Total Concept

Håndbok for implementering og kvalitetssikring
Norsk utgave

Versjon 1.6: Januar 2017

Denne håndboken er utarbeidet som en del av forskningsprosjektet "The Total Concept method for major reduction of energy use in non-residential buildings", støttet av Intelligent Energy Europe Programme.
Kontrakt nummer: IEE/13/613/SI2.675832
Hjemmeside: www.totalconcept.info

Håndboken er utarbeidet av: CIT Energy Management AB
Kontakt: Åsa Wahlström, asa.wahlstrom@cit.chalmers.se
Mari-Liis Maripuu, mari-liis.maripuu@cit.chalmers.se;
www.energy-management.se

Nasjonal bearbeiding av håndboken er utført av: SINTEF Byggforsk
Kontakt: Marius Hammer
e-mail: marius.hammer@sintef.no
www.sintef.no

Versjon 1.6- Januar 2017

Co-funded by the Intelligent Energy Europe
Programme of the European Union

Forord

Denne håndboken er utviklet som en del av prosjektet "The Total Concept method for major reduction of energy use in non-residential buildings", støttet av Intelligent Energy Europe-programmet i EU. Prosjektet har som mål å introdusere og implementere Total Concept metoden i fem nordeuropeiske land, slik at den er klar til å bli brukt av interessenter og sentrale aktører i prosessen ved oppgraderinger av eksisterende bygninger. Prosjektpartnerne er CIT Energy Management AB og foreningen Byggherrarna fra Sverige, SINTEF fra Norge, Bionova Oy fra Finland, Statens Byggeforskningsinstitut (SBi) / Aalborg Universitet, Bygherreforeningen og Rambøll fra Danmark og State Real Estate Ltd og VVS-foreningen, EKVÜ, fra Estland.

Denne håndboken er laget for å øke kunnskapen om konseptet og gjennomføringen av Total Concept-metoden. Målgruppen er prosjektpartnerne, byggherrer og eiendomsforvaltere, konsulenter og andre sentrale aktører som vil gjennomføre prosjekter basert på Total Concept-metoden. Håndboken beskriver de grunnleggende prinsippene som metoden er basert på og inkluderer erfaringene fra gjennomførte Total Concept-prosjekter i Sverige. De to første kapitlene av håndboken er på norsk, mens resterende innhold er på engelsk.

Noe av innholdet er basert på informasjonsmateriell utviklet av BELOK-gruppen som en del av den første utviklingen av Total Concept-metoden. Erfaringene fra BELOK gruppen har blitt innhentet og videreutviklet for å gi veiledning til byggherrer, konsulenter og andre sentrale aktører som er involvert i prosessen med energieffektivisering av eksisterende bygninger i deltakerlandene.

Innhold

1 Innledning

1.1 Bakgrunn

Total Concept er en metode for å forbedre energieffektiviteten i eksisterende næringsbygg. Metoden benytter en systematisk tilnærming for å jobbe med energispørsmål i bygninger der formålet er å oppnå maksimale besparelser på en kostnadseffektiv måte. Total Concept-metoden er basert på en handlingsplan og omfatter en tiltakspakke. Tiltakspakken oppfyller de kravene til lønnsomhet som er satt av byggeieren. Forutsetningen for å oppnå lønnsomhet er at hele pakken blir implementert.

Energieffektivisering og reduksjon av det totale energibehovet i bygningssektoren har vært på agendaen de siste tiårene i de fleste europeiske land. Miljømål satt på EU-nivå tar sikte på å redusere bruken av primærenergikilder med 20% innen år 2020. Dette innebærer en nedgang i energibruken i bygningssektoren. Den ambisiøse visjonen for energiytelse i europeiske bygninger krever at alle nye bygg skal være "nesten nullenergi-bygninger" innen utgangen av 2020. Det er viktig at nye bygninger er utformet slik at energibehovet er så lavt som mulig. Dette betyr at økningen av energibehov blir lavere, men ikke at det totale energibehovet blir mindre. For å redusere energibehovet i bygningssektoren og nå 20-20-20-målene fra EU, er det viktig å redusere energibehovet dramatisk i en stor andel eksisterende bygninger. Dette betyr at byggherrer må øke sine ambisjoner ved gjennomføring av rehabilitering og energisparende tiltak.

En viktig drivkraft for å gjennomføre rehabiliteringsprosjekter er behovet for å opprettholde funksjonaliteten og holde lokalene attraktive for leietakere og andre brukere. For eksempel i næringsbygg er det ofte ganske åpenbare forretningsmessige relasjoner mellom byggeiere på den ene siden og leietakere på den andre. I et marked der leietakere har mulighet til å finne gode alternative steder er det viktig for et framtidsrettet eiendomsselskap å sørge for at deres bygningen er godt forvaltet, vedlikeholdt og tidsmessig pusset opp. Det gjør at de nåværende leietakerne ikke flytter ut, eller når det er aktuelt, potensielle leietakere synes det er attraktivt å flytte inn.

En stadig viktigere faktor her er reduksjon av energibehov samtidig som funksjonen opprettholdes eller forbedres. Fremtidig økning i energikostnader er sannsynlig og en reduksjon av energibehovet vil bli stadig viktigere for å holde driftskostnadene på et konkurransedyktig nivå. Det er svært sannsynlig at de krav som stilles av samfunnet om høy energieffektivitet vil bli strengere, selv for eksisterende bygninger. Det betyr at byggeiere som ikke i nær fremtid gjennomfører tiltak for å forbedre energieffektiviteten, senere kan bli tvunget til å utføre straks-tiltak som kunne vært gjennomført tidligere på en mer lønnsom måte.

1.2 Utvikling av en Total Concept-metode

Tidligere utførte energieffektiviseringstiltak i eksisterende næringsbygg i Sverige har vist at det er relativt lett å identifisere en rekke enkelttiltak som hver for seg kan redusere energibehovet i en bygning. Selv om noen av disse tiltakene kan utføres med liten kostnad, er de fleste tiltakene som reduserer energibehovet ofte forbundet med betydelige investeringer. I hovedsak må de tiltak som anses nødvendige betales av byggherren. I praksis betyr dette at følgende forutsetninger må være oppfylt:

- Investeringen som anses nødvendige for å gjennomføre de nødvendige tiltakene skal være lønnsom. Med andre ord må byggherrens økonomiske krav til langsiktige investeringer være oppfylt.
- Grunnlaget for vurdering av nødvendige investeringer og fremtidig årlig besparelse må være pålitelig.

Når energieffektiviseringstiltak gjennomføres i eksisterende bygninger er det vel så viktig at de blir utført slik at:

- Kvaliteten på bygningen og dens nytteverdi opprettholdes eller forbedres.
- Størst mulige besparelser oppnås med investeringen.

Frem til nå har byggeiere manglet verktøy som synliggjør de beste investeringsbeslutninger for å bedre energieffektiviteten i sine bygninger og på den måten spare driftskostnader. Beslutningene er ofte basert på lønnsomheten til enkelttiltak vurdert med enkle økonomiske metoder som Pay Back-metoden. Denne metoden tar som regel ikke hensyn til levetiden og endringer i energipriser. Med denne tilnærmingen blir ofte bare de veldig lønnsomme tiltakene gjennomført. Dette fører til heller beskjeden energieffektivisering i eksisterende bygninger.

For å få bukt med denne hindringen, har en ny og innovativ arbeidsmetode kalt Total Concept blitt utviklet av BELOK-gruppen i Sverige. Metoden har blitt anvendt på et begrenset utvalg av næringsbygg med suksess. Resultatene fra disse pilotprosjektene i Sverige viser at det er mulig å oppnå energibesparelser på opptil 50-70 % i eksisterende bygninger innenfor de krav til lønnsomhet som byggherren har satt.

Total Concept-metoden fokuserer på å oppnå maksimal energisparing i bygget innenfor de lønnsomhetsrammer som er fastsatt av byggeier, som utfører investeringen. Ideen med Total Concept-metoden er å ha en helhetlig tilnærming til prosessen med å forbedre bygningenes energiytelse. Ulike interessenter og sentrale aktører må ha kunnskap og være bevisst sine roller og ansvar.

Total Concept-metoden er basert på en økonomisk lønnsomhetsvurderingsmodell som er enkel å forstå. Den inkluderer i korte trekk følgende:

- En grundig gjennomgang av bygningen utføres for å identifisere mulige energisparende tiltak. Ut fra de ulike tiltakene utarbeides det en tiltakspakke som i sin helhet oppfyller byggeiers / kundens krav til lønnsomhet.
- Gjennomføring av tiltakspakken.

- Kontroll av resultatet: energibruken etter ett år blir sammenlignbar med energibruken før tiltakspakken ble implementert.

