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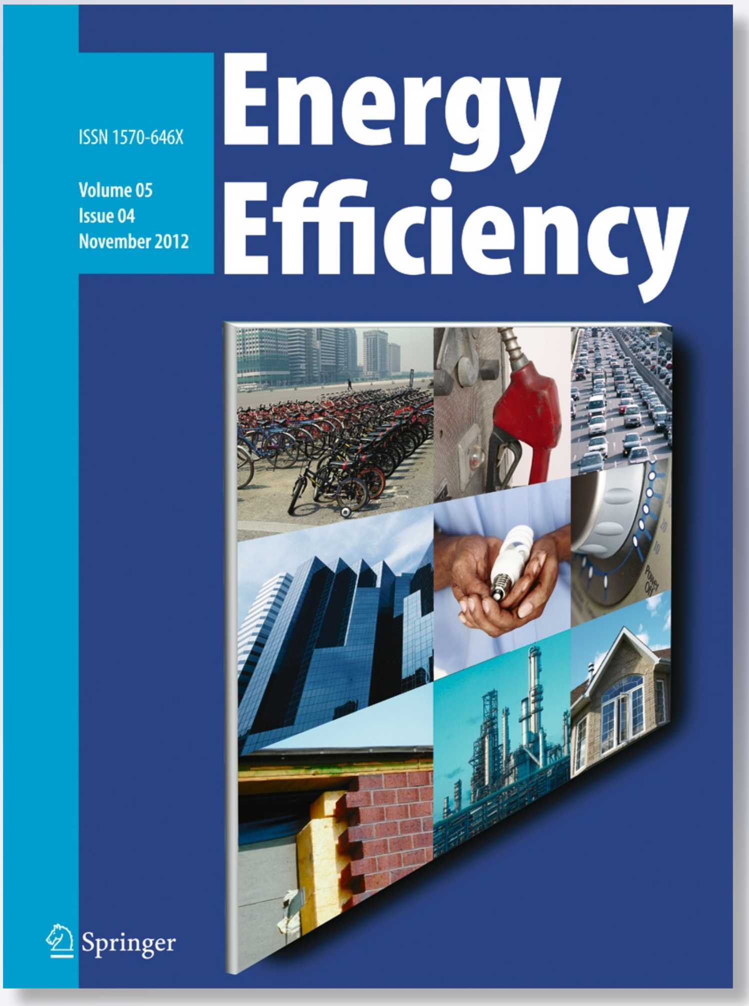

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ORIGINAL ARTICLE

Financial appraisal of efficiency investments: why the good may be the worst enemy of the best

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Abstract This methodological paper has a didactic goal: improving our understanding of what "cost optimal energy performance of buildings" means and how financial appraisal of efficiency investments must be set up. Three items merit improvement. First, focus on the endowment character of energy performance of long-living assets like buildings. Second, defining cost optimal requires more than a comparative static trade-off scheme; cost optimal refers to dynamic efficiency, which results from technology dynamics induced by changes in society and policy. Third, financial appraisal is a more complex issue than simple net present value and life cycle cost calculations. It must reflect the time sequential dynamics of real-life processes including real-life decision making. Financial appraisal is embedded in a complex framework made up by three dimensions: future time, doubt and irrevocability. The latter dimension connects with issues like lock-in and path dependency that are generally overlooked in net present value calculations. This may lead to very erroneous recommendations regarding efficiency investments, in particular regarding the energy performance endowment of buildings. Mostly irrevocability is used as an argument to "wait and learn" what has, for example, blocked the pace of climate policy. But the opposite "choose or lose" is the logical outcome when the methodology is fed with evidenced expectations. The latter boosts energy efficiency to its boundaries, saving it from the middle-of-the-river quagmire where incomplete appraisals are dropping it too often (making the good the worst enemy of the best).

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Acronyms

CBA	Cost–benefit analysis
EPBD	Energy Performance of Buildings Directive (2010/31/EU)
EPE	Energy performance endowment
NPV	Net present value

Introduction

In debating what levels of energy efficiency are "optimal," financial–economic arguments have a big stake. According to neoclassical economic analysis, investors and operators search for levels of energy use, casu quo energy efficiency, being expected to be least cost. Public decision makers argue that their mandated regulations are cost-effective or cost optimal for private investors. The Energy Performance of

Buildings Directive 2010/31/EU (EPBD) is a case in point of adherence to the narrow economic viewpoint. However strong the focus on costs, the EPBD lacks a clear definition of what cost optimal could mean.

This article has three main parts, followed by a conclusion. The first part spells out the three-dimensional framework that is needed to situate decisions and investment decisions. It is made up by the dimensions future time, doubt and irrevocability. The dimensions are briefly discussed one by one, although analysis is based on their interaction. Most attention is devoted to irrevocability because not that many scholars are familiar with it and it is mostly overlooked in practical studies, what can lead to "very erroneous" recommendations (Dixit and Pindyck 1994). Like time and doubt, the factor irrevocability also "comes in degrees". Therefore a metric of irrevocability as strong (preclusion), medium (rigidity) and weak (flexibility) is proposed.

