this. A highly energy efficient construction increases the building's value. In addition, energy efficiency is one of the few measures which also result in direct returns – saved energy costs.

The economic assessment of buildings has to be based on life cycle costs. From the beginning this was the concept of the Passive House, and the concept of cost optimality ("cost optimal level") based on life cycle costs has become a major issue in the Energy Performance of Buildings Directive (EPBD) of the European Union.

There are several methodological frameworks that fit more or less in this scheme: not all methods though fulfil the requirement of reflecting the whole economic picture. Furthermore, boundary conditions are as important as the method. Inadequate methods, different assumptions or boundary conditions are the most important cause of extremely different results of empirical studies. The main sources of major distortions are assignment of costs that are not related to energy efficiency, underestimation of life expectancy, failure to consider residual values at the end of the calculation period, unrealistic assumptions on energy price increases, unreliable design and quality of measures, inadequate expectations on return and related discount rates, and lock-in effects. The net effect of these influences is usually that calculated economic results of investments in energy efficiency and renewables look worse than they are in reality after a proper evaluation. This has turned out to be a strong barrier for the implementation of energy efficiency, and thus proves the need of a thorough knowledge of proper economical assessment.

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1 Economic assessment of investments in energy efficiency

Economic criteria are used for deciding energy efficiency measures. These are derived from methods, boundary conditions and target values. Assessment always takes place based on alternatives.

Unlike investments in manufacturing plants in which the alternative is to invest in something else which has a possibly higher return on investment, the comparison standard for energy efficiency measures is fixed: the otherwise unavoidable costs of energy supply. Investments in energy efficiency must therefore be assessed In comparison with the energy costs that would result otherwise. An efficiency measure is profitable if the desired energy service provided through this is not more expensive than the alternative energy purchase. For this comparison, each measure can only be considered over its life cycle. In the economic and political debate, however, this is often neglected which can lead to serious distortions in the assessment.

In the following section, we will only deal with the economic assessment of the profitability of investments in energy efficiency. Benefits which cannot be clearly monetised, such as increased comfort, structural quality, reliable supply etc. will not be included. External costs such as the cost of climate change are significant in so far as their internalisation is possible but the amount is uncertain.

There are different methodological approaches for the assessment, but boundary conditions play a major role even with the same method. These are never known in full, and are often far in the future. The exact calculation process may not therefore obscure the fact that a profitability calculation can never provide exact figures for future costs and future benefits of investments

On the other hand, the inadequate methods and boundary conditions frequently used in practice lead to substantial distortions in the calculation of the results and therefore different economic results and decisions.

Investment theory differentiates between static and dynamic methods.

1.1 Payback period

The payback period is a comparison criterion that is still frequently used today. It describes the time duration within which the investment will pay off. It is usually calculated statically, but in principle can also be calculated dynamically.

However, in both cases

- it does not take into account the lifetime of the investment
- it does not provide any conclusions about the amount of the profit up to the end of the amortisation period
- in principle, any profits occurring after this are not taken into account at all
- if the lifetime is shorter than the payback period, this will result in a loss which is neither quantified nor evaluated

The payback method is therefore ***unsuitable*** for comparing investment alternatives, particularly if long-term investments are included in the comparison.

In the assessment, those investments are preferable in practice which cost less and also do not bring much profit, but are quickly paid back. This short-term perception is not inherent in economics, as is often claimed; it only arises if the calculation is incorrect, e.g. when the payback time method is used. For a correct accounting and assessment, costs and revenues over the life cycle have to be regarded.

1.2 Life cycle cost (LCC) based on dynamic methods

When investing in buildings, the whole life cycle and the interest (cost of capital) should be taken into account. This approach is implemented in dynamic methods based on present values.

1.2.1 Net present value method (NPV)

Dynamic methods take into account the payments due at different times, in that they discount or supplement these to a joint time point using a compound computation of interest calculation. An investment C and the later repayment of C plus interest, discounted to the time of investment, balance out. Not only the nominal amount but also the time point of a cash flow therefore has a significant influence on the result.

Discounting has the effect that all cash flows of all payment dates can be made comparable in monetary terms. When a revenue/costs of A which will arise in the future in m years, then the present (or cash) value C is the amount which would have to be invested today at an interest rate p in order to make the amount A available in m years.

Due to the interest, this account will increase by a factor of (1+p) each year. After m years, the account will have grown to $A = C * (1+p)^m$. The amount C to be invested is therefore

$\mathbf{C = A * (1+p)^{-m}}$ with the discount factor $\mathbf{(1+p)^{-m}}$; p = interest (discount) rate

Since the present values refer to the same point in time, all receipts and expenditures become comparable, but the result depends on the discount rate. High expected rates of return depreciate later revenues, thus the upfront investments. Therefore, the choice of an adequate interest rate is important.

The net present value (NPV) is the sum of all present values: costs (or payments, e.g. the investment) are negative, and revenues are positive. The NPV is the total gain of the investment when all lifetime costs and revenues are included. Therefore, a non-negative NPV means that the investment is profitable. As long as capital (including loans) is available, it is financially profitable to make any investment down to an NPV of 0. If the net present value is 0, then there is no profit or loss, or the rate of return is exactly the same as the discount rate. Conversely, we can also determine the return on an investment by setting the net present value as 0. The respectively calculated interest rate is called the internal rate of return.

The net present value relates everything to a single point in time – this approach is particularly suitable if the specific benefit of an investment is to be assessed. The investment at the starting time is included with its nominal value. This puts the investment in relation to the total costs and gains. If the calculation period is shorter than the life cycle, then a **residual value** must be taken into account at the end of this period (see below).

$$K_0 = \sum_{t=1}^{n} a * (1 + p)^{-t} = a * B(p,n)$$

(a = amount of the constant annual payments)

Often the cash flows recur annually, e.g. constant (instalments of a loan, or regular annuity payments from an initial financial investment) or associated with a price increase (e.g. regular costs for maintenance or energy). In this case it is easy to calculate the net present value.

In the case of constant annual payments a, the present value is the same as the total of the discount factors, multiplied by the amount of the annual payment:

with the **Cash value factor** for constant periodic payments

$$B(p,n) = \frac{1-(1+p)^{-n}}{p} \quad \text{(for } p>0; \; n \text{ for } p=0) \quad \text{[years]}$$

p = discount rate

n = calculation period

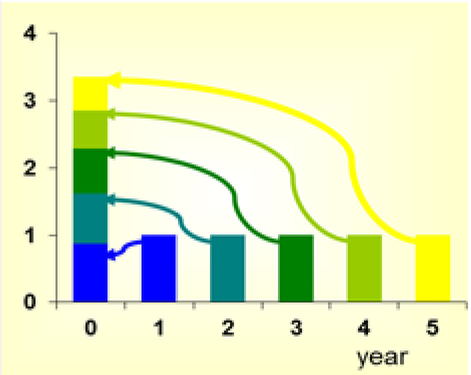

Figure 1: Present value of periodic payments

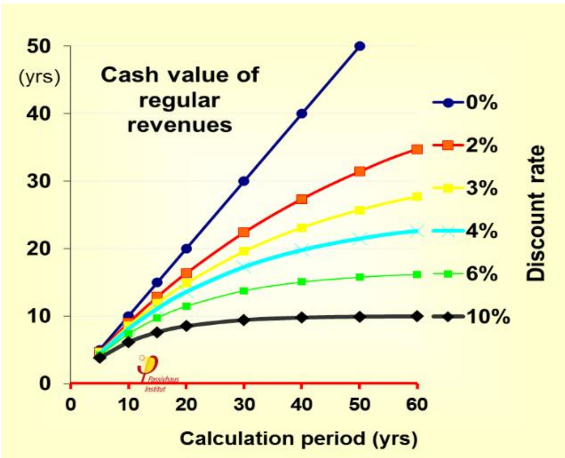

Figure 2: Cash value (or present value) of periodic revenues r (in the figure: scaled to a revenue of r=1 every year). The cash value depends on the number of periods and the discount rate. High discount rates depreciate the value of the revenues and thus of the market capitalization

Typical values for the construction branch are B = 20 - 40 years, with a rising tendency due to declining interest rates.

In the case of a price increase s, the present value is calculated with the same formula, inserting an adjusted interest rate (p-s)/(1+s) in the place of the discount rate p.