Kriteriet som avgjør hvor mange tiltak som skal inngå i tiltakspakken er at internrenten for tiltakspakken er større enn byggherrens avkastningskrav. Byggeieren / kunden bestemmer både de økonomiske betingelsene og vilkårene kapitalkostnadene er basert på. Den økonomiske modellen som benyttes i Total Concept-metoden tar også hensyn til endringer i energipriser og økonomisk levetid for investeringen.

Denne måten å arbeide på, hvor en "pakke" av tiltak utføres, gir en stor fordel når det gjelder å oppnå mye mer energisparing innen de kravene til lønnsomhet som byggets eier stiller. De mest økonomisk lønnsomme tiltakene vil hjelpe de mindre lønnsomme tiltakene. På denne måten vil det være mulig å vise at en stor reduksjon i energibruken vil være økonomisk gjennomførbar. Dette vil hjelpe til å heve byggeierens ambisjoner. Total Concept-metodene som er gjennomført, viser at det i mange tilfeller kan være mulig å nesten halvere energibruken i eksisterende næringsbygg på en lønnsom måte.

1.3 Om BELOK

Arbeidsmetoden kalt Total Concept er utviklet innenfor BELOK-gruppen. BELOK er et samarbeid mellom den svenske Energimyndigheten og Sveriges største eiere av næringsbygg, både offentlige og private. Disse medlemmene representerer 25 prosent av all næringseiendom i Sverige.

Innenfor BELOK, som ble initiert av og støttes av den svenske Energimyndigheten, samarbeider 21 eiendomsselskaper for å gi et vesentlig bidrag til energieffektivisering. Dette gjøres ved at samkjørte kriterier for energieffektivisering stipuleres i alle kontrakter i tillegg til at det utvikles og testes nye og lovende systemer, komponenter og metoder ved gjennomføring av nybygg og rehabilitering. På denne måten danner BELOK koblingen som ofte er nødvendig, men ofte mangler, slik at ny teknologi og nye metoder kan bli tilstrekkelig utviklet og testet og på den måten oppnå bred anerkjennelse for bruken. Alle resultatene av arbeidet utført av BELOK blir publisert og er tilgjengelig via www.belok.se.

Members of BELOK group (January 2017):
Akademiska Hus, Castellum, Fabege, Fortifikationsverket, Jernhusen, Locum, Göteborgs Stad Lokalförvaltningen, Malmö Stad Serviceförvaltningen, Midroc Property Development, Skolfastigheter i Stockholm, Specialfastigheter, Statens Fastighetsverk, Swedavia, Vasakronan, Västfastigheter, Hufvudstaden, AMF Fastigheter, Atrium Ljungberg, Fastighetskontoret Stockholms Stad, Skandia Fastigheter, Uppsala kommun.

1.4 Referanseprosjekter basert på Total Concept-metoden

1.4.1 Resultater fra referanseprosjektene:

De første prosjektene ble startet i 2007 for å teste og utvikle metoden. Disse innledende prosjektene ble startet i fem ulike kontorbygg eid av selskaper involvert i BELOK. Omfanget har økt med andre typer næringsbygg som skolebygg, sykehus og museer.

Så langt har omfattende tiltakspakker for energieffektivisering blitt utarbeidet for 18 eiendommer. I en rekke av disse implementeres tiltakspakkene fortsatt. I andre eiendommer er tiltakene allerede implementert, og energibruken blir nå overvåket og fulgt opp. Tre prosjekter er fullført i sin helhet, inkludert kartlegging av energibruk i et helt år etter overtakelse. Det har tatt tre til fem år å fullføre disse innledende prosjektene, blant annet fordi det krever et helt år med overvåking i ettertid.

Resultater fra pilotbyggene i Sverige indikerer at med Total Concept-metoden kan man nå lønnsom reduksjon i energibruk hos sluttbrukeren på 40-70% hvilket i enkelte tilfeller gir en forbedring ned til nesten null-energi bygg. I andre tilfeller er dette store skritt i samme retning. I mars 2010 ble det første Total Concept-prosjektet, Getholmen-eiendommen fullført. Dette kontorbygget, eid av Brostaden, ligger i Skärholmen kjøpesenter utenfor Stockholm. Energibruken ble redusert fra 200 kWh/m^2 til 86 kWh/m^2 per år og energikostnadene for de mer enn 8000 m^2 med bygningsmasse ble redusert med 58.000 Euro (493.000 NOK) per år. Oppgraderingen var lønnsom med en internrente på 13%. I følge teknisk avdeling i ulike eiendomsselskaper er den største fordelen med Total Concept-metoden verktøyet som gjør det mulig å overbevise økonomiavdelingen og ledelsen i selskapet om å ta beslutninger om store investeringer og forbedre selskapets ambisjoner til å strekke seg mot nesten null-energi bygg.

Resultater fra tre fullførte prosjekter er presentert i vedlegg1 (Appendix 1)

1.4.2 Investeringskostnader når Total Concept-metoden benyttes.

Så langt har erfaringer fra Sverige vist at innvesteringen for å innføre tiltakene fra Total Concept-metoden ligger på 600 NOK per kvadratmeter ((Kalkulert 1 Euro = 8,5 Nok)). Denne investeringen halverer byggets energiforbruk (se Tabell 1.1). Investeringskostnaden inkluderer detaljanalyse av bygningen for å kartlegge energisparende tiltak, kalkulere investeringskostnadene og energibesparelsen så vel som å utforme en tiltakspakke, prosjekteringen og implementering av tiltakspakken samt sluttkontroll.

Tabell 1.1
Investeringskostnader i avsluttede Total Concept-prosjekter utført av eiendomseiere i BELOK-gruppen. Beløpene er hentet fra de svenske prosjektene. Anslått kostnad i NOK er basert på kronekurs i januar 2016.

Kostnadspost	**Kostnad i €/m^2** (1€=8,5 NOK)
Trinn 1: Lage en tiltakspakke	3 – 4**€** (ca. 25-35 NOK)
Trinn 2: Gjennomføre tiltakene	9 – 270€ (ca.77-2.300 NOK, snitt 555 NOK)
Trinn 3: Oppfølging	1 - 2**€ (**8,5 – 17 NOK)
Total (eks. mva.)	**~ 13 – 276 €/m^2** (110 – 2350 NOK)
Årlig besparelse	**2 – 35 €/m^2 ·år** (17-298 NOK/m^2·år)

Tabell 1.2 gir en oversikt over de vanligste energisparende tiltakene som er iverksatt i de svenske pilotprosjektene.

Tabell 1.2
De vanligste energisparende tiltakene som er iverksatt i de svenske pilotprosjektene.

Type energisparetiltak
Nytt ventilasjonsanlegg med energieffektiv varmeveksler og vifte
Optimalisere luftmengden i ventilasjonsanlegget
Optimalisere driftstid og temperatur i ventilasjonsanlegg
Installere varmegjenvinner i ventilasjonsanlegg
Bytte ut vifter med reimdrift til energieffektive vifter med frekvensomformer
Installere behovsstyrt ventilasjon i definerte soner/rom/systemer
Optimalisere set-punkt for kjølesystemer.
Installere fri-kjøling
Gjenvinne kondensatorvarme fra kjølemaskiner
Bytte termostater i radiatorer og innregulere vannbårne varmeanlegg riktig
Installere nye energieffektive pumper
Bytte ut eksisterende vinduer med nye energieffektive vinduer
Etterisolere taket
Installere tilstedeværelsessensor for belysning i definerte rom/soner.
Bytte ut eksisterende belysning med mer energieffektiv belysning