The second part delves into the terminology "cost optimal energy performance of buildings". It argues that comparative statics (BPIE 2010) offers but a text-book trade-off scheme to explain the impact direction of cost drivers. It does not meet the challenge of assessing cost optimal in the dynamic contexts of the real world. For a (better) consideration of the dimension irrevocability, it is necessary to extend the term energy performance with the concept of *endowment*, and put the emphasis on the latter when studying long-living assets with an important energy efficiency bequest. Buildings are a clear example why refinement of our vocabulary is preferable. The degrees of freedom in setting energy performance endowment (EPE) properties correlate with the type of constructive measures undertaken. Most freedom is available in case of a green meadow construction. A full overhaul of an existing building, maintaining only its skeleton, also permits the overhaul of its energy performance endowment, but some aspects may be excluded, for example the orientation, compactness or addition of basements and cellars. A light refurbishment of buildings may exert only little impact on the endowment. This article mostly refers to the construction of new buildings, covering the full range of important endowment attributes and components. But the analysis is also applicable with a truncated list of endowment attributes and components when a limited retrofit is considered.

The third part introduces the basic concepts of investment appraisal taking into account time sequential dynamics. With simple binary choice, two-period examples, the standard case of "wait and learn" and the opposite case of "choose or lose", are presented. Referring to the SWOT (strengths–weaknesses–opportunities–threats) framework for considering strategic decisions, the "wait and learn" path is taken when future threats are identified. The "choose or lose" path is prevalent when opportunities are available with waiting not being possible or no longer an option, and when irrevocability has a significant impact. While the two applications deliver opposite advice to the investor, they are the result of a single methodological approach. The conclusion wraps up the major findings of the article, but is put under the title "The good as worst enemy of the best", because the findings signal the real danger that this happens when irrevocability is not considered.

A three-dimensional framework embeds investment decisions

Financial appraisal (Bierman and Smidt 1971) is a structured way of processing assessed flows of expenses and revenues over time resulting from a decision (investment). The analysis is extended to a cost–benefit analysis (CBA) when non-market (un-priced) aspects are included (Layard 1972). The term cost–benefit analysis is used wrongly or loosely when non-market aspects are neglected or but partially included, which is generally the case.

When a private economic agent is investing, a CBA means that difficult to measure values (comfort levels, amenities, security, etc.) are monetized and included in the financial appraisal. An inherent difficulty is how reliable and complete the assessments of the costs and benefits related to the decision are. From a societal point of view, the CBA must cover all costs and benefits to society wherever and whenever they fall upon whoever. Neither the public nor private CBA perspectives are adopted in the EPBD (EU 2010), given article 2 states: "the lowest cost is determined taking into account energy-related investment costs, maintenance and operating costs (including energy costs and savings, the category of building concerned, earnings from energy produced), where applicable, and disposal costs, where applicable"; this contribution will stick to the reduced EPBD approach, although being less favourable for efficiency options that in most cases are expected to provide more intangible benefits than energy wasting equipment and apparatus (Verbruggen 2008). The advantage of the narrowed scope however is that we can focus on the bare methodology of financial appraisal, generating already enough material for study, discussion and clear conclusions.

An investor can only decide on future investments, and the future is uncertain. For day-to-day and transient actions suffice intuitive decision making. But for long-term, complex, and persistent investments, only correct, scientifically based methods are adequate (Matheson and Howard 1968). Constructing a solid building is a unique and complex decision for most people, entailing important lifelong consequences. It is helpful to consider investment decisions in a three-dimensional context (Fig. 1). Each dimension requires case-dependent elaboration with due regard for the interactions with the other dimensions. Most investors consider the dimensions time and doubt, but are less familiar with irrevocability. The three dimensions are described in Verbruggen et al. (2011), and this section provides a more concise and updated version.

Future time

First is future time: one only can decide for the future because the past cannot be changed whatsoever. Analysing investment opportunities is an exercise in looking into the future. Who looks how far, at what and for what in the future are case dependent. The time axis of Fig. 1 mentions years–decades–centuries, which in a building's case corresponds to appliances, equipment, constructions and infrastructure. Many architects have acquired familiarity with discounted cash flow tables and calculations, and profusely use the discounting operator (Bierman et al. 1977; Jelen and Black 1983; Rushing and Lippiatt 2008). Discounting at a positive rate represents exponential decay as being the inverse of exponentially growing compound interest. This standard practice is more and more questioned when discounting is applied over long periods (beyond 50/100 years), but there exists no consensus about alternative approaches (Portney and Weyant 1999).

Doubt

Second is doubt: the future being unknown, there is doubt about expectations and forecasts of what the future will bring. Doubt is due to our incomplete knowledge about events that may happen and about the likelihood or probability of occurrence of the events. Depending on the subject, on the investigated aspects and on the distance in time, three levels of doubt are identified: risk, uncertainty and ignorance.