The net present value K_0 is the sum of all present values. All revenues and expenditures are discounted and added together, with revenues being positive and expenditures being negative. For investment in efficiency of buildings, the net present value is

$$\textbf{Net present value } K_0 = -\sum_{\text{building components } k} I_k * (1 - r(p,n,N_k)) + \sum_{t=1}^{n} e(t) * (1+p)^{-t}$$

with: n = calculation period ; I_k = **additional investment** for building component k

N_k = life cycle ; $r(p,n,N_k)$ = residual value factor of building component k

$e(t)$ = gains (saved costs) in year t

Only the extra costs for energy efficiency should be used for the assessment of the investment. The residual value of the investment is taken into account with the residual value factor at the end of the calculation period if this is shorter than the life time of the building component.

The outcome K_0 is the profit calculated as the present value. An investment or mea-sure is profitable if the net present value of all cash flows attributable to it is non-negative.

Criterion for profitability: Net present value $K_0 \geq 0$

For commercial activities, the aim is to maximise the profit K_0.

Maximise net present value K_0

Due to the variance of parameters and limited predictive accuracy, there is not a precisely definable optimum, but an optimal range of economically equivalent results (net present values). The decision should be made within this range according to non-monetary goals, particularly also for precautionary purposes based on the principle of risk minimisation under different developmental assumptions, sustainability and keeping options open in relation to alternative courses of action for the future.

Within the range of optimal measures

- Taking into account of non-monetary parameters
- Risk minimisation and sustainability: maintaining the scope for future action (precautionary principle)

1.2.2 Annuity Method

It is often practical to consider annual costs instead of the total costs. With the annuity method the investment, or the present value K_0 is spread over equal annual instalments K_a during the calculation period, including the interest.

The present value of the annual payments results in

$$K_0 = K_a * B(p,n)$$

Annuity factor for constant annual payments

$$a(p,n) = 1 / B(p,n) = \frac{p}{1-(1+p)^{-n}} \quad \text{(for } p>0; \ 1/n \text{ for } p=0)$$

p = discount rate
n = calculation or depreciation period

Annuity factor for constant annual payments

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p = discount rate
n = calculation or depreciation period

or conversely, the annual costs are calculated from the net present value with the

$$K_a = K_0 / B(p,n) = K_0 * a(p,n)$$

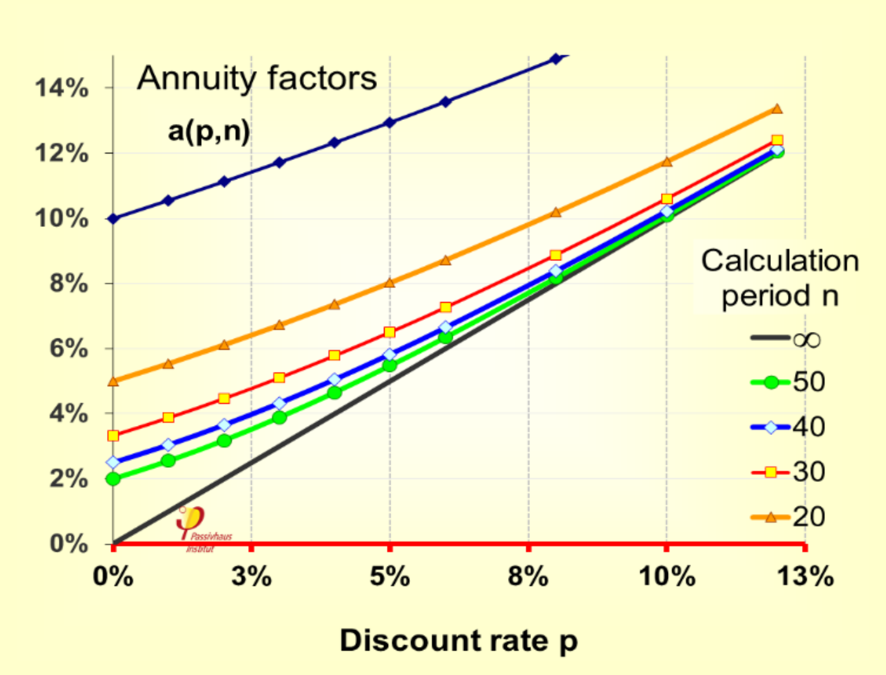

Figure 3: Annuity factors (annual debt service) as a function of the interest rate and depreciation period

In the annuity method, the investment **I** is included with its **annual capital costs**:

$$K_{a,I} = I * a(p,N), \quad N = \text{lifetime}$$

This is the (annual straight-line) economic depreciation of the investment. One can illustrate this as the debt service for a loan (with constant annual instalments) which has been taken out for the investment, or as "lost annual revenues" which could have been gained alternatively from the invested amount. The shorter the depreciation period (assessed useful life) and the higher the interest rate is, the higher the annual capital costs will be. With the annuity method, the current revenues and expenditures e_1, e_2 .. e_n in the years from 1 to n appear as mean values. Mean payments are accordingly calculated by discounting the annual payments from the starting date (i.e. the present value of these annual payments) and then spreading them evenly over the calculation period (i.e. annuities).

The annuity method is equivalent to the NPV method, and has the advantage that annual costs are more intuitive than a cash value. In more complex situations, however, it can become more difficult to regard the full picture.

1.2.3 Internal rate of return

The required rate of return is the interest rate at which the net present value would be 0. If the required rate of return is at least as high as the discount rate, then the investment will be profitable, and if the required rate of return is lower, then it will be unprofitable. In principle however, a discount rate does not have to be specified. The required rate of return is an interesting measure if one wishes to compare completely different types of investments with each another. But caution is advised: the required rate of return method has not the same universality because it cannot be applied to each series of annual cash flows. Its field of application is limited to investments which will subsequently yield profits.

1.2.4 Complementary instruments

While our main focus here is on the investment’s object, investors may have a different point of view (equity perspective). Instruments like the Discounted Cash Flow (DCF) or the Visualisation of Financial Implications (VoFI's) methods are used to optimise financing, taxation, or liquidity aspects. These methods are based on the same principles.

2 Boundary conditions, parameters, distortions

The above-mentioned dynamic methods lead to the same economic result as long as the boundary conditions and perspectives are the same, but they are very sensitive to the assumptions for the boundary conditions. Special attention has to be paid to all estimates of future data; in uncertain cases, sensitivity analyses shed light on the possible range of results. Otherwise, the economic assessment may be severely distorted. In particular, it is necessary to look at:

- Proper attribution of investment costs: only (additional) investments that serve energy efficiency may be taken into account in the economic analysis.
- Life cycle of the measures
- Residual values must be taken into account at the end of the calculation period
- Discount (interest) rates:.
- Maintenance costs
- Taxes and subsidies/ incentives
- Future energy prices and price increases: assumptions about a constant rate of growth may lead to unrealistically high energy prices
- Does the measure fit within the normal renewal cycle, when minimal capital costs are achieved? Otherwise, a residual depreciation of the existing component has to be added.
- Efficiency levels of existing components: existing medium quality measures reduce the potential for further energy savings and thus the revenue of any additional energy efficiency investment.

Note that historic or actual data cannot simply be extrapolated into the future. Predictable changes have to be taken into account. Thus exponential growth is typical for development phases; long-term growth is more linear, or saturation may even be reached. Interest rates, inflation and energy prices are often subject to large fluctuations which can nevertheless be averaged out again. in case of uncertainty, decisions should be made in such a way that control is still maintained over any worst case scenario. However, there are also systematic reasons why this extrapolation of the present delivers a false picture, for instance in the case of innovation: prices for innovative developments and building components may fall due to the learning effects and economies of scale when they become established.. Looking into the rear mirror is not the way to predict the future. Last but not least, we cannot change the past, but we can shape the future.

2.1 Return and risk: Discount rate

The discount rate corresponds with the interest rate which is to be paid for a mortgage loan, or the rate of return for an alternative investment which is comparable in terms of the risk and amount invested. One of the most prominent distortions results from the frequent expectation of high returns. The expected rates of return are the discount rates in the dynamic economic assessment. We have seen that the present value of future payments decreases with high interest rates and thus the value of the investment is impaired. But high interest rates are coupled with high risks. On the capital market, it is not possible to earn high interests with risk-free investments.