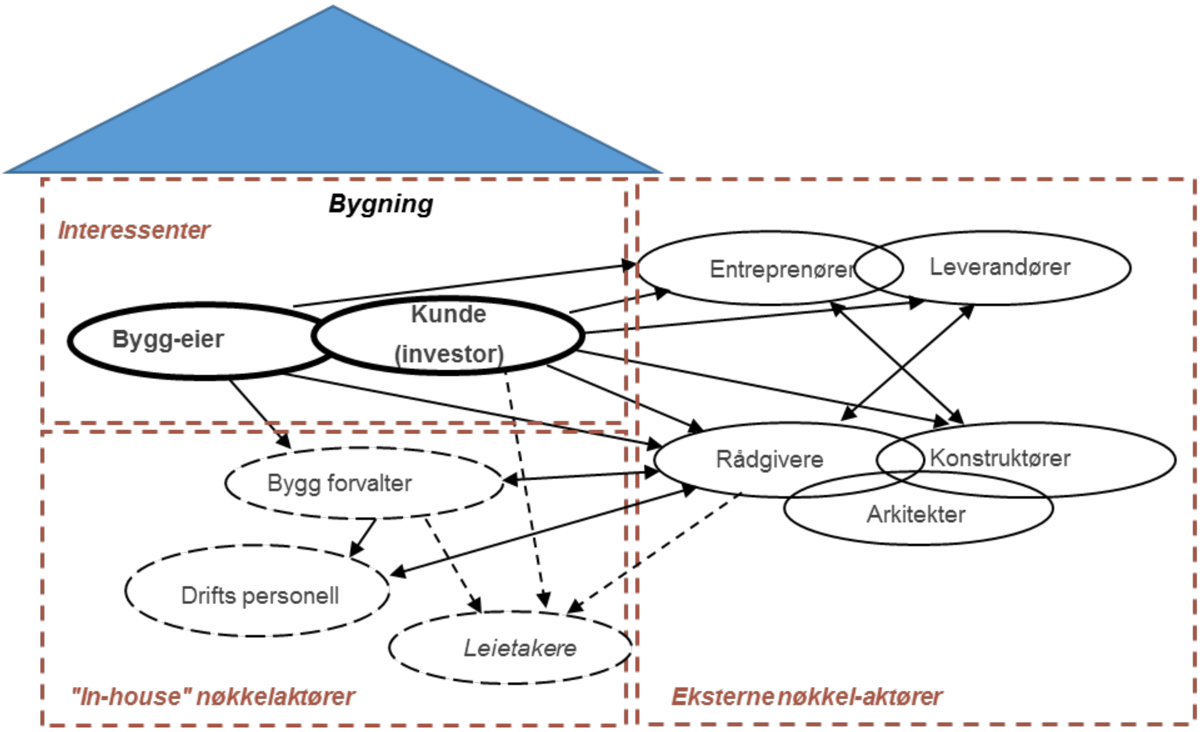
I næringsbygg kan det ofte gjøres store besparelser i ulike tekniske installasjoner slik som belysning, ventilasjon, oppvarming og kjøling. Det er relativt lett å identifisere en rekke energisparende tiltak som har stort sparepotensiale, men likevel ikke krever store investeringer. Dette er en av grunnene til at man kan oppnå gode resultater med Total Concept-metoden i næringsbygg. De mest lønnsomme tiltakene kan hjelpe de mindre lønnsomme tiltakene slik at tiltakspakken i helhet likevel tilfredsstiller byggherrens krav til avkastning.

I boligbygg er det ofte færre tekniske installasjoner og antallet lønnsomme tiltak vil derfor være begrenset. Tiltak som fører til store energibesparelser, slik som inngripen i bygningsskallet kan være svært dyre. Derfor vil det å implementere Total Concept-metoden i boliger ikke nødvendigvis føre til store energibesparelser innenfor rammene av lønnsomhet. Imidlertid kan metoden i seg selv benyttes med suksess selv i boliger.

1.5 Interessenter og sentrale aktører i Total Concept-metoden

Gjennomføring av et prosjekt etter Total Concept-metoden berører en rekke interessenter og sentrale aktører som direkte eller indirekte påvirker resultatet av energieffektiviseringsprosjektet. De ulike interessenter og aktører er beskrevet i Figur 1.1. Pilene markerer koblingen mellom de ulike partene.

Interessenter i Total Concept-metoden henviser til byggets eier/ klient. Det er de som starter opp og fullfører prosjektet basert på Total Concept-metoden. Utrykket klient kan referere til både eier og annen investor eller beslutningstaker, som har interesse i å investere i energibesparende tiltak i et bygg. Eksempel kan være en leietaker som betaler utgifter til energi selv, ESCO-bedrifter, etc.



Figur 1.1. Koblinger mellom interessenter og nøkkel-aktører involvert i Total Concept-prosjekter.

"In-house" nøkkel-aktører omfatter byggforvaltere, personer som jobber i bygget eller som jobber for byggets eier og har informasjon om hvordan bygget brukes og driftes, samt leietakere. Som sluttbrukere påvirker de i stor grad energibruken i bygget. Det er derfor essensielt at byggeieren holder dem godt informert og tar til etterretning tilbakemeldinger som kommer fra leietaker. Noen energibesparende tiltak kan også være leietakers ansvar, f.eks. tiltak i forbindelse med aktiv bruk av belysning og maskiner brukt i deres daglige virke.

Eksterne nøkkel-aktører i Total Concept-metoden er selskaper som tilbyr tjenester og produkter til byggeier/klient i forbindelse med et energieffektiviseringsprosjekt. Gruppen omfatter energirådgivere som jobber med energieffektiviseringstiltak; arkitekter og konstruktører, som står for detaljprosjektering av tiltakspakken; entreprenører og leverandører.

1.6 Veiledning til håndboken

Denne brukerveiledningen er delt inn i ulike kapitler som beskrevet nedenfor.

Kapittel 1 - Innledning gir bakgrunnen for utviklingen av Total Concept-metoden i Sverige og gir detaljer om resultatene fra de første referanseprosjektene. De viktigste interessenter og sentrale aktører i Total Concept er også beskrevet.

Kapittel 2 – De grunnleggende prinsippene for Total Concept-metoden drøfter prinsippene for Total Concept-metoden og hva som er de største fordelene. Arbeidsoppgaver og struktur i metoden presenteres.

Kapittel 3 - De økonomiske prinsippene i Total Concept-metoden beskriver internrentemetoden som er brukt for lønnsomhetsberegninger i Total Concept-metoden. Videre er valg av inndata og følgende innvirkning på resultatene forklart. *Dette kapittelet er på engelsk.*

Kapittel 4- Trinn 1 i Total Concept-metoden - Opprette en tiltakspakke og gi retningslinjer til aktører involvert i Trinn 1. Oppgaver til oppdragsgiver og rådgivere, og deres respektive ansvar når det utarbeides en tiltakspakke blir diskutert. *Dette kapittelet er på engelsk.*

Kapittel 5 - Trinn 2 i Total Concept-metoden - Gjennomføring av tiltakene drøfter viktige spørsmål ved gjennomføring av Trinn 2 i et prosjekt basert på Total Concept-metoden. Ansvaret som ligger hos henholdsvis klient, design-ingeniør/arkitekt, utførende virksomhet, vedlikeholdspersonell og eiendomsforvaltere er omtalt i tillegg til de de grunnleggende krav som må stilles i et anbud. *Dette kapittelet er på engelsk.*

Kapittel 6- Trinn 3 i Total Concept-metoden – Kontrollere resulatet tar opp viktige spørsmål i Trinn 3 i Total Concept-metoden. Deriblant de forberedelser som må gjøres før du kan begynne på Trinn 3, fordeling av ansvar, måling av energiforbruk og vurdering av lønnsomhet. *Dette kapittelet er på engelsk.*

2 De grunnleggende prinsippene for Total Concept-metoden

Dette kapittelet omhandler grunnleggende prinsipper som ligger til grunn for Total Concept-metoden. Arbeidsstrukturen og arbeidsoppgavene for implementering av metoden er presentert.

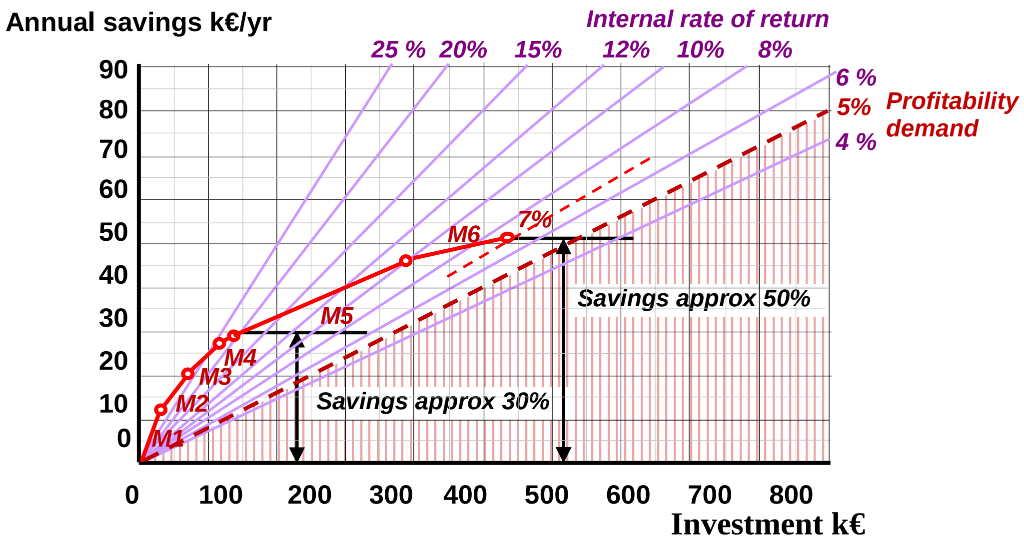
2.1 Oppsummering av Total Concept-metoden

Total Concept er en systematisk metode for å oppnå maksimale energibesparelser på en kostnadseffektiv måte.