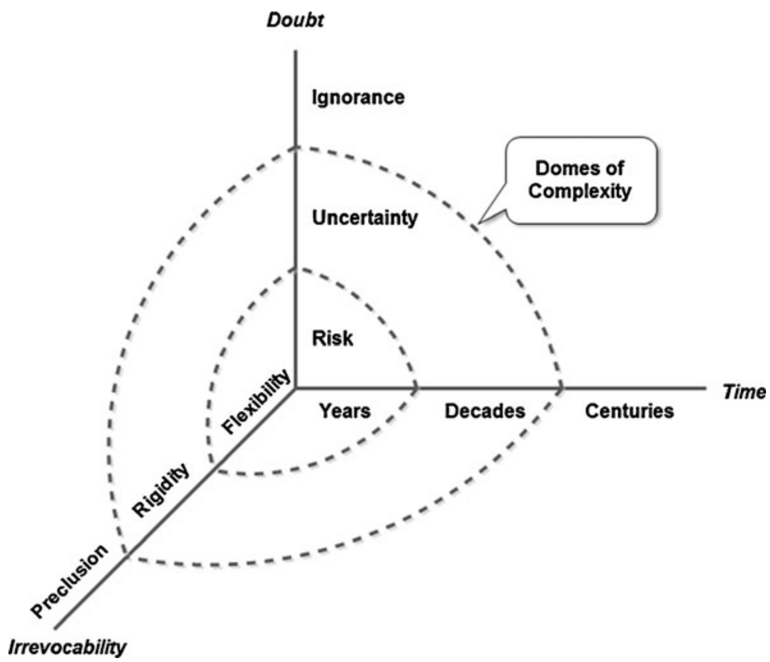


Fig. 1 Three dimensions make up the context of investment appraisals

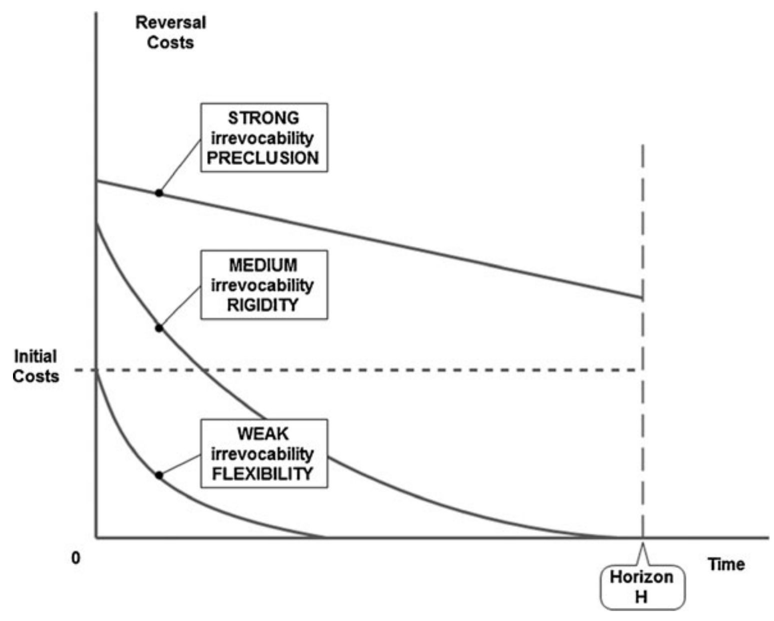
Risk is the most informative level: the relevant future events are recognized, and the probabilities of their occurrence are assessed, based on long-time experience and on scientific evidence. Uncertainty has a good record of possible events too, but very little information about probabilities that therefore are assessed in a subjective way (for example expert opinions). Ignorance is deeply problematic because future events cannot be forecasted, a fortiori not their probabilities. Ignorance must be considered when the likelihood exists that at this moment unknown events important for our decisions may emerge in the future (Munasinghe et al. 1995; Stirling 1999). In the process of investing in buildings, most doubt belongs to the shallow class of risk. Risks can be inventoried and studied to obtain information about events that may have an impact on the project and about the related probabilities. Uncertainty is forthcoming from sudden changes in political, social, economic and technical systems that affect the builder's project, for example when climate change urges drastic changes (increase) in the future prices of fossil fuels and of grid power. Also the level of ignorance, for example about future technologies or about catastrophic impacts triggered by climate change or by nuclear accidents, affects the decisions and their outcomes. Private investors pay often little attention to society wide events and their impacts on the projects they plan. However, such events may affect significantly the performance of the investments. Public authorities (governments; the EU Commission) should assess the future with minimum spatial and temporal myopia and consider the full range of doubt from risk to ignorance. The assessments then find their way in enacted laws, directives and regulations that guide private decision makers towards the best decisions. Taleb (2010) advises to opt for robustness in hedging against ignorance.

Irrevocability

Third, irrevocability is an attribute of every decision as its definition "an irrevocable allocation of resources" (Matheson and Howard 1968) reveals. Verbruggen et al. (2011) discuss irrevocability as the economic constituent of irreversibility, both coming in degrees. Practical use of the attribute irrevocability requires a workable metrics for gauging degrees of irrevocability. Workable metrics are based on reversal costs implied at a given moment in the future for undoing a previous decision. "Undoing" is considered feasible when accepting substitutability of all types of goods and values. This article deals with buildings made of substitutable materials, and undoing a previous resource allocation is technically feasible, however costly it may be in reality.