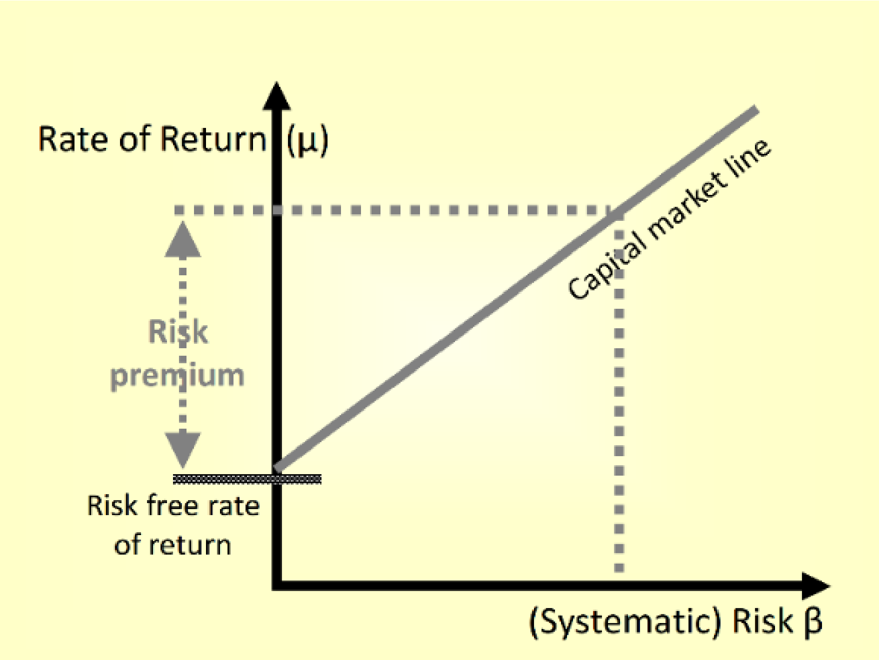

Figure 4: Risk and return. Risk premium on the capital market is the additional expected rate of return attributed to the risk.

However, energy saving investments are risk-free or even risk reducing - as long as the building they belong to is not in question [Ebel 2013]. Which buildings should be kept in the stock and upgraded is a decision concerning the real estate portfolio management. However, once the decision to proceed with the retrofit has been made, it is always advantageous to include the energy efficiency investment, reducing the risk of higher energy prices that might affect the market. Since risky investments with the chance of higher ROI's are not comparable with energy efficiency investments, they are not eligible as alternative assets for measuring economic success. For low risk investments, however, a "risk premium" cannot be expected.

2.1.1 Real interest rates and prices

Interest is the cost of capital. As in the case of products, real prices are decisive for comparison. Real prices and interest rates are corrected for inflation, which is subject to uncertain and short-term factors. The real interest rate p_{real} is the interest which would lead to the same economic result (present value or net present value).

Although the real interest rate also fluctuates, it has a clear downwards trend over long periods of time. Oversupply of capital decreases its price, and currently hardly anyone assumes that this will exceed 2.0 % p.a. again in the longer term. It is essential to recognise that this is a very important determining factor for economic assessment. High interest rates "devalue" future returns through discounting; the higher the interest is, the stronger this effect.

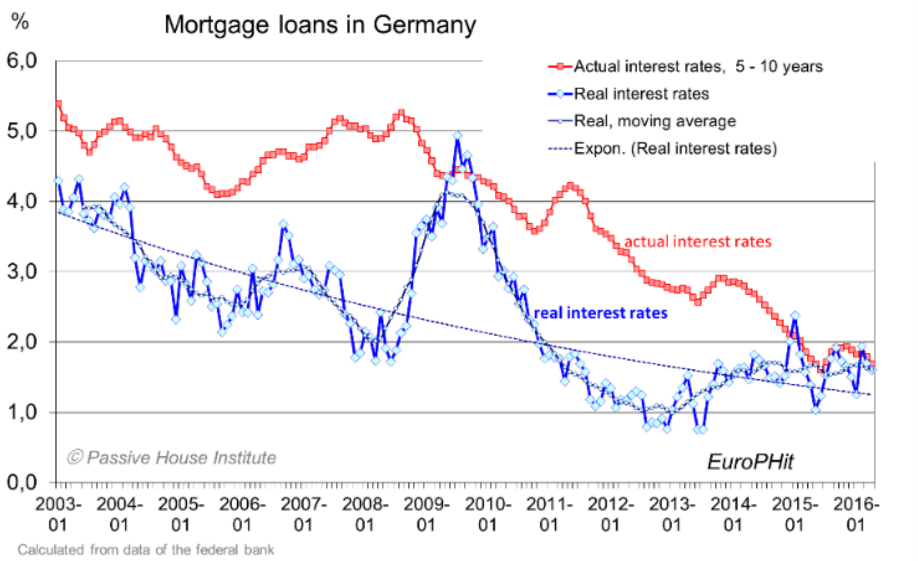

Figure 5: Actual and real interest rates for mortgages in Germany. Data from [Bundesbank 2016]

2.2 Life-cycle and calculation period

If the benefit of an investment is to be assessed, it is easiest to choose the same calculation period as the lifetime. This ensures that all costs incurred during the lifecycle are taken into account. Some reference points for the useful life are provided by national institutions, in the European Standard [EN 15459] which is also referred to in the European Buildings Directive or the Delegated Act [Del Act 2012] or by associations of architects and engineers. 50 years can be assumed for components of the opaque building envelope, with 30 to 40 years for windows, 25 to 30 years for ventilation systems and 20 to 25 for heating systems.

It is evident that the assessed service life greatly influences the result. In practice, the usage periods in calculations are often too short and the value of the investment is therefore greatly underestimated. A "golden end" after a short depreciation period (in which the measure already yields a profit) may appear attractive, but leaving this period out of the calculation does not allow for a valid assessment and will ultimately harm the investor.

2.3 Residual values and attributable capital costs

If the lifetime and the calculation period do not correspond, then a **residual value** must be taken into account as a revenue at the end of the calculation period, or a **replacement investment** occurs as an expenditure at the end of the life.

Residual values are often forgotten and in practice lead to significant overestimation of capital costs, and corresponding distortions in the economic result.

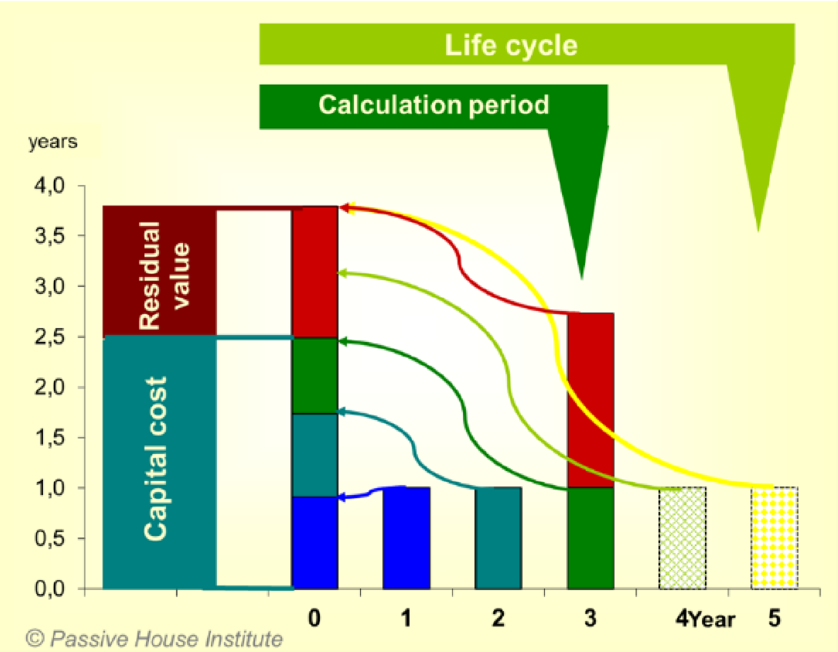

Figure 6: Investment, residual value and economic depreciation

The residual value is calculated as the total of the discounted annuities after the calculation period.

Residual value

$$R = I * r(p,n,N) = I * \sum_{t=n+1}^{N} a(p,N) * (1 + p)^{-t} = I * (1 - a(p,N) * B(p,n))$$

p = discount rate, n = calculation period; I / N = amount / lifetime of the investment

The capital costs of an investment during a calculation period n, are the investment costs reduced I by the residual value, or equivalently, the economic depreciation over the calculation period:

$$I - R = I * (1 - r(p,n,N)) = I * a(p,N)*B(p$$

p = discount rate, n = calculation period, N = lifetime of the investment

The same formula applies in the opposite case if a replacement becomes necessary during the calculation period.