Grunnlaget for gjennomføringen er en omfattende inspeksjon av bygningen. Det er ikke bare et spørsmål om de tilsynelatende mest kostnadseffektive tiltakene, men alle tiltak som kan ha et fornuftig energisparepotensial. Kostnad og energigevinst ved hvert enkelt tiltak estimeres og det utarbeides en tiltakspakke som i sin helhet tilfredsstiller bygningseierens krav til avkastning. Lønnsomheten er bestemt ved at internrenten for hele tiltakspakken må være høyere enn byggherrens minstekrav til avkastning.

Figur 2.1 illustrerer hvordan en tiltakspakke visuelt kan presenteres i et internrentediagram. I et slikt diagram, med reduksjon av årlige kostnader på y-aksen og investeringskostnaden på x-aksen, er det mulig, for en gitt økonomisk beregningsperiode, å legge til linjer for å representere ulike internrenter. Hvert energisparetiltak innebærer en viss kostnad og resulterer i en reduksjon av årlige driftskostnader. I diagrammet vises hvert tiltak som en strek med en viss lengde og et visst stigningstall. Stigningstallet representerer avkastningen investeringen gir. En pakke kan bli utformet ved å rangere de ulike energisparetiltakene etter lønnsomhet, det vil si at stigningstallet reduseres når tiltakene er plassert etter hverandre.

Hvor mange tiltak som skal implementeres bestemmes av at den kalkulerte avkastningen for hele tiltakspakken skal være høyere enn byggeiers krav til internrente. Det endelige resultatet av lønnsomhetsberegningen er den mest omfattende tiltakspakken som tilfredsstiller kravene til lønnsomhet fastsatt av eier/klient. Figur 2.1 illustrerer tiltakene satt i et internrentediagram. Dette er beskrevet i detalj i kapittel 2.3.



Figur 2.1. Fremstilling av en tiltakspakke med seks tiltak (M1-M6) i et internrentediagram. Diagrammet viser den faktiske avkastning, som reell internrente, som investeringen gir. Eierens lønnsomhetskrav for investeringen tilsvarer en internrente på 5%. Tiltakspakken i eksempelet gir en avkastning på 7%.

Denne måten å arbeide på, hvor en "pakke" av tiltak utføres i stedet for bare å utføre de isolert sett lønnsomme tiltakene, gjør flere tiltak lønnsomme. De mest lønnsomme tiltakene gjøre opp for de investeringene som, på egen hånd ville ha vært ulønnsomme. Slik at tiltakspakken som en helhet fortsatt er lønnsom. På denne måten kan en betydelig større energireduksjon oppnås enn ved å gjennomføre kun de isolert sett lønnsomme tiltakene. Dette er essensen av Total Concept-metoden.

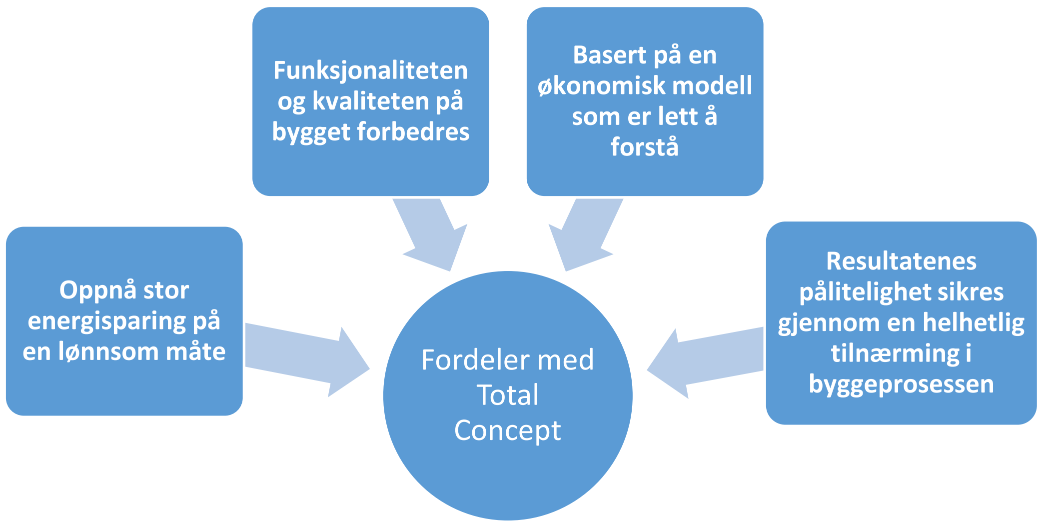
I eksempelet i Figur 2.1 er lønnsomhetskravet at internrenten er på minst 5%. Hele tiltakspakken (M1-M6) tilfredsstiller kravet med 7% og fører til en halvering av årlige energikostnader, hvilket også tilsvarer å halvere energiforbruket. Dersom kun de tiltakene som alene var lønnsomme (M1-M4) ble utført ville besparelsen bare ha vært 30%. Hele tiltakspakken blir lønnsom i og med at de lønnsomme tiltakene bærer de andre tiltakene. Det ville vært en ulempe først å utføre de mest lønnsomme tiltakene og utsette de andre til et senere tidspunkt. På den måten ville tiltakene som alene ikke var lønnsomme, men likevel viktige sett ut fra et energisparende perspektiv, høyst sannsynlig aldri blitt gjennomført. Dette fordi det ikke lenger er lønnsomme tiltak som ville veie opp for kostnaden.

Det må understrekes at Total Concept metoden baserer seg på at tiltakspakken utføres i sin helhet.

2.2 De største fordelene med Total Concept-metoden

De største fordelene med Total Concept-metoden er illustrert i Figur 2.2 og beskrevet under.

Å oppnå større energibesparelser på en økonomisk lønnsom måte.
Total Concept-metoden kan, på en kommersielt lønnsom måte, utløse store deler av energisparepotensialet som finnes i næringsbygg. Metoden bygger på en grundig analyse av bygget i sin helhet der alle mulige tiltak som kan føre til vesentlige besparelser blir identifisert. Tiltakene blir utført som én tiltakspakke. De mest lønnsomme tiltakene betaler for de tiltakene som alene ikke er lønnsomme, men likevel viktige sett i et energispareperspektiv.



Figur 2.2. De største fordelene med Total Concept-metoden.

Byggets funksjon og kvalitet forbedres
Implementering av metoden fokuserer på å beholde eller forbedre byggets funksjon og kvalitet. Metoden kan bli inkludert i totalrenoveringer. Da vil ekstra investeringer for å oppnå bedre energieffektivitet bli analysert. Når man kombinerer metoden med en totalrenovering, vil investeringskostnaden til energisparetiltak kunne optimaliseres.

Basert på en økonomisk modell som er enkel å forstå.
Oppgraderende energitiltak sees gjerne på som en langtidsinvestering, da levetiden til oppgradering ofte er lang. Derfor bør økonomiske modeller som viser investeringspotensialet brukes. Samtidig må modellene være enkle for beslutningstakerne å forstå. I Total Concept-metoden er internrente benyttet i lønnsomhetsanalyse. Metoden viser avkastning uttrykket som internrenten investeringen genererer. Nå en tiltakspakke utarbeides tas det hensyn til fremtidig endring i energipriser i tillegg til at tiltakspakkens egen levetid tas i betraktning.

Påliteligheten av resultatene er sikret gjennom en helhetlig tilnærming i hele prosessen
Total Concept-metoden gir en helhetlig tilnærming i prosessen med å forbedre byggets energieffektivitet. Arbeidsprosessen er strukturert med klart definerte oppgaver, roller og ansvarsområder for de ulike aktørene som er involvert. Hele energioppgraderingsprosessen må følges opp slik at det ikke gjøres ubevisste valg som kan påvirke energibesparelsen.