Figure 2 shows three degrees of irrevocability as a function of how undoing costs develop over time:

Fig. 2 Reversal costs over time as metrics of irrevocability



strong, medium and weak, referring to conditions of preclusion, rigidity and flexibility. The reference point for categorizing irrevocability is the initial (investment) cost at point 0 in time. Visual inspection of Fig. 2 shows that 'strong' irrevocability (preclusion) refers to reversal costs in the future that remain above the reference of the initial costs but decay over time due to depreciation of the initial investments and to technological progress. For example, a basement underneath a house is a not so expensive space, but it is precluded to construct it once the house is built. When after the building is ready, a cellar would be considered to be anyhow a necessity; very special techniques could be applied to add cellar space, mostly of reduced size compared to what an original design could deliver and at very high costs. 'Medium' irrevocability (rigidity) refers to undoing costs higher than initial costs at moment zero and for some years, but falling below the initial costs later. 'Weak' irrevocability (flexibility) is when the investment could be undone at a price equal or lower than the initial costs. Prevalence of categories of reversal costs and patterns of reversal cost curves depend on several variables, for instance physical characteristics of the object, existence of markets for used equipment, technological innovation and economies of learning regarding possible substitutes in the future, etc.

What does "cost optimal energy performance of buildings" mean?

In industrialized countries, almost 40 % of all commercial energy supplied as processed fuels and grid electricity is used in buildings (Laustsen 2008; EU 2010). The fourth assessment report by IPCC (2007) is very optimistic about the contribution of the buildings sector in reducing the emissions of carbon dioxide by energy efficiency. Also the EU sees the huge energy savings potentials, and the EPBD is the main instrument to unlock the potentials. The EPBD (and so the EU authorities) assign a crucial role to the costing aspect. European energy efficiency policy bets most on regulation by standards, also when targeting the energy quality of buildings. The prescribed standards are derived from extensive physical and technical analysis of materials, building physics modelling, demonstration projects, statistical studies of the building stock, etc. One may enlarge the debate about the meaning of regulation and about the optimal way to organize regulation with balancing the various instruments that policymakers can handle. This debate, however, is beyond the scope of this article. In any case, regulation of "cost optimal energy performance of buildings" should start from a clear understanding and definitions of this goal. Two parts in the goal definition ask for particular attention: "energy performance" and "cost optimal".

Energy performance endowment of buildings

Verbruggen et al. (2011) introduce the concept 'energy performance *endowment*' of a building with emphasis on the word endowment. This extends the EU Directive's 'energy performance'. EPE of a building covers several attributes (orientation, compactness, size, etc.) and items (components, equipment, etc.) that have an impact on the later energy use in the building. EPE is the incorporated capability (made up by attributes, structures, installations, equipment, etc.) of a building that largely determines energy use in delivering the functions wanted by the occupants. Later energy use or in other words the actual energy performance not only depends to a large degree on this endowment but also depends on a range of other variables that are not under control of the EPBD (or any other directive). The latter are factors like actual functional[1] use of the building, amount and quality of plug-in appliances, occupants' behaviour, etc.

The endowment encompasses for example orientation, compactness, availability of passive construction parts (e.g. a cellar for cool storage), insulation and air tightness, shading blades, heat distribution equipment, coolers, sensors, meters, etc. One can equip a new building with an excellent, mediocre or poor energy endowment. Endowments are narrowly related to degrees of irrevocability, and need consideration during the planning phase (Laustsen 2008). Building regulations should focus

[1] Functional use refers on the one hand to the main function intended for the building (e.g. living, education, office work, health care), but on the other hand to the use intensity of provided capabilities of the building (e.g. number of actual occupants with time and duration of their occupation of the building, number of hot meals prepared in the building's kitchen, laundry—washing, drying, ironing—at home or processed externally, etc.). Regulations are or can be specific for intended functions, but cannot cover actual functional use (Verbruggen 2008).

on the endowment character of energy performance, which ultimately promotes and guarantees the best actual energy performance during later use of the excellently endowed buildings.

Cost optimal energy performance endowment

Regulations are easier to implement, control and enforce in a target constituency when prescribed rules and imposed standards correspond with financially beneficiary practices and with other pursued objectives. Fixing performance standards requires economic and financial assessment of the benefits and costs they may imply. This explains the high interest the EPBD adheres to the cost aspects and to cost optimality.

EPBD article 4 states: "Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost optimal levels", and "A Member State shall not be required to set minimum energy performance requirements which are not cost-effective over the estimated economic lifecycle". The directive defines 'cost optimal level' in article 2 (definitions) as "the energy performance level which leads to the lowest cost during the estimated lifecycle". This definition only refers to the time dimension of the decision context (Fig. 1) without attention for the other two crucial dimensions: uncertainty and irrevocability. The three dimensions taken together and the interactions between them determine what cost optimality means when investing in energy-efficient buildings. The directive announces in article 5 "a comparative methodology framework for calculating cost optimal levels of minimum energy performance requirements for buildings and building elements".