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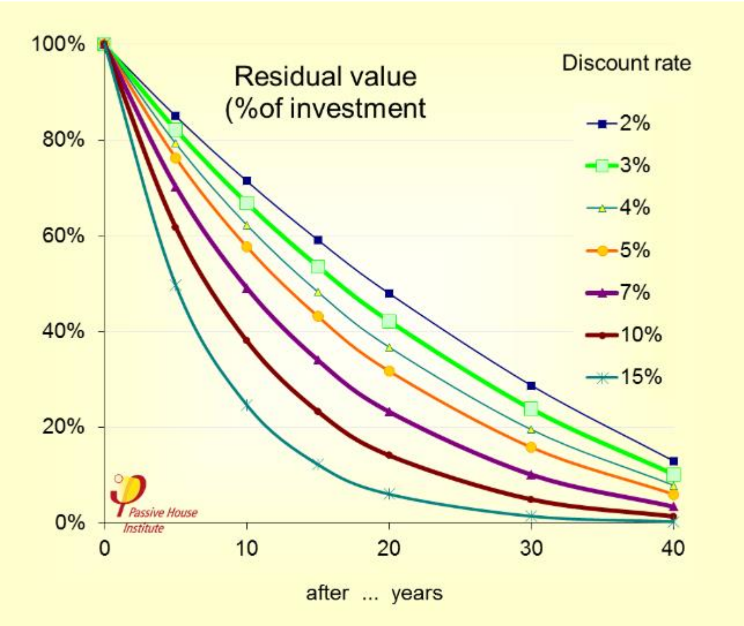

Figure 7: Residual values of an investment with a lifetime of 50 years, remaining after a calculation period of years. The residual value depends on the discount rate

2.4 Coupling principle and extra investment

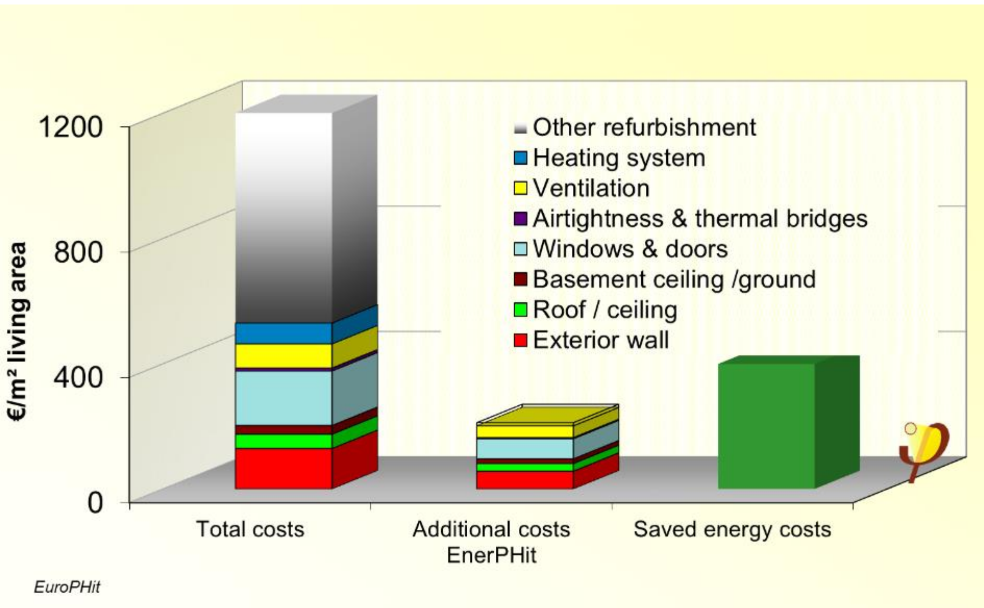

Figure 8: Total investment, with costs attributable to energy efficiency (extra costs) and saved energy costs for a non-renovated multi-storey building built in the 1950 and 1960s. Since the save energy costs are higher, the investment is profitable.

As a rule, making investments only for the sake of energy efficiency is not recommended. We do not construct buildings in order to save energy, and refurbishment is also carried out for completely different reasons and follows different patterns. It makes sense to follow the normal pace of renewal. If a major part of the investment has to be invested in framework of the cycle of renewal anyway, without resulting in energy savings, then it cannot be expected that the investment as a whole will pay off through the energy savings alone. For economic assessment, we will assume that – in ordinary cases – the cycles of renewal are not changed and only the extra investment necessary for efficiency is added.

2.5 Costs of the wrong time point

Recognition of the extra costs incurred in comparison to normal refurbishment only applies if the measure takes place when it is due or is required by the building owner and therefore will carried out in any case. In contrast, if a retrofit is brought forward in time then it will obviously become more expensive because in addition to the extra investment, it will also be necessary to raise the amount required for the “anyhow” measures. Bringing forward by k years equates to economic depreciation over k years

$I_O * a(p,N)*B(p,k) = I_O * (1 - r(p,k,N))$,

which must be added to the extra (energy efficiency) investments **I**. Based on the example of a building component (window), the figure shows that bringing forward the installation will have serious effects on the capital costs and therefore can lead to a completely different assessment. The attributable costs related to the “anyhow”-measures can dominate the energy efficiency investment.

In practice, refurbishment outside of the cycle of renewal is perhaps much less relevant than it would seem in the political debate; this question does not even arise for investors as hardly anyone wants to invest money again without any reason after a retrofit has just been carried out. However, this does not justify improper allocation of costs, distorting the economic assessment.

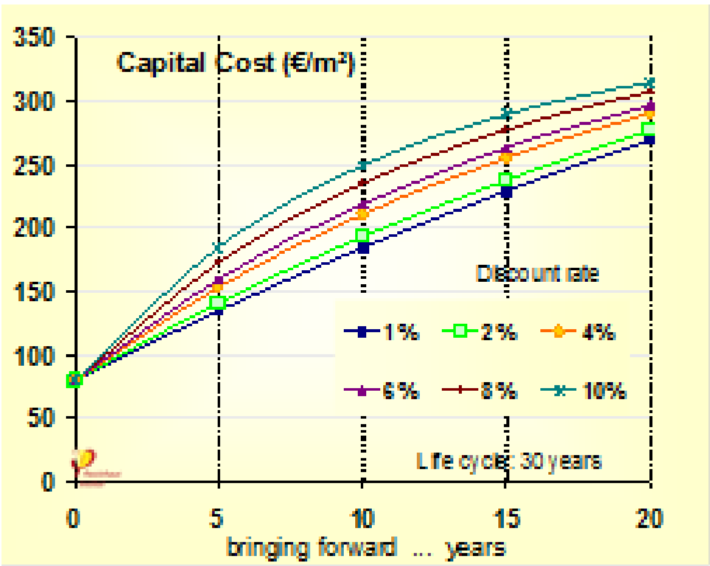

Figure 9: Attributable capital costs for a Passive House window, brought forward … years. The extra cost of energy efficiency is dominated by the costs of bringing forward.

In practice, refurbishment outside of the cycle of renewal is perhaps much less relevant than it would seem in the political debate; this question does not even arise for investors as hardly anyone wants to invest money again without any reason after a retrofit has just been carried out. However, this does not justify improper allocation of costs, distorting the economic assessment.

2.6 Operating costs and revenues

The operating costs include costs for energy as well as other costs such as those for servicing and maintenance. In principle, these costs should be treated in the same methodical way. Energy efficiency and passive systems are characterised by particularly low maintenance, while servicing and repairs are more likely for active systems. We will assume that the differences are not significant and need not be considered (ceteris paribus).

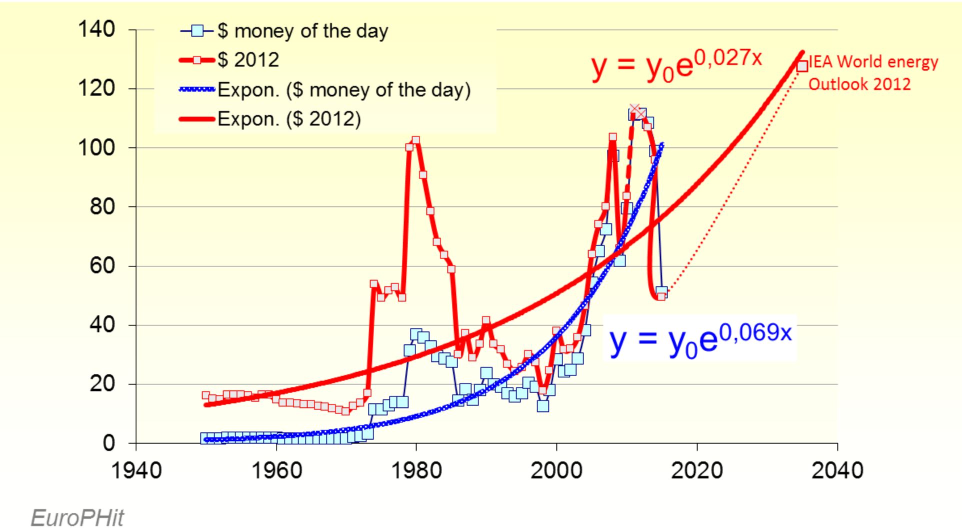

Figure 10: Oil prices and price scenario of the IEA, 2012/2015.