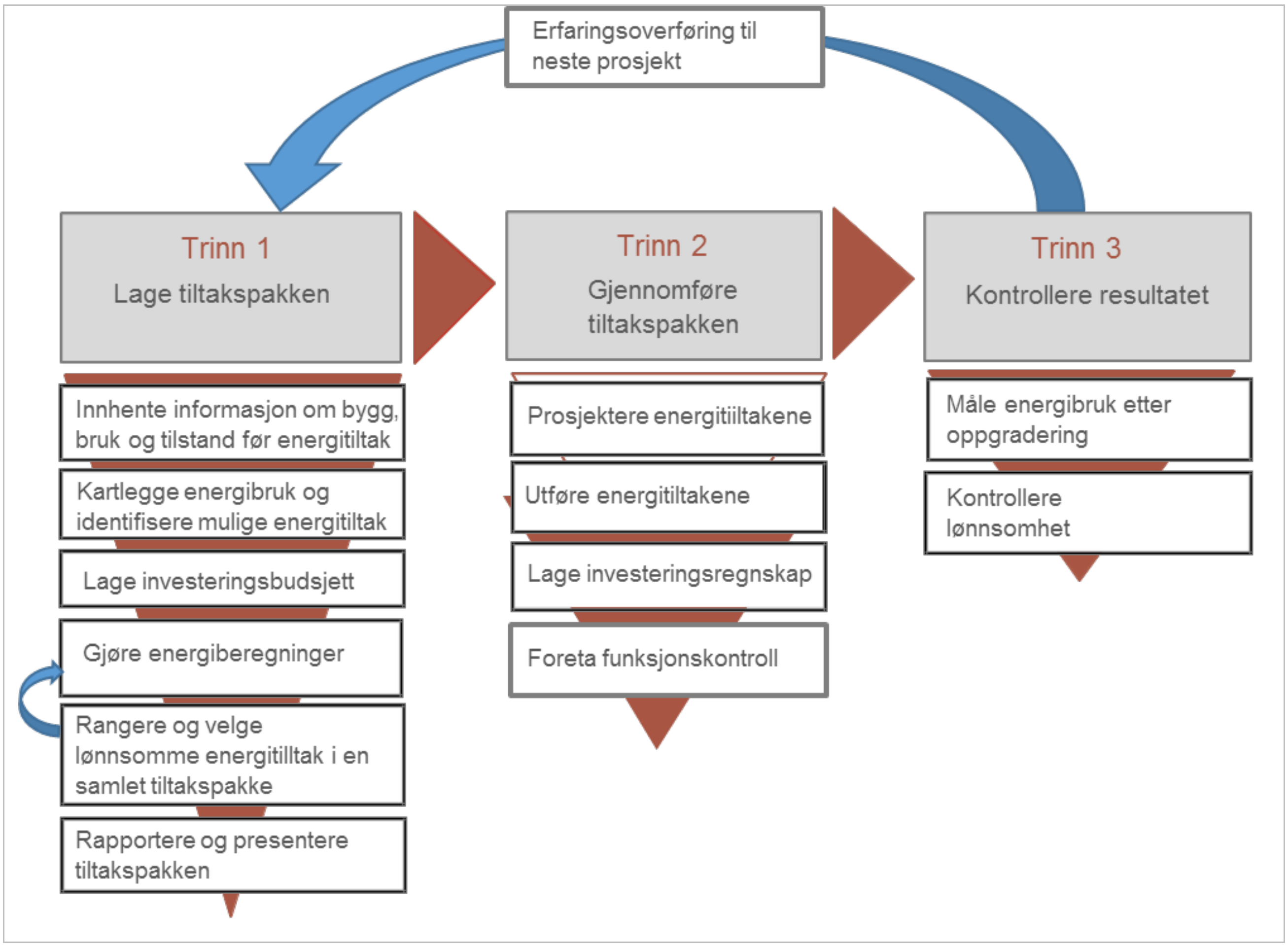
2.3 Total Concept-metoden

2.3.1 Arbeidsstruktur

Hovedtanken rundt Total Concept-metoden er å ha en helhetlig tilnærming til bedring av byggets energieffektivitet. En systematisk tilnærming og profesjonell utførelse er viktig. Det må være god kunnskap og bevissthet blant ulike interessenter og sentrale aktører og de må være sine roller og ansvar bevisst. For å sikre en slik systematisk tilnærming er arbeidsprosessen i Total Concept-metoden delt opp i tre trinn:

- Trinn 1 – Lage en tiltakspakke
- Trinn 2 – Gjennomføre tiltakene
- Trinn 3 - Oppfølging med kontroll av resultatet

Arbeidsstrukturen i Total Concept-metoden er illustrert i Figur 2.3. Hvert trinn innebærer en rekke ulike oppgaver som skal utføres og krever medvirkning fra interessenter og sentrale aktører. Dette beskrives mer detaljert i de neste kapitlene.



Figur 2.3. Visuell fremstilling av arbeidsstrukturen i Total Concept-metoden. Arbeidet er delt inn i tre trinn: Trinn 1 - Lage tiltakspakken; Trinn 2 – Gjennomføre tiltakspakken; Trinn 3 – Kontrollere resultatet. Den strukturerte arbeidsformen gjør det enklere å følge opp gjennomføringen og overføre erfaring mellom prosjekter.

2.3.2 Trinn 1 – Lage en tiltakspakke

I Trinn 1 gjennomføres det en grundig teknisk analyse. En tiltakspakke blir satt sammen. Pakken inkluderer tiltak som i sin helhet fører til store energibesparelser, og samtidig oppfyller byggeiers lønnsomhetskrav.

Resultatet fra Trinn 1 legger grunnlaget for beslutningen om hvorvidt man vil investere i tiltakspakken eller ei. En forutsetning for å ta en slik beslutning er at grunnlaget er lett å forstå både fra et økonomisk og et teknisk ståsted. En annen forutsetning er at det er mulig å stole på at kalkulerte besparelser faktisk vil bli oppnådd og at den reelle kostnaden vil bli slik den fremgår i investeringskostnadsberegningene. Nøye analyse er avgjørende for at prosjektet skal bli en suksess. Samarbeid mellom energi-konsulenter, byggeiere/klienter, eiendomsforvaltere og vedlikeholdspersonell er en forutsetning for et godt resultat.

Trinn 1 kan deles inn i følgende hovedoppgaver:

- Innhenting av informasjon om bygget med tilhørende teknisk data.

- Energianalyse og identifisering av energibesparende tiltak.
- Estimert investeringskostnad for hvert tiltak.
- Energiberegninger.
- Lønnsomhetsberegninger og opprettelse av en tiltakspakke.
- Rapportering og presentasjon av forslag til tiltak som skal iverksettes.

Trinn 1 i Total Concept-metoden starter med en detaljert teknisk vurdering av bygget. Generell informasjon om bygget og relevant teknisk data samles inn. En omfattende energianalyse gjennomføres og mulige tiltak identifiseres. Det er ikke snakk om bare tiltak som ser ut til å være mest kostnadseffektivt, men alle tiltak som kan ha et fornuftig energisparepotensiale. Energisimuleringer utføres for å estimere besparelsen for hvert av tiltakene. En helhetlig tilnærming benyttes når det utføres en teknisk vurdering av bygningen. Vurderingen er vesentlig grundigere enn det som blir lagt til grunn for energimerking, selv om data fra en slik energimerking kan brukes som et utgangspunkt. Grundig analyse er avgjørende for å velge riktig tiltakspakke og nå ønsket energireduksjon. Det er derfor viktig at konsulenten som er engasjert er spesialisert innen energivurderinger av næringsbygg. Konsulenten må også kunne bruke energiberegningsprogrammer og ha tilgang til gode kostnadstall for å beregne investeringskostnader riktig.

Investeringskostnadene vurderes for hvert enkelt tiltak, men tar hensyn til at samtidighet i utføring av tiltakene påvirker kostnaden. Byggeieren/klienten fastsetter de økonomiske vilkårene som ligger til grunn for investeringskostnadene. Dette inkluderer blant annet å vurdere hvorvidt klientkostnader og kostnader forbundet med planlegging og design skal inngå. Det er svært vanlig at bygningen på grunn oppgraderes av andre årsaker enn energieffektivisering. Når bygget likevel skal oppgraderes ønsker man å vurdere muligheten for å energieffektiviser i tillegg.

I beregningene er tiltakene rangert etter lønnsomhet basert på internrentemetoden. Lønnsomhetsberegningene kan gjøres ved å benytte Total Concepts beregningsverktøy Total-tool. Resultatet av lønnsomhetsberegningen er internrenten, som fra et energisparingsperspektiv, korresponderer med den mest omfattende tiltakspakken som kan iverksettes og likevel møter lønnsomhetskravene byggeieren eller klienten har satt.

2.3.3 Trinn 2 – Gjennomføre tiltakene

Trinn 2 i Total Concept-metoden skal bidra til at energisparetiltakene i tiltakspakken gjennomføres i sin helhet. Trinn 2 er basert på grundig planlagt innkjøp, prosjektering og utførelse. I utgangspunktet er disse tre stegene de samme som i ethvert rehabiliteringsprosjekt. Trinn 2 kan deles inn i følgende tre hovedoppgaver:

- Planlegge og utvikle tiltakene
- Byggearbeid og installasjon
- Funksjonskontroll

En rekke tiltak i tiltakspakken vil være så enkle at de kan utføres uten noen spesiell form for forberedelser. Andre tiltak må detaljplanlegges og utføres av entreprenør. Her må også leietakere og byggets brukere tas i betraktning.

Arbeidet ferdigstilles ved å gjennomføre omfattende funksjonskontroll slik at alle feil er identifisert og korrigert før tiltakspakken evalueres. Dette er viktig å gjøre for å forsikre seg om at alle tiltakene fungerer som tenkt. Hvis for eksempel et oppgradert ventilasjonsanlegg ikke fungerer som forutsatt, vil en stor del av energibesparelsen gå tapt.