A September 2010 report (BPIE 2010) seems a first step in that direction. The methodology presented for defining what cost optimal means is however based on a static trade-off scheme used in textbooks to illustrate the impact of efficiency technology costs versus energy use bills. With such trade-off graphs, teachers explain the impact of technological progress lowering the costs of efficiency technologies and the impact of higher energy use prices (for example through a levy on non-sustainable energy sources). Both measures together make the cup of the total costs roll towards a lower static optimal energy use. This comparative statics graph is a weak methodological basis for identifying the cost optimal level of buildings' energy performance in the reality of the world characterized by technological innovation and accumulating climate change challenges. The added BPIE argument that the cost of overshooting energy use is as high as the cost of undershooting is not convincing builders to change habits and flip from one side to the other, as BPIE (2010, p.16) wants to impose. BPIE (2010, p.21) limits attention to irrevocability to a footnote on lock-in effects.

According the long-standing theory on investment, it is necessary to consider irrevocability explicitly and process this aspect interactively with time and uncertainty for "avoiding very wrong answers that the traditional net present value rule can give" (Dixit and Pindyck 1994). Instead of fleshing out the shortcomings of the BPIE proposals, this contribution tries to clarify what the methodology is for assessing and supporting cost optimal investments in buildings.

Dynamic people in a dynamic world

Theory and methodology testify improvement when they offer a better representation of reality. The reality of decision making can grow complex and is dynamic when long time spans are covered.

A life cycle analysis considers the lifetime of a project, and discounting concentrates the history of the project during every year of that lifetime in summary statistics at the start of the project's life, like expected net present value (NPV). Because the future is uncertain, the analyst imagines future scenarios about the evolution of the major determining variables, and calculates NPV values for every scenario. This can be automated in Monte Carlo simulations offering nice graphs of the sensitivity of NPV for the various scenarios and their combinations.

The NPV or life cycle costing approach processes time in a professional way, and the sensitivity analysis informs about what variables may have an expected major or minor impact. Its shortcomings lay in assuming the bundle of future scenarios as composed of once through trajectories starting with investment (year 0) and ending with decommissioning (last year of the lifetime). This tunnel view does not reflect real-life processes that actually are sequential, bifurcating and sometimes traversing, as we all know in looking back at our own life experience. The sequential character is modelled as an alternating flow of events–decisions–

events–decisions–events,[2] and so on. Decisions at a given moment in time are conditional on preceding events and earlier taken decisions, and affect later decisions as well as the impact future events and later decisions may have. When theory and methodology want to truly mimic reality, the sequential process needs to be studied and modelled for future decision making. Adopting sequential decision making is critical for analysing investments that span a long period (beyond 20 years), but is also appropriate and recommended for analysing many shorter term investments. Only the sequential analysis reveals the impact of irrevocability interrelated with time and doubt on the optimality of decisions. Sequential decision-making processes are graphed as decision trees (Raiffa 1970).

In the literature the sequential investment analysis (also named real option investment analysis) spends most attention to cases and circumstances leading to postponement (deferral) of the irrevocable allocation of resources (Arrow and Fisher 1974; Dixit and Pindyck 1994; Lind 1999). First, the standard framework of "wait and learn" is illustrated with an example, borrowed from Verbruggen et al. (2011). Then, I show that the case and circumstances of deciding on the energy performance endowment of buildings are the opposite of the standard and that the theory there leads to the situation of "choose or lose".

Irrevocability supports "wait and learn" decisions

Verbruggen et al. (2011) illustrate the standard framework with an example of a family considering the construction of a new house. The plot of land they own is situated in a suburb where authorities developed a draft master plan on major new infrastructure. Figure 3 shows the most basic decision tree covering two periods of decision moments (present and a moment in the future) with an intermediary stochastic event evolving (with only two possible outcomes: negative with probability p and positive with complementary probability $1-p$).

At the starting stage (mostly present time), a family may choose to wait or to build their own house. In principle, building at present only happens when the value V the house offers in the first period is assessed as positive ($V>0$). Because living in their own house, built according to the family's preferences, more benefits and amenities are expected than living in a rented house, with additional saving on rent paid, making $V>0$. When for some reason one decides to wait, the first period positive value is foregone ($V=0$). When the house can be occupied in a quiet environment, the future value (FV) is also positive or FV>0; when the environment gets hectic, it is no longer a pleasure to live in that house, and because of this one cannot sell the house at a worthwhile price or FV<0.

In the years between the present and future (e.g. a 5-year period), some uncertain events of high significance for the house building project may become reality: assume for example the location of the real estate where the house is planned could be overspanned by a mega traffic bridge. At present there is doubt the bridge will be constructed between yes (probability p) or no (probability $1-p$). Placing you as decision maker 5 years in the future, the best feasible actions will depend on the history that evolved up to that moment, and the decision made 5 years earlier will have a big impact. Four cases may happen:

- You waited to build, and the bridge hangs above your plot: you stop the construction plan there (likely frustrated, but at least happy that you do not have to live for the rest of your life under continuous traffic flows; FV=0)
- You waited, and the bridge project is definitely ditched: you can now build your house (you have lost the V over the first 5 years, but this is the price of the option to decide with hands untied at this future moment; FV>0)
- You have built, and the bridge and traffic are there above your roof (loss is your part; your investment is almost worthless, and you have spent your credit so you cannot move: V+FV<0)
- You have built, and the bridge project is definitely ditched (relief is yours; you already enjoyed the value V during 5 years, and you can continue to live quietly on the plot you wanted: V+FV>0)

Which decision (wait or build) is best at the start of this process depends on the actual values of V, FV (negative and positive) and the probabilities p and $1-p$. But only the sequential layout of the decision

[2] Events are out of control of given decision makers, while decisions (also called strategies) are created by decision makers or selected from a range of alternatives under control.