Although the price of oil has increased by under 3 % per year on average in real terms since the 1950s, past trends cannot be extrapolated.

Future **energy costs** are regarded as particularly uncertain; these are also subject to great fluctuations. Since saved energy costs are the revenues of energy efficiency investments the future energy price is an important parameter for the economic assessment. Permanently low energy prices can no longer be expected; similarly, it makes just as little sense to assume high rate exponential growth with over a longer period of time, which would lead to incredibly high energy costs and the resultant distortions of the economic assessment. Although the price of oil has increased by under 3 % per year on average in real terms since the 1950s, past trends cannot be extrapolated.

Instead of price increase rates over a long period of time, it makes more sense to apply a *substantiated future energy price* here [Feist 2013]. This is orientated on the real costs of future energy sources, especially renewables. On the other hand, there is a considerable risk in potential energy price increases and fluctuations.

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2.7 Influence of the existing situation on the economic result

The poorer the existing energy standard is, the more energy can be saved and the more economically advantageous the result will be. A building component of an average quality, even if optimised, can no longer generate such a high profit on account of the saved energy costs – and possibly none at all. The improved quality of the initial situation proves to be a hindrance for achieving a sustainable level – it causes a “lock-in” effect.

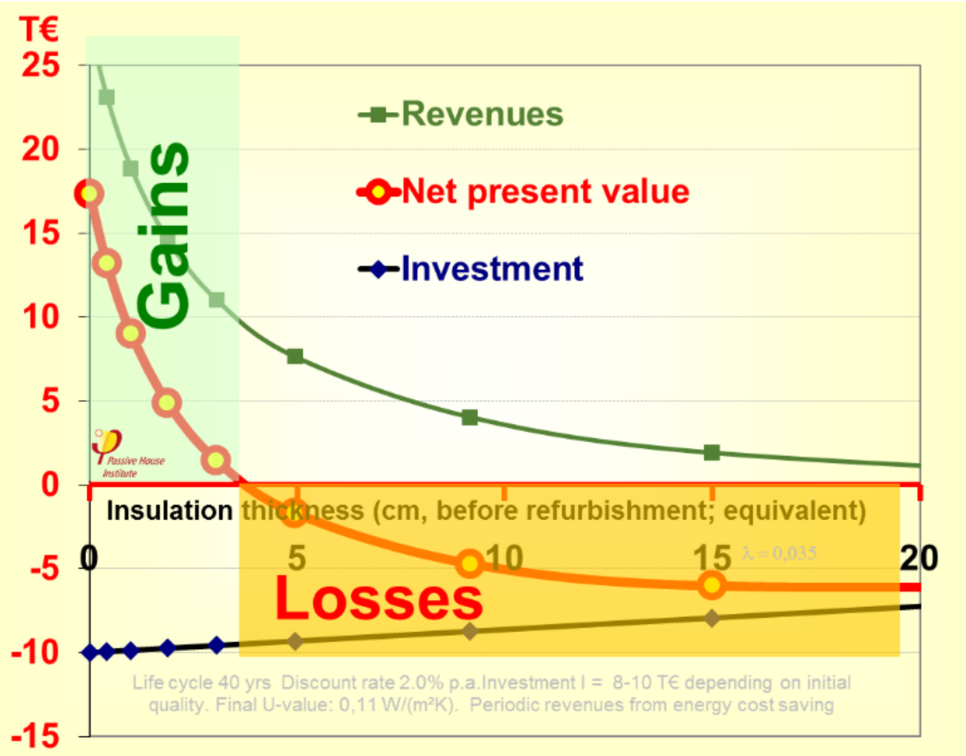

Figure 11: Net present value dependent on energy efficiency standard before retrofit (here: wall insulation thickness equivalent).

The figure 11 shows that medium quality reduces the revenues of the investment and turns possible profits (left side) into losses (negative, NPV, right side) thus creating a barrier to future energy efficiency investments. As a result, further quality improvements don't pay and become improbable, thus impeding future sustainable developments. Therefore: "when you do it, do it right".

3 Cost optimality

3.1 Passive House and EnerPHit

The European EPBD aims for the implementation of "nearly zero energy buildings". Minimum requirements defined by the member states must meet the "cost-optimal level". Economy is assessed solely on the basis of life cycle costs. The "cost optimal level" should move in the direction of higher efficiency after the effects of learning and scale; member states are expected to support this development. It has been shown that Passive House components allow the achievement of cost-optimal levels with the PH low energy demand, allowing a significant share of renewable energy produced nearby (see the IEE project "Passive House Regions" [PassREg].)

Passive House components for renovation projects are economically optimal when correctly evaluated on the basis of life cycle costs. The "EnerPHit" label was established for such renovations. Depending mainly on the building conditions before refurbishment, high economic gain may lead to an extremely good rate of return with a low risk investment. It has been shown in actual cases that this strategy works and a high level of performance is achieved, documented through measurements.

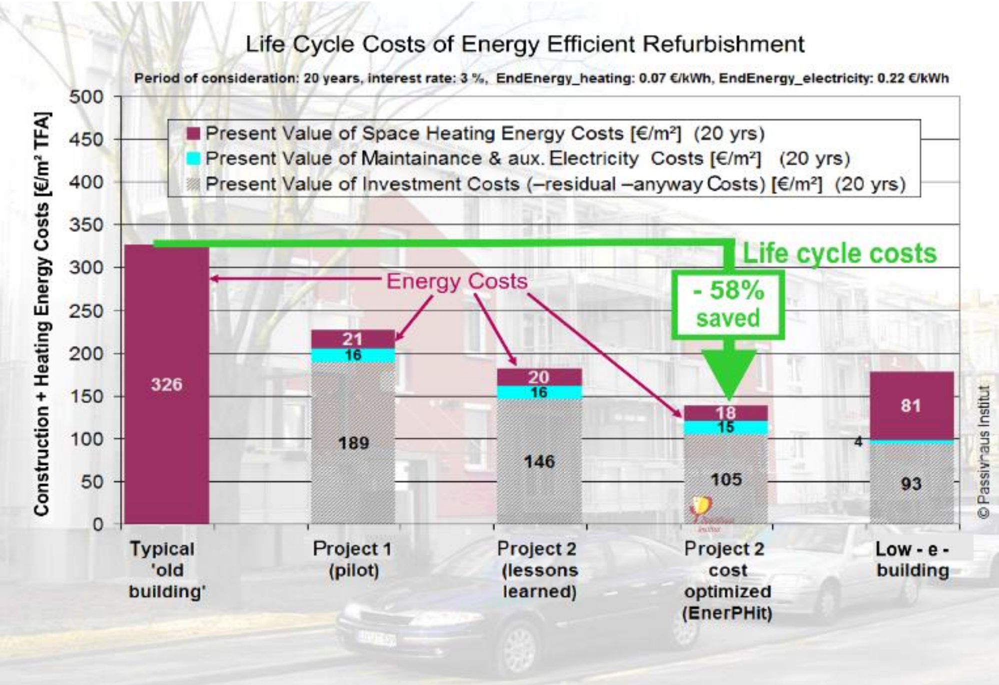

Figure 12: Comparison of life cycle costs of renovation: an actual case. The built EnerPHit variant [IEA 37] was cost optimal.. Shown costs = total energy-relevant costs over 20 years

The economic optimum is characterised by the maximum profit or net present value (capitalised net gains with deduction of the attributable investment). If the benefit – in this case the energy services – are clearly defined, then the economic optimum describes the combination of measures which provide the energy - services with minimum overall expenditure compared with other alternatives. The total costs over the life cycle constitute the economic effort; in the process. One can limit the assessment to the additional investment and the resultant net returns (essentially the costs of saved energy).