I Trinn 2 er det også nødvendig å starte planlegging av oppfølgingsarbeid i trinn 3 og forsikre seg om at energibruken i bygget lar seg måle i ettertid. Dette kan påvirke oppdeling i elektriske kurser og gi behov for å installere ekstra energimålere. En eller annen form for systemovervåking som en del av byggets driftssystem er ofte allerede på plass, men noen tillegg kan være nødvendig. Disse tilleggene bør implementeres samtidig som selve energisparetiltaket utføres. Dette er både viktig og nødvendig å kunne følge opp de reelle kostnadene forbundet med tiltakspakken.

2.3.4 Trinn 3 – Oppfølging

Hensikten med Trinn 3 er å følge opp energibruken etter at tiltakspakken er implementert og å kontrollere lønnsomheten av tiltakspakken.

Trinn 3 kan deles i følgende hovedoppgaver:

- Måle energiforbruk
- Kontrollere lønnsomheten

Når det er bekreftet at alt fungerer som det skal i Trinn 2 kan energibruken følges opp ved å foreta månedlige avlesninger i minst ett år. Resultatene fra målingene brukes i endelig lønnsomhetsanalyse.

Når bygget er i bruk og det foretas innhenting av data, er det viktig å være bevisst på hvordan bygget faktisk brukes. Målet er å se hvorvidt det er avvik mellom den reelle bruken og den antatte bruken i trinn 1 og 2. Bruken kan ha endret seg i forhold til det som var antatt, en del av bygget kan stå tomt. En oppfølgingsundersøkelse i ettertid er nødvendig slik at avvik mellom forventet og faktisk bruk kartlegges og kan gi forklaring på resultatet.

For å kontrollere lønnsomheten, legges målt energibruk fra trinn 3 og den reelle investeringskostnaden fra trinn 2 til grunn for å bestemme den reelle internrenten for hele tiltakspakken. Dette blir så sammenliknet med internrenten som ble kalkulert i Trinn 1. Hvis det finnes avvik mellom forventede og faktiske resultater, er det viktig at man finner årsaken til avvikene, og bruker denne kunnskapen i neste Total Concept-prosjekt.

3 The economic principles of the Total Concept method

This chapter discusses the economic principles and terminology on which the Total Concept method is based. The selection of input data and its impact on the results is explained as well as how the internal rate of return method works, which is applied for profitability calculations in the Total Concept method.

3.1 Introduction

Economic calculations in the building sector may have different objectives:

- Provide a basis for decision making whether to carry out an investment or not;
- Prioritize between alternative technical solutions;
- Size systems or parts of systems in a certain building.

The first objective counts for the case when an investor has to make a choice if invest or not. As an example this might be the case when deciding if and in what extent energy renovations should be carried out. A starting point here is a defined profitability the investment has to provide. There is a number of different economic models for profitability determination. Most of them give the same result, presupposed same economic input data are used.

The second objective applies when the decision on investment is already made, but there are different possible systems and devices to choose from. Then the aim is to identify the profitability of different solutions and not to find out if the investment itself is profitable or not.

The third objective applies in the design phase for when dimensioning specific building components. This is a part of the design process.

In the case of Total Concept method it is the first objective that counts, i.e., forming a basis for investment decisions. In the following the focus is the model for profitability assessment in the Total Concept method.

3.2 Basic concepts and terminology used in the profitability calculations

There are some basic concepts of the profitability calculations that have a great impact on the overall results, e.g. selection of calculation interest rate (the cost of capital), estimation of relative price change and choice of a calculation period for the investment, etc. It is important to fully understand these basic concepts and input data.

3.2.1 Interest rate, the present value of savings and capital cost

To determine whether an investment is profitable or not, all costs and savings related to an investment proposal should be known. However, if the question of profitability is to be answered correctly, it must also be possible to consider the value of money on a time scale. Money that is available today has an actual worth that is more than future income. The relationship between the present value of money and future income is determined by *the interest rate.*

The interest rate set for the calculations gives a picture of how the company estimates future assets in relation to present assets. The owner of an amount of money can decide whether to keep its money, invest it or lend it out in order to have a profitable return over a period of years. The interest rate must be sufficiently large in order to make an investment or to take a loan. It must be an interesting prospect compared to keeping the money or using it for some other purpose.

How the rate of interest affects the present value of money is illustrated in Fig. 3.1. For example, when investing a certain amount A_0 (€) today with the annual yield of the deposited amount i, then after n years the amount will have grown to an amount A_n (€). How high the amount A_n (€) will be depends on the rate of interest i. The higher the interest rate the higher the amount A_n (€). If instead after n years a certain amount A_n (€) is received the value of it today would be A_0 (€). This value will be lower when the rate of interest is high. The value A_0 (€) today of an amount A_n (€) that will be paid out in n years is called *the present value of a single amount.*

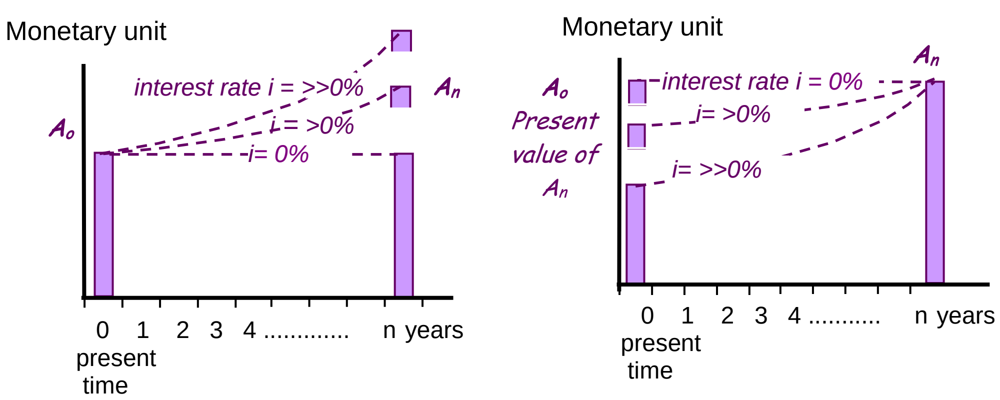


Figure 3.1 Illustration of how the rate of interest affects the present value of money.

The present value A_0 (€) of a single amount A_n (€), which is received after n years in the future, can be calculated as follows:

$$A_o = A_n \cdot i(i,n)$$

The Net present value factor for individual yields *i(i,n)* is a function of an interest rate *i* and economic calculation period *n* and can be calculated or easily obtained from a table, see Appendix 2.

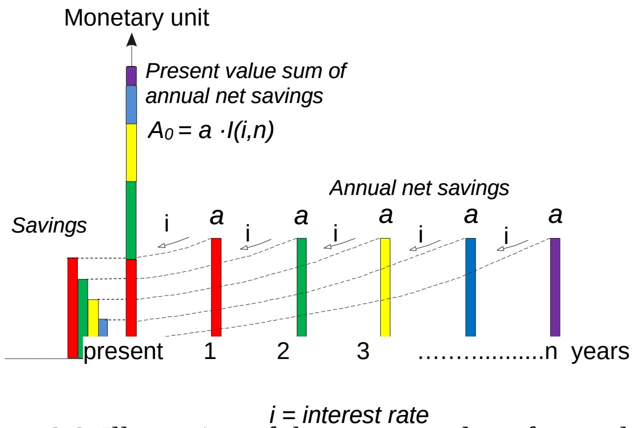
> *Example:*
> Borrowing money A_0= 1000 € with the interest rate of 10 % means that the single payment of the loan after 10 years must be: $A_n = A_0 \times 1/i(10,10)$ = 1000 x (1/0.3855) ≈ 2600 €.
>
> Receiving back amount of money A_n= 1000 € after 10 years is with the interest rate of 10 % worth today: $A_0 = A_n \times i(10,10)$ = 1000 x 0.3855 ≈ 390 € .
>
> In this example the net present value factor for individual yields is *i(10,10)* = 0.3855

Every energy saving measure leads to certain cost saving in annual operational costs over a certain economic lifetime. To evaluate what is the present value of annual savings received in the future each annual saving is discounted to the present point in time and summed. Sum of the present values of each annual net saving is defined here as present value sum of net savings. This is illustrated in Fig. 3.2.

The present value sum A_0 (€) of annual net savings *a* (€/yr), which are saved every year up to *n* years in the future, can be calculated as follows:

$$A_o = a \cdot I(i,n)$$

The net present value factor *I(i,n)* is a function of an interest rate *i* and economic calculation period *n* and can be calculated or obtained from a table, see Appendix 2.