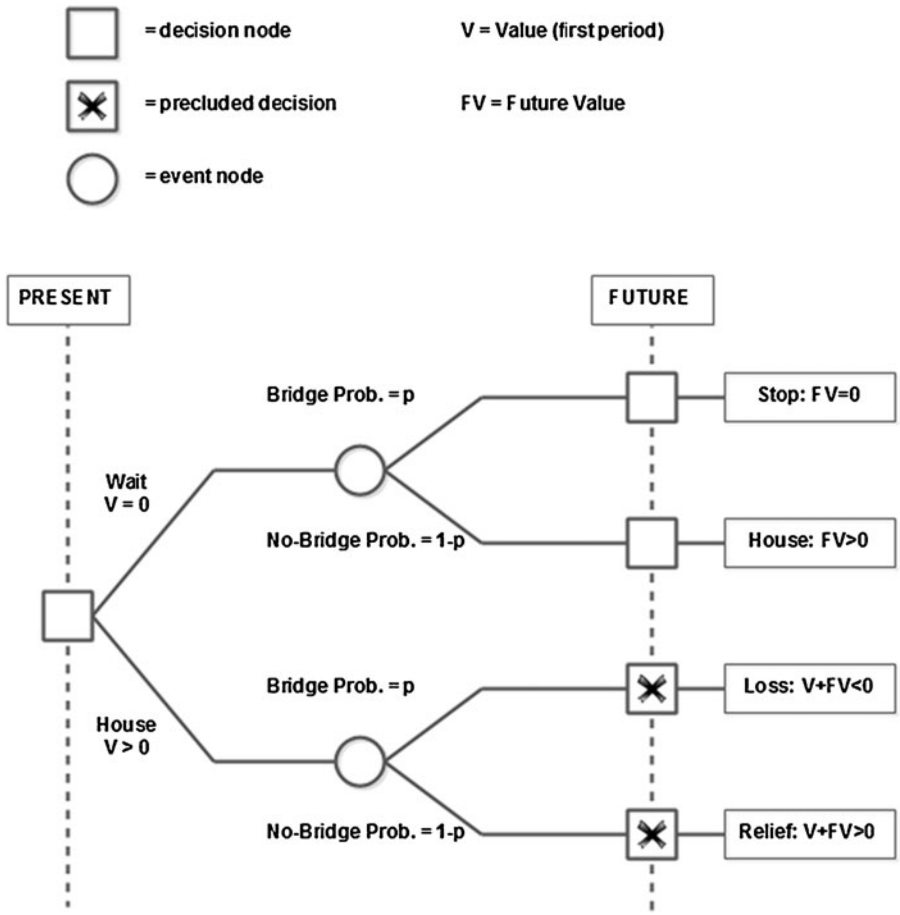


Fig. 3 Sequential decision making revealing "wait and learn" options

process makes apparent the option of "wait and learn". That sequential option is obscured when sticking to the easier static approach of expected life cycle values. The necessity to perform a careful sequential decision analysis grows with the degree of irrevocability that characterizes particular investments. It should also be emphasized that the decision maker owns and uses the same amount and quality of information in the two approaches: the defecting comparative statics of the life cycle cost analysis versus the appropriate sequential dynamics of option value analysis. The difference is that only the latter methodology is a good representation of real-life decision making.

Irrevocability supports "choose or lose" decisions

The decision analysis literature is heavily loaded with "wait and learn" arguments and cases, for example Dixit and Pindyck (1994), Lind (1999), Manne and Richels (1991) and Kolstad (1996). A few authors have pointed to this imbalance and suggested that also the inverse cases need attention (Grubb 1997; Fisher and Fisher 2001; Webster 2002) because if one does not develop alternatives in time one may be locked in old pathways for too long if not forever. Lock-in may also occur in the development of efficiency and renewable energy technologies as a substitute for non-sustainable energy supplies. For buildings, lock-in is magnified because of the long lifetime and the irrevocability of major components and connected attributes of buildings.

Constructing a building implies many decisions. Some decisions are (almost) independent, not affecting each other; other decisions are interrelated or conditional and need evaluation in sequence. Decisions also differ in their degree of irrevocability (Fig. 2). When thinking about building investments, the distinction between physical and economic irrevocability is important. Physically a building is an irrevocable investment; economically (financially), a building investment is rather liquid according the activity on the real estate market (selling/buying; letting/renting). When a decision maker avoided irrevocability funnels like a bad location illustrated above, weak or medium irrevocability applies on the largest share of building investments.