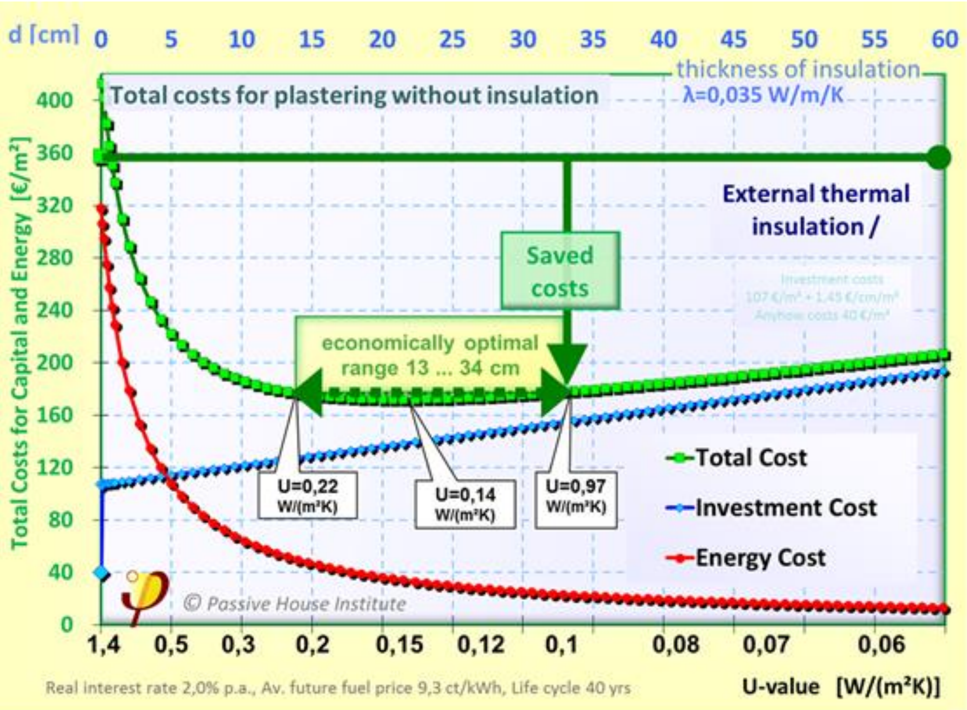

Figure 13: Life cycle costs for external insulation with mineral wool (refurbishment) depending on insulation thickness.

As shown in Figure 17 the cost optimal range is within the range of the EnerPHit Standard. Far left and green line at the top: costs without insulation, for new plaster without any energy saved. The difference to the green curve for total costs is the cost savings over the lifetime. The measure is profitable in the range where the curve for the total cost remains below the total costs without insulation. In the optimal range, about half of the total costs are saved in the case of additional investment costs between 90 and 120 €/m².

The optimal solution depends mainly on the energy prices and the additional costs for further energy efficiency steps (additional insulation thickness), but does not depend on the fixed costs and the initial situation. However, the latter do determine the amount of the profit and whether a measure is profitable at all. In the example shown, starting from an uninsulated wall, a very high profit – saved life cycle costs – will be yielded, almost regardless of the insulation thickness. The better the existing (original) situation is, the less energy and costs for energy can be saved, even if it is still far from the optimal solution - and the higher the hurdle which has to be overcome for an investment to become worthwhile. A typical task is the determination of the optimum specific values of the investment, e.g. the "optimal insulation thickness". This depends on the accruing costs per unit of thickness and the energy price, whereby the investment costs depend roughly linearly on this parameter, while the saved energy costs run into saturation since more than the total energy costs of the initial situation cannot be saved.

This mostly results in flat cost optima so that in view of the uncertainties of many calculation parameters, one cannot speak of an exactly ascertainable optimum. Rather, there is a whole range of "relatively optimal" measures from which one has to be selected based on other criteria, see for example [Kah 2013]. Besides aspects other than economic aspects ("co-benefits" or sustainability aspects), one must also remember to include risk assessment at least qualitatively; the higher the energy consumption is, the higher the economic risk will be which in an ideal financial market would be subject to a risk premium, with the result that the future revenues generated by the investment should be more heavily discounted and thus devalued.

3.2 Historic buildings

In the case of cultural heritage buildings, insulation is often applied internally. Due to thermal bridges and lost space, the optimal range for these is located at lower insulation thicknesses (Fig.). Combined with the energy retrofit of other components, factor 4 is often achievable, even with interior insulation.

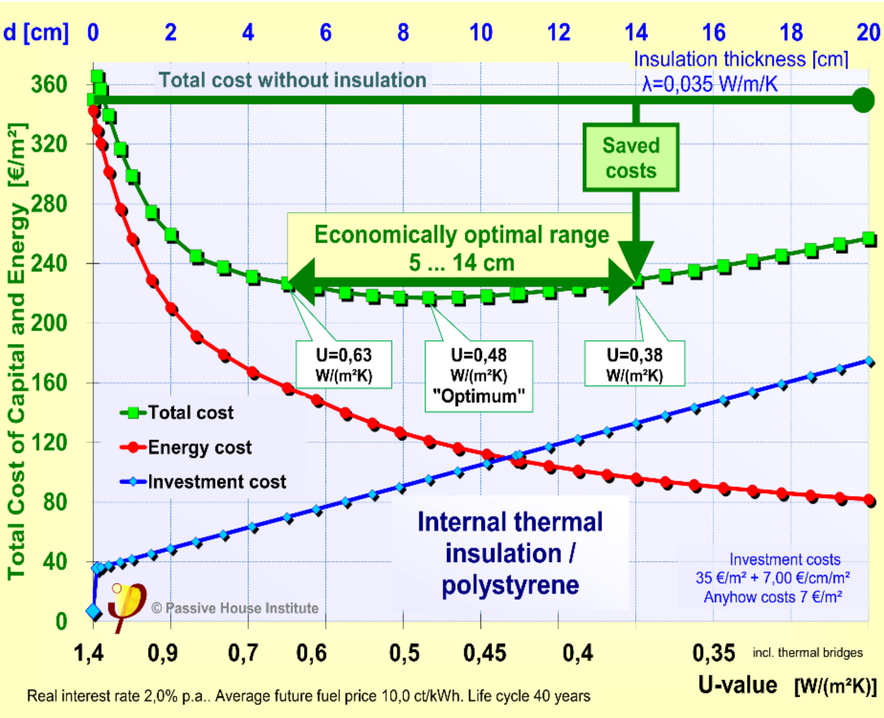

Figure 14: Capital, energy and life cycle costs for energy efficiency measures depending on the quality (insulation thickness).

While the cost optimum for the Central European climate typically is 0.15 W/(m²K) or below, the cost optimal range is lower for internal insulation. Rent lost on account of the reduced living space is taken into account.

3.3 Climate zones

The results of economic optimisation may differ according to the location with its specific climatic conditions. This also applies to the cost optimal levels of components. The PHI has analysed this relationship in detail in a global study [Schnieders 2012], concluding that this principle always leads to a very low energy demand. A clickable map visualizes cost optimal levels in the different European countries [PassREg 2015]. Climate dependent criteria are now integrated in component certification [Component Database], EnerPHit certification criteria and in the PHPP [PHPP 9].

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4 EuroPHit: quality and step-by-step retrofit

4.1 The importance of quality and performance

As soon as energy efficiency is negotiated or becomes a business case, it is important that it is transparent – and predictable. Tenants are only willing to pay a higher rent when a better comfort and lower energy expenditures are realised, which in turn is the prerequisite for visibility in rent or market value. Financing institutions will only believe in a low-risk credit when success is achieved resulting, e.g. in a lower financial burden for the borrower. Public funding will ask for the (guaranteed) value for the public and the environment. And reliable performance is obviously a prerequisite for the business case of energy service and energy performance contracting. Ambitious energy efficiency goals demand reliable instruments to guarantee quality and performance. The Passive House planning package (PHPP) has been developed as a calculation and design tools which is especially appropriate for energy efficient buildings and renovations [PHPP 9]. For energy balancing, the correct data of relevant product properties are decisive: for this reason, product certification was developed and the data are public in the [component database].

The EuroPHit project - supported by the EU within the Intelligent Energy Europe framework - focuses on highly efficient renovation, including step-by-step retrofits. This part of the renovation market is often not perceived, although it represents the highest share of the renovation market in Europe. Step-by-step retrofitting is not an exception but normal practice: modernisations are carried out when there is a reason for these, and we have seen that this is also reasonable from the economic point of view. Furthermore, owners tend to avoid big renovations when possible. It is also true that the energetic renovation cannot be adjusted or completed later without extra effort, which would not pay back. The opportunity can be taken or not.