> *Example:*
> Existing windows are to be replaced by triple glazing. The net savings are calculated to be 10 000 € per year.
>
> At a calculation interest rate 4% over a economic calculation period 20 years, the net present value factor will be *I(4,20)* = 13.6
>
> Present value sum of annual net savings:
> A_0 = 10 000 x 13.6 = 136 000 €

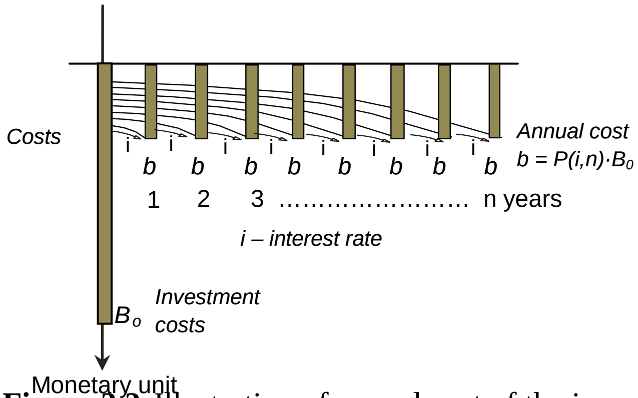
Figure 3.2 Illustration of the present value of annual net savings. For each annual saving the present value can be calculated to the present point in time and summed.

Assuming that the investment for energy saving measure(s) is made through a bank loan with interest rate *i*, then it is common that the loan is paid back to the bank on an ongoing basis. In order to evaluate these payments done to the bank the investment is recalculated to an annual cost, evenly apportioned over the calculation period. Evaluation of annual capital cost is illustrated in Fig. 3.3.

If an amount B_0 (€) is invested, to be repaid over the following n years, then the annual cost of investment (annual capital cost) b *(€/year)* can be calculated as follows:

$$b = B_0 \cdot P(i,n)$$

The annuity factor $P(i,n)$ is a function of an interest rate i and economic calculation period n and can be calculated or easily obtained from a table, see Appendix 2.



Example:
An investment of 10.000 € needs to be paid back within 10 years with the interest rate 6%.What will be the annual cost of the investment?

The annuity factor is *P(6,10)* = 0.13597

The annual cost of the investment is:
b = 10.000 x 0.13597 ≈ 1.360 €/yr

Figure 3.3 Illustration of annual cost of the investment. An investment B_0 (€) is recalculated to an annual cost b *(€/year)*, evenly apportioned over the calculation period.

3.2.2 Nominal interest rate and real interest rate

Investments are normally made on the supposition that they will be repaid using future incomes or savings. However, in actual amounts of money, the future incomes or savings will become greater because of future relative price changes, inflation. This is illustrated in Figure 3.4.

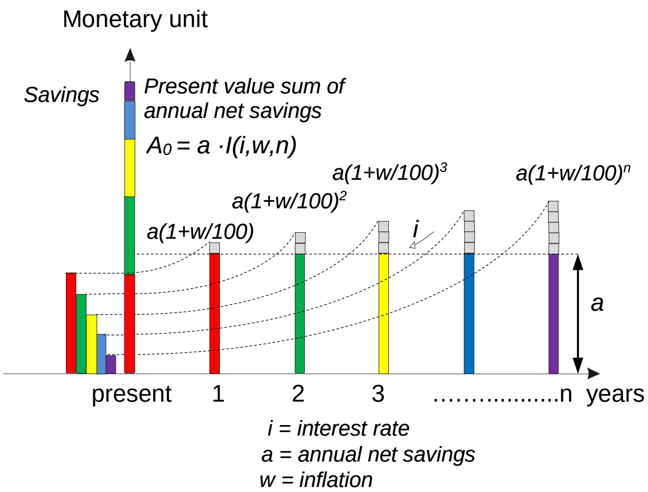


Figure 3.4 Illustration of future relative price changes, inflation. The present value sum of net savings A_0 rises with the size of the future price changes.

In a normally functioning economy there is a continual increase in the price of goods and services and, consequently, a continual reduction in the value of money. In Europe, the rate of inflation is around 2 to 3 % per year.

However, the capital cost (€/yr), amortization and interest will remain the same at their nominal values. This is taken into account in the *nominal interest rate* i_n, which is the rate of interest current at the time making investment (today) and is consequently higher than it would have been if there had been no inflation. Nominal interest rate is for example interest rate required at the bank loan.

If nominal interest rate is used as a starting point, then inflation must be considered when determining the profitability of an investment. On the other hand, inflation can be seen as a change in a scaling factor. Inflation can be taken into account as follows:

$$A_o = \left(\frac{1-\left(\frac{1+i_n/100}{1+w/100}\right)^{-n}}{\frac{1+i_n/100}{1+w/100}-1} \right) \cdot a = I(i_n, w, n) \cdot a$$

where $I(i_n,w,n)$ is a net present value factor which also includes inflation.

The net present value factor $I(i_n,w,n)$ is not included in tables in standard financial publications nor is it readily available. However, when working practically with profitability calculations taking into account future price changes can be conveniently done with a good approximation:

$$I(i_n,w,n) \approx I(i_n - w,n)$$

The error due to this approximation depends on the nominal interest rate i_n, size of inflation w and economic calculation period n and is less than 3% for nominal interest rates in between 5 to 15%, for inflation rate less than 4% and for economic calculation periods up to 30 years [3]. The financial limits for investments are lowered slightly if the approximation $I(i_n,w,n) \approx I(i_n - w,n)$ is used but the discrepancy is small compared to the uncertainties that are always connected to investment assessments. When energy saving measures in an existing building are evaluated there is always a degree of uncertainty when assessing the cost of a single measure and what it will result in, in terms of energy savings. It is therefore reasonable to accept a number of mathematical approximations when handling financial issues, if they contribute significantly to simplifying matters. One such approximation is relevant when the future relative price changes are taken into consideration.

The rate of interest that excludes inflation is called the *real interest rate* i_r, and is, approximately, the nominal rate of interest i_n reduced by the annual change of the average level of costs w expressed as a percentage: $i_r \approx i_n - w$ %,

3.2.3 Future relative price changes of energy

The reasoning above is only true if all prices roughly follow the rate of inflation. If any part of the gains resulting from an investment does not follow the general rate of inflation, then this must be taken into account. It is reasonable to assume that the future price of energy will increase more than the average rate of inflation and this must be addressed when determining the cost effectiveness of energy saving measures. And this is most often the case.

The same arguments can be used here as for inflation. If it is assumed that the annual relative energy cost increase is q % more than the average increase in prices, then the real interest rate r can be corrected by deducting the rate q %: $i_{adj} \approx i_r - q$ %. The real interest rate that takes into account relative energy price change above inflation q % is called here the *adjusted real interest rate* i_{adj} .

Please note: Adjusting the calculation interest rate with energy price change above inflation is applicable in the situations where the majority of the annual net savings consist of energy savings and the savings in other annual costs, e.g. maintenance cost, is a marginal part of total annual net savings. However, when the savings in other operational costs than energy cost become important part of total savings, then taking into account the impact of relative price change needs more detailed calculation. This can easily be done with the calculation tool, *Totaltool* (see chapter 3.4).

The assumption of future relative energy price change above inflation q % must be decided by the property owner. The energy price change estimation is different for different countries in EU. There are no common national guidelines in Sweden what relative energy price change should be taken into account. Some Swedish property owners estimate this price change to be about 2 %.

3.2.4 Calculation interest rate (the cost of capital)

One way in which a company's financial requirements can be expressed is by specifying the level of the rate of interest, *the calculation interest rate (the cost of capital)*, to be used when assessing profitability.

The requirement of profitability can be combined with complementary terms and conditions. However, defining the calculation interest rate is perhaps the most fundamental means of control to ensure profitability when taking into account a company's financial situation and investment discipline. Decisions regarding the calculation interest rate are therefore always a question for the management. Only the management of a company, sometimes in consultation with the board of directors, can decide on the calculation interest rate and on any and every change which it is subject to. Put somewhat more simply, the decision about the calculation interest rate is based partly on the actual rate of interest for invested capital, for example a bank loan, and partly on the company's general financial situation and long-term plans. The calculation interest rate is therefore the rate of interest that has to be paid on investment capital with an investment mark-up that is determined by the company's solidity, liquidity, borrowing capacity, alternative investment opportunities, long-term ownership, etc.

The calculation interest rate can be *nominal calculation interest rate* $i_{c,n}$, i.e. it includes assumptions about inflation, or *real calculation interest rate* i_c, i.e. it excludes the effects of inflation. If a nominal rate of interest is used, then inflation must be included in an investment analysis. If energy price increases above inflation are expected, *the adjusted real calculation interest rate* is used, i.e. $i_{c,adj.} = i_c - q\ \%$, where $q\ \%$ is the relative energy price increase in addition the average change in prices (inflation).

Fig 3.5 summarizes the various concepts of interest rates and how they are related to each other.