Several components and attributes of a building are tied to the particular construction and characterized by strong irrevocability. This is the case for most energy performance items (Verbruggen et al. 2011). During planning and design of a building, its EPE is decided. In the literature so far, there was few attention for the endowment aspect of the energy performance properties of buildings. Because physically the EPE is fully interwoven with the construction as such, the distinction between a building and its EPE is seldom made. The custom in the literature is to label houses as a whole on their energy efficiency merits. There exist no precise delineations on what components and attributes distinguish standard houses (meeting the imposed energy standards, considered as optimum by regulators) form low-energy houses, passive houses, net zero energy and energy-producing houses (Sartori and Hestnes 2007; ECEEE 2009). Therefore numbered energy consumption levels per square metre are used as a substitute, which is not very precise because of the wide range in functional performance of buildings within the same category.

Buildings receive their initial EPE at construction. Generally, new constructions face many degrees of freedom for optimizing their EPE. Examples are building orientation, size and type; slope, orientation, and overarching of roofs; insulation quality and quantity; air tightness; rainwater collection and storage; position, size and thermal integrity of windows and doors; floor space layout; pipes; ducts; the provision of cellars (basements), etc. Urban planning may inhibit the realization of particular components or attributes, for example orientation. Several important features that make a construction passive belong to the strong irrevocability or preclusion class (Fig. 2): costs to adapt the attribute or add the item after finishing the construction are higher than costs of realization during construction and remain higher (mostly prohibitive) during the building's lifetime. The attribute of being passive or not is part of the energy performance endowment that only can be decided at the design table. The decision on the EPE cannot be delayed,[3] excluding the option "wait and learn". Under Dixit and Pindyck (1994) conditions, more irrevocability strengthens the wait option. In the EPE case, the thrust is opposite: more irrevocability stimulates builders to choose now for the most irrevocable EPE attributes and items in order to avoid preclusion of efficiency solutions in the future. This is illustrated in Fig. 4 (like Fig. 3 a binary choice, two-period example).

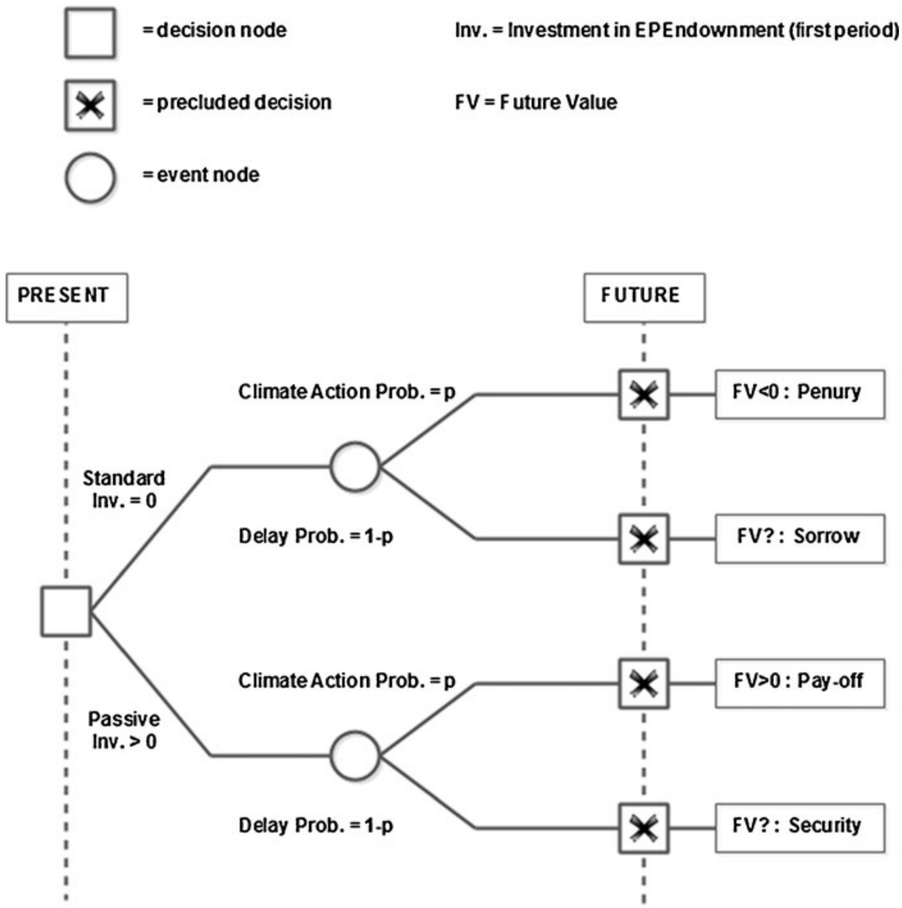
In the example an investor can at present choose between a standard and a passive building, more precisely between a building with a standard EPE and a building with a passive EPE. This choice on EPE is highly irrevocable, and once taken, future decisions and performance are characterized by preclusion or by rigidity: changing the EPE of the building is ruled out or very costly because it would require drastic retrofitting of the construction. The following events are considered: either the reversal in present climate policy towards firm "climate action" (probability p) or the continuation of climate policy delay (probability $1-p$). The four possible future states are:

- Standard EPE and climate action: the future value is highly negative and the owner will experience penury.
- Standard EPE and delay: the nearby FV is fine, but the longer term FV remains uncertain because climate change is increasing; the owner is left in a situation of sorrow.
- Passive EPE and climate action: the initial extra investment inv.>0 is paid, but the energy savings in the coming years (FV>0) brings a good pay-off for the owner.
- Passive EPE and delay: the extra inv.>0 is spent and there is no immediate high return for it. The future value FV remains uncertain, but security for energy price rise is obtained.