The point in time of the measure is crucial: does it fit within the normal renewal cycle, or is there a residual depreciation of the component? We have shown that the capital costs for bringing forward the measure can easily exceed the extra investment due to energy-efficiency reasons. This proves that undertaking refurbishment only because of potential energy savings is not an effective strategy. The concept of step-by-step retrofitting - carried out when it becomes necessary – makes it possible to use the normal renewal cycles. Components that meet the special requirement for use in a step-by-step process have been developed within EuroPHit (see e.g. [IPHC Comp 2015]). A certification scheme was developed especially for step-by-step retrofits including the retrofit plan. We have seen that the initial energy efficiency standard is decisive for economic feasibility. This implies that medium quality measures might reduce energy demand, but also reduce the potential revenues of later energy efficiency investments. Future adjustments to improve their quality are unlikely because they will not pay back, thus impeding future sustainable developments. Therefore, the principle "if you do it, do it right" applies for every single measure – also in a step-by-step procedure.

EnerPHit renovations, some of them step by step. All of them have been designed with the Passive House Planning Package (PHPP).

For a viable economic assessment, it is crucial that the planned energy savings are realised, as they define the revenues. This refers to the influence of the energy efficiency standard of the building, in addition the normal user influence that occurs in all buildings standards must be considered. Step-by-step renovations differ in that each step must be calculated.

Figure 15: Quality and performance: Case studies of the EuroPHit project.

For economic assessment, applying the net present value method is easiest; the costs are determined according to the due date and discounted to the reference date. It can also be used to compare different strategies of retrofit. A complete also has advantages: it may save costs (which will only be incurred once instead of several times), does not require long-term planning for a damage-free sequence of refurbishment steps and spares subsequent expenditure at unsuitable points in time. When the parameters are known, these instruments help to calculate the economic implications of the alternatives. But in reality, we don’t expect decisions to be made in this way. In Europe the majority of renovations are made in a step-by-step manner. It doesn’t matter how these decisions are made: the main point is to reach the end sustainability goal, step-by-step and component by component.

5 Financing energy efficiency

5.1 Loans for energy efficiency investments

The questions relating to financing and liquidity must be clearly separated from the economic assessment. Investments must be financed - even when they are profitable. For this, substantial funds must often be made available for properties. If these are not covered by equity, debt capital should be available, since the buildings serve as the securities, and the investment as such is practically risk-free.

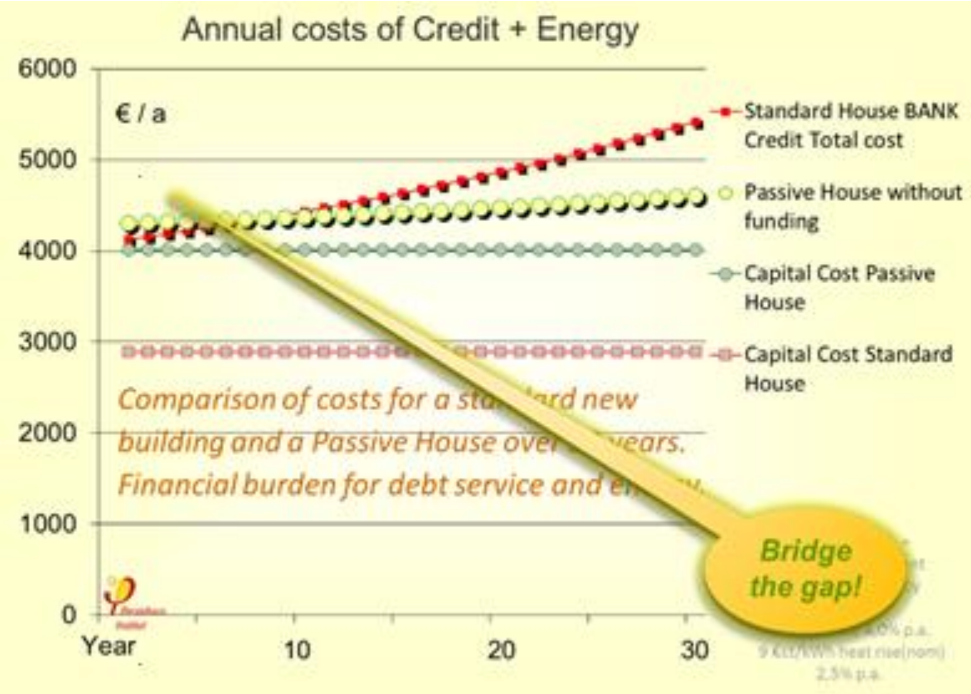

Figure 16: Financial burden of an energy efficient building/ renovation compared. For an economic measure, the initial capital cost are often too high with a normal bank loan.

On the other hand, loans required for partial renovations are smaller, and do not seem to be particularly relevant for banks, which is why these don't offer attractive conditions. The picture might change regarding the huge renovation market, and the fact that a large amount of capital is hoarded in financial institutions, looking for assets - especially low-risk. Financing building energy efficiency will become an attractive investment when a simple, reliable, non-bureaucratic standard procedure is developed, including building quality and performance investors and banks can rely on [EuroPHit Financial workshop 2016[1]].

[1] At the final EuroPHit financial workshop in Frankfurt, representatives of financing institutions pointed out that lack of transparency with regard to quality and performance is a major barrier for the development of adjusted programs.

5.2 The market value of energy efficiency

The disparity between cost burdens and benefits is often seen as one of the greatest problems (“split incentives”). Revenues go to users while expenses are borne by the investors. Under these circumstances there is naturally a lack of interest on the part of the latter, and investment does not occur. In actual fact, this is no real dilemma, since there is no inextricable conflict or contradiction in the situation presented here; rather, the cost for utilization has not been adequately negotiated. Making the benefits visible is most important – only then will it be possible to assess them. This is equally important for the rental market as for the property market: owners will be more likely to invest in energy efficiency when they achieve higher rents, and/or an adequate sales price. Several studies show that tenants and buyers pay a premium once the energetic advantage is transparent; quality assurance measures should be ensured.

Therefore, the "investor-user dilemma" is solvable. The reason why this does not often seem to succeed is usually due to the well-known reasons for the way in which the gains from a profitable investment are simply removed from the equation (expectation of short payback periods and high returns, ignoring the coupling principle, calculation with short lifetimes, disregarding residual values etc.) s.

5.3 Business concepts: Energy performance services and contracting

Instead of achieving a market value, owners can use other instruments. When a significant object-related profit can be achieved, this can be used to pay for additional services. Energy services are favourable in the case of split incentives, when the market is not transparent, and/or an additional third party financing is needed. In this case, a partner designs and implements energy efficiency measures with a guaranteed performance and derived minimum energy cost savings. While the user pays the same price for the energy service, the energy cost savings finance the investment and the service. When the Esco sells the future user’s payments to the bank (“forfaiting”), the bank can give a credit.

Obviously, the investment becomes less profitable because a third party’s service has to be paid, too. Therefore, usually this works only for investments with a high saving potential. The wish to achieve short payback times is an additional trade-off the contracting parties have to be aware of. Note that an important prerequisite is the quality assurance procedure in order to guarantee that the prospected efficiency goals are met.

5.4 Funding and incentives

Funding and incentives help overcome financial barriers. When the investment is not profitable based on life cycle costs (e.g. in markets that are new to energy efficiency), a subsidy can make it economically feasible. This situation can be used to influence the market in an effective way; incentives should aim at supporting an effective and sustainable reduction of energy demand and carbon emissions, and to guarantee good performance through quality assurance requirements.

If energy efficiency investments are already economically viable, public financial support will still help to improve liquidity, create trust, provide consultation and quality assurance services, or help in case of split incentives, home owner association, etc. But funding should avoid contributing to retain high prices. Instead, financial aids should focus on:

- Improving liquidity and reducing the financial burden. This can be achieved through direct financial support or special credit lines with low interest rates
- supporting collaterals (guarantees) to facilitate access to attractive bank credits and leverage private capital thus significantly boosting effective investments
- binding financial support to quality-assured design and guaranteed high performance
- supporting the quality assurance procedure as well as accompanying measures like training, information, transparency and visibility, and development of simplified effective processes
- also supporting step-by-step plans aimed at effectively reaching the EnerPHit standard in the end, ensuring high quality, cost effectiveness and profitably
- Achieving very high energy efficiency, because the next renovation will only take place after many years. In this respect, a medium quality would hinder the necessary reduction of the energy demand causing a "lock-in" effect.