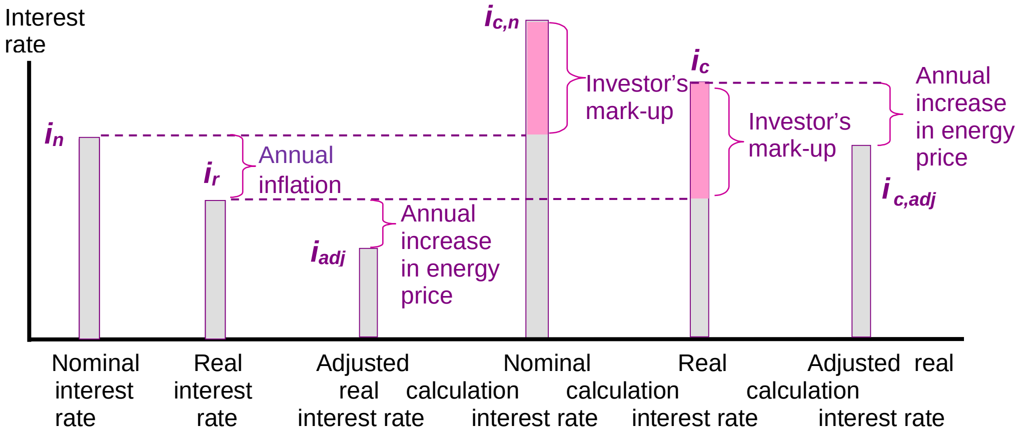


Figure 3.5 Different concepts of interest rates. The real calculation interest rate or adjusted real calculation interest rate are used in profitability calculations.

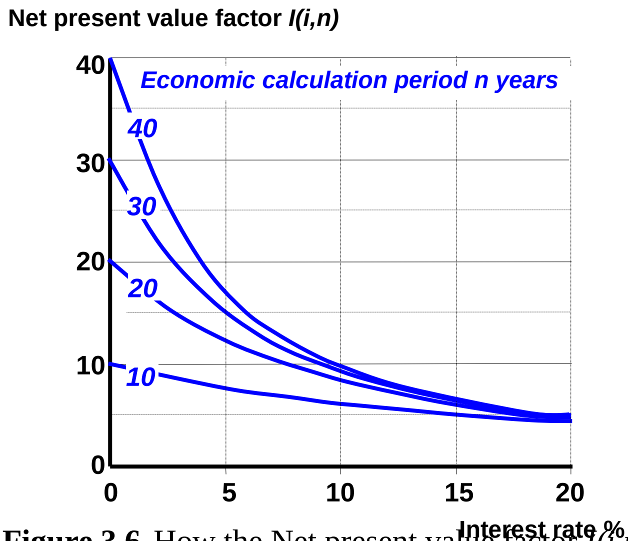
Example:
The numerical example below illustrates the relationship between the various concepts of interest rate. It is the client, the investor, who determines which values apply in each case.

Interest rate	***Value***
Nominal interest rate i_n, in this case the bank interest rate	i_n = 4%
Nominal calculation interest rate $i_{c,n}$ with 3% investor´s mark-up	$i_{c,n}$= 4% + 3% = 7%
Real interest rate i_r assuming 2% annual inflation	i_r= 4% - 2% = 2%
Real calculation interest rate i_c with 3% investor´s mark-up	i_c= 2% + 3% = 5%
Adjusted real calculation interest rate $i_{c,adj}$ with 2% future relative energy price increase above inflation	$i_{c,adj}$ = 5% - 2% = 3%

3.2.5 Selection of a calculation interest rate

The selection of a calculation interest rate as well as economic calculation period has a great impact on the profitability of an investment in feasibility calculations.

Fig. 3.6 illustrates the size of the Net present value factor *I(i,n)* and how it varies depending on interest rate *i* and economic calculation period *n*. It can be seen that a low interest rate means that future savings will have a high value compared to a saving of the same amount made today. It can also be seen that the influence of the economic calculation period is reduced as the interest rate increases. A low interest rate is beneficial to investments with long economic calculation periods even if the returns are low. A high interest rate will tend to be used for investments with high returns even if the economic calculation period is short.

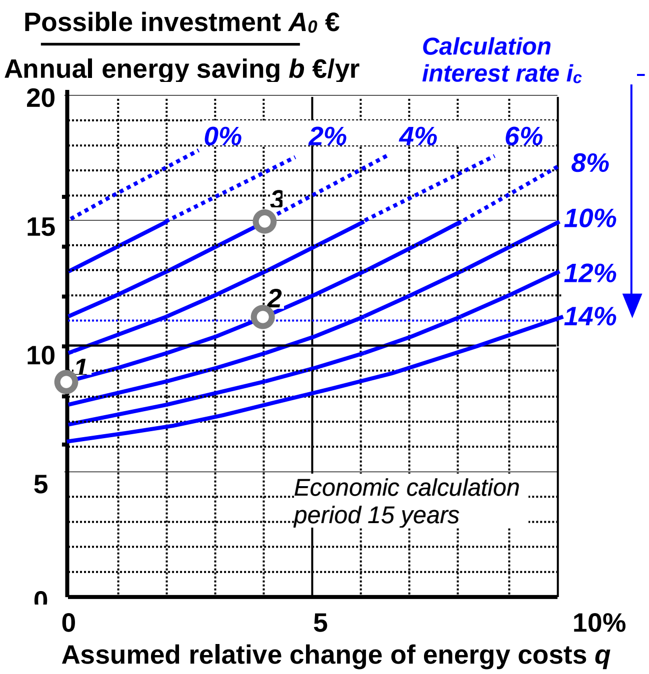


Main remarks:

- A low interest rate means that future savings will have a high value compared to a saving of the same amount made today.
- The influence of the economic calculation period is reduced as the interest rate increases.
- A low interest rate is beneficial to investments with long economic calculation periods even if the returns are low.
- A high interest rate will tend to be used for investments with high returns even if the economic calculation period is short.

Figure 3.6 How the Net present value factor *I(i,n)* varies depending on interest rate *i* and economic calculation period *n*.

Furthermore, the assumption that an income or saving that is used to pay off an investment will increase in value more than inflation means, in practice, that the calculation interest rate is reduced. This has a major effect when calculating the profitability of an investment. As an example, Fig. 3.7 shows how the choice of calculation interest rate and assumptions about future relative energy price increases affect the profitability assessment.



Example:

A certain measure will save 20 000 €/year at present energy prices.

1. If *the calculation interest rate is 8 %,* it would be profitable to invest up to
   8.5 · 20 000 = ***170 000 €***
2. With the same *calculation interest rate*, *8 %*, but assuming that energy prices will rise by *4 %* more per year than average inflation it would be profitable to invest up to
   11 · 20 000 = ***220 000 €***
3. If *the calculation interest rate is 4 %*, and it is assumed that energy prices will rise by *4 %* more per year than average inflation it would be profitable to invest up
   15 · 20 000 = ***300 000 €***

Figure 3.7 The effect on the profitability calculation of the choice of calculation interest rate and assumptions about future energy prices increases.

The diagram in Fig. 3.7 is valid for an energy measure that has an economic calculation period of 15 years. For a measure with a longer period, the curves will be steeper, i.e. the assumptions about future energy price increases will have a greater effect.

In a profitability calculation that is used to provide a basis for a decision to carrying out an investment it must be perfectly clear which rate of calculation interest rate has been used and if the future energy price increases are taken into consideration and which future energy price increases have been assumed.

3.2.6 Concepts of time in profitability calculations

Different concepts of time are often used when carrying out profitability calculations and they can have completely different meanings when used in the building and property sectors, and when assessing energy measures. When applying the Total Concept method it is therefore necessary to explain how different periods of time are defined and to advise property owners/clients of important aspects when choosing periods for profitability calculations.

Technical lifetime
The term technical lifetime refers to the length of time that an energy performance improvement measure can be regarded as technically useful, i.e. the time span for which the investment will function in a satisfactory way and fulfill the stipulated technical requirements.

Economic lifetime
The term economic lifetime refers to the length of time that an energy performance improvement measure can be regarded as being economically profitable.

European Commission recommends that member states must strive towards using the CEN 15459 [1] standard when deciding on which economic lifetimes are to be used for different energy efficiency improvement measures. The standard states economic lifetimes for a number of components and products but not, for example, for measures taken that affect the building envelope, or the use of solar cells. The recommended lifetimes for the measures that are not included in the standard can be found at [2].
In Appendix 3 the recommended lifetimes for different measures are shown.

Economic calculation period
This is the length of time over which the profitability calculations are valid. The calculation period is decided by the property owner/client. For example, the calculation period for a technical system could be 30 years even if its economic lifetime of that technical system is only 15 years. A reason for this might be that the technical system makes up part of a larger complex system and the calculation period for the complex system as a whole is 30 years.

Depreciation time
This is an accounting term that states during which length of time an investment is written off.

3.3 Internal rate of return method

The profitability assessment in the Total Concept method is based on the internal rate of return model.

3.3.1 The principles of the internal rate of return method

One way in which the profitability of measures requiring heavy investments can be assessed is to see what the actual yields, expressed as an interest rate, the investment creates. This rate of interest is called the *internal rate of return* and is equal to an interest rate that will provide a present value sum of annual net savings that is equal to the actual investment.

If an investment of