When the probability of climate change and therefore climate action in the future pass some threshold and the EPE investment is not prohibitively large (as most empirical evidence confirms), it is recommended

[3] It may be understood that the standard option theory as described in the "wait and learn" case and in Dixit and Pindyck (1994) also can be applied to find the optimum date for starting the construction as such, a timing also influenced by EPE choice opportunities. However, many other (for people more important) considerations will fix the date of constructing, and therefore, analytical separation of the two decisions is plausible.

Fig. 4 Sequential decision making revealing "choose or lose" options



to invest in the best passive EPE. The acceptance of such recommendation will depend on the personal time preference and on the time horizon of the decision maker. For example older people may be less interested in the longer time future of their house, and in particular of its EPE.

When considering the EPE of a building, application of decision analysis methods recommend "choose or lose" options, i.e. provide irrevocable components and attributes now, in order to avoid preclusion. This is the opposite recommendation to the common "wait and learn", deferring the irrevocable investment for keeping open the option to decide later. The irrevocability characteristics of EPE are a stimulus for immediate very efficient (passive) buildings, because construction of buildings obeying weak standards is financially risky in the long term. Standard versions are mostly advised on the basis of traditional net present values or life cycle costing that in this setting "may give very wrong answers" (Dixit and Pindyck 1994).

The good as worst enemy of the best

Decision making and investment appraisal occur in a context space with time, uncertainty and irrevocability as dimensions. In this context decisions on the EPE attributes and items of buildings are studied. Time sequential analysis of future events–decisions–events, and so on, is necessary for a proper reflection of reality. This type of analysis pays off most when irrevocability is salient. This article applies concepts and tools of the science of decision making on investing in energy-efficient buildings. The identification of the endowment character of many components and attributes determining the energy performance of buildings opens the way to appropriate analysis. For measuring the degrees of irrevocability, a classification in strong (preclusion), medium (rigidity) and weak (flexibility) is developed. Timing of EPE decisions is locked to the building's design/construction year, and the "choose or lose" option substitutes for the standard "wait and learn" situation.

The purpose of the article is didactic, but the methodology also entails highly relevant lessons for practical decision-making and regulatory policy. First, energy performance of buildings requires a focus on the endowment character of many components and attributes that are decisive for later energy efficiency of the building. Therefore it is necessary to adopt and develop the concept of energy performance *endowment*, in particular also for a good regulatory regime as intended by the EPBD. A regulator can have an impact on the endowment by suitable regulations and standards; a regulator has little or no influence on the utilization of buildings and on the behaviour of occupants and users. Also it is many times more important to decide on the uttermost efficient endowment during the building's design phase. Removable equipment is easy to adapt later, and supports a continuous improvement of the actual energy performance of a building over its lifetime. For example lighting innovations are expected to come available in the nearby future, and can be applied mostly in a flexible way; regulators may better refrain from imposing particular solutions for such fast innovating technologies. When an overall energy performance is imposed, users may invest highly in today's best but expensive and within a few years outdated lighting equipment, rather than spend attention on the passive attributes of the project.

Second, the definitions and methods to find the cost optimal levels of EPE should be based on proper science and investment appraisal theory. This includes the consideration of the dynamics of sequential decisions with irrevocability in its various degrees. The regulation would have to identify the endowment character of the important attributes and components with an (significant) impact on the later energy performance of buildings that are newly built or drastically renovated. Examples are orientation of the building, functional type, size and compactness; slope, orientation and overarching of roofs; daylight access and transmission inside; insulation quality and quantity; air tightness; the provision of rainwater storage capacity, of basements and cellars, of underground pipes for ventilation air. Making the passive options available should be ranked higher than the nearby realization of a 15-kWh/m^2 occupied space target, because they provide a robust basis for a reduced energy use.

Third, the methodological stalemate is of high policy importance. Using scientifically correct and comprehensive regulations will provide investors with incentives to choose immediately the most passive EPE approach. The limited scope of lifecycle costing will come with middle-of-the-road expected values that preclude high-efficient performance in the future.

Fourth, when taking the warnings and recommendations by IPCC and several other climate expert institutions, serious, irreversible climate change develops ever faster. The fourth assessment report (IPCC 2007) expects a significant and rapid contribution of the buildings sector in reducing greenhouse gas emissions. This emphasizes the importance of advancing quickly towards the highest efficiency building constructions, and of avoiding preclusions in the EPE. When climate policies become serious, fossil fuel prices will have to go up. Then it is financially rewarding to prefer the highest quality EPE for a new construction or deep retrofit.

Fifth, a private investment appraisal focuses on expected expenses and revenues. This excludes attention for the more intangible amenities and for co-benefits that high-quality energy performance brings for occupants of buildings and for society at large. Also this account should be established in full size and in all clarity. It will mostly strengthen the push to optimal energy performance endowments of buildings.

By now the title of this article has lost its mystery: the good can indeed be the worst enemy of the best. And for addressing climate change only the best energy efficiency is acceptable.

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