It is important to raise awareness and to give incentives leading into the right direction. Many standards, tools, and voluntary quality assurance and certification schemes are already available on the market, or have been developed within the EuroPHit project.

6 Conclusions and outlook

As we have seen, economic assessments should be based on life cycle costs. The net present value method forms the basis, the annuity method is equivalent to this. Specific values such as the internal rate of return or equivalent price of the saved energy can be helpful, but attention must be given to the limitation of the area of application. In case of uncertainty, especially in more complex tasks, the methodological principle of the net present value calculation can be resorted to.

However, not only the method but also the boundary conditions are decisive for the result. Here, great care must be taken that these are chosen correctly, otherwise this can lead to severe distortions in the assessment. In particular, attention must be given to the following:

- correct allocation of investment costs
- life cycle costs
- residual values at the end of the calculation period
- assumed interest rates (excessively high returns are often expected)
- assumptions relating to energy prices and rate of price increase
- point in time of the measure
- existing energetic quality (before measures)

With correct consideration of the boundary conditions, it turns out that many energy efficiency investments are extremely profitable, and frequently also contribute to the financing of a large part of the investment for the measures that are due anyway. Moderate-quality retrofits which don’t meet a sustainable level, but they no longer allow sufficient additional energy savings which would finance a new investment; will produce lock-in effects which have to be avoided in the future. Incentives may have an important function here.

A comparative economic calculation is an important information but cannot be the sole basis for deciding between different investment alternatives, even with a methodologically correct method, realistic assessment of all included boundary conditions, and careful analysis. In many cases the results of the economic calculation for different alternatives are so close to each other that they do not allow for a reasonable decision in the context of the uncertainties of the parameters alone. In view of the uncertainties of many calculation parameters, the decision should be made within range of "relatively optimal" measures on the basis of criteria other than purely economic criteria.

"Subjective" benchmarks, which have an influence on investment decisions as well as "objective" criteria which are important in addition to profitability must be taken into account. Also economically relevant factors are often difficult to monetise on account of the lack of transparency or (evaluated) experiences. These include for example:

- increased comfort (e.g. pleasant indoor climate, easy and convenient operation)
- increased productivity, particularly in workplaces
- safety aspects (e.g. greater reliability of supply due to higher individual reserves of energy sources)

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- environmental criteria (e.g. lower emissions and therefore protection of human health and affected ecosystems)
- increase in value (e.g. retention and preservation of building substance, design)
- social effects (e.g. creation of communal areas, improved living environment)
- national economy aspects and impacts
- protection against risks and management of worst-case scenarios as well as avoidance of lock-in effects

Renovation of buildings needs lots of capital. For a huge low-risk financial market, it should be attractive to develop business models with attractive offers for investing in energy efficiency. Furthermore, funding can help to raise awareness, ensure quality, and overcome barriers. Funding finances itself: Energy efficiency in the building sector results in positive economic impacts through job creation, economic growth, increase of income, and reduced needs for capital stock in the energy sector.

7 Literature

[AkkP 11] Arbeitskreis kostengünstige Passivhäuser Nr. 11: ***Kostengünstige Passivhäuser.*** Passivhaus Institut, Darmstadt 1997
Research Group for Cost-effective Passive Houses No. 11: Cost-effective Passive Houses, Passive House Institute, Darmstadt 1997 (in German)

[AkkP 39] Arbeitskreis kostengünstige Passivhäuser Nr. 39: ***Schrittweise Modernisierung mit Passivhauskomponenten,*** Phase IV, Passivhaus Institut, Darmstadt 2009.
Research Group for Cost-effective Passive Houses No. 39: Step-by-step refurbishment with Passive House components, Passive House Institute, Darmstadt 2009 (in German)

[AkkP 1996 – 2015] ***Arbeitskreis kostengünstige Passivhäuser Nr. 2 – 51: Protokollbände.*** Passivhaus Institut, Darmstadt, 1996 – 2015.
Research Group for Cost-effective Passive Houses. 2 – 51: Proceedings. Passive House Institute, Darmstadt, 1996 – 2015

[Bundesbank 2016] Deutsche Bundesbank: ***Zinsstatistik*** http://www.bundesbank.de
Deutsche Bundesank: Interest rate statistics

[Component Database] International Passive House component database. www.componentdatabase.org

[Del Act 2012] ***Commission delegated regulation No 244/2012*** of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and European Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. E N L 81/18 Official Journal of the European Union 21.3.2012

[Ebel 2013] ***Rendite, Risiko und Gewinn bei der Bewertung und Optimierung von Energieeffizienzmaßnahmen an Gebäuden***. In: Protokollband Nr. 42 des Arbeitskreises kostengünstige Passivhäuser, Darmstadt 2013
Return, risk and profit in assessment and optimisation of energy efficiency measures in buildings. In Proceedings of the Research Group on Cost-effective Passive Houses No. 42, Darmstadt 2013

[EN 15459:2007] ***Energy performance of buildings*** – Economic evaluation procedure for energy systems in buildings, November 2007

[EPBD 2010] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the ***Energy performance of buildings*** (recast), Official Journal of the European Union L 153/13 dated 18.6.2010

[Feist 1998] W. Feist, ***Wirtschaftlichkeitsuntersuchung ausgewählter Energie-sparmaßnahmen im Gebäudebestand,*** Studie im Auftrag des Bundesministeriums für Wirtschaft, Darmstadt 1998.
Feasibility study of selected energy saving measures in existing building stock, study commissioned by the German Federal Ministry for Economic Affairs, Darmstadt 1998

[Feist 2013] Wolfgang Feist: ***Ökonomische Bewertung von Energieeffizienzmaßnahmen.*** In: Protokollband Nr. 42 des Arbeitskreises kostengünstige Passivhäuser, Darmstadt 2013
Economic assessment of energy efficiency measures, in Proceedings of the

	Research Group on Cost-effective Passive Houses, No. 42, Darmstadt 2013
[Financial workshop 2016]	EuroPHit Financial workshop in Frankfurt/M. 17 March, 2016
[IEA 2012]	International Energy Agency: World energy outlook, 2012
[IEA 37]	Kaufmann, B; W. Ebel: ***Economics of high thermal performance of old house renovation projects in the framework of IEA Task 37 "Advanced building renovation"***. Passive House Institute, Darmstadt 2010
[IPHC 18]	***International Passive House Conference 18, Keynote*** D. Ürge-Vorsatz, Aachen 2014
[IPHC-Comp 2014]	Passive House Component Award Windows: optimization of life cycle costs. International Passive House Conferences in Aachen, 2014
[IPHC-Comp 2015]	EuroPHit Passive House Component Award Windows: step by step solutions. International Passive House Conferences in Leipzig, 2015
[Kah 2008]	Oliver Kah; Wolfgang Feist, et al: ***Bewertung energetischer Anforderungen im Lichte steigender Energiepreise für die EnEV und die KfW-Förderung.*** *Evaluation of energy-relevant requirements for EnEV and KfW subsidies in light of rising energy prices (in German).* Study commissioned by the German Federal Office for Building and Regional Planning, Darmstadt 2008
[Kah 2013]	Oliver Kah: ***Wirtschaftliche Beurteilung energierelevanter Bauteile.*** In: Protokollband Nr. 42 des Arbeitskreises kostengünstige Passivhäuser, Darmstadt 2013 *Economic assessment of energy-relevant building components. in Protocol Volume No. 42 of the Research Group for Cost-effective Passive Houses, Darmstadt 2013*
[Kaufmann 2013]	***Passivhaus Wohngebäude – Neubau & Sanierung: Wirtschaftlichkeitsanalyse anhand realisierter Projekte mit abgerechneten Kosten***. In: Protokollband Nr. 42 des Arbeitskreises kostengünstige Passivhäuser, Darmstadt 2013 *Passive House residential buildings – New builds and retrofits: feasibility analysis based on built projects with documented costs. in Proceedings of the Research Group on Cost-effective Passive Houses No. 42, Darmstadt*
[Passipedia]	Passive House knowledge resource www.passipedia.org
[PassREg 2015]	PassREg: ***Component guidelines for cost-optimal Passive Houses and EnerPHit retrofits.*** In: www.passipedia.org
[PHPP 9]	PHI: ***Passive House Planning Package***. Passive House Institute, Darmstadt 1998 – 2016. Current version PHPP 9.6, 2016
[Schnieders 2012]	Schnieders, J.; Feist, W. et al: ***Passive Houses for Different Climate Zones.*** Passive House Institute. Darmstadt, May 2012

Technical References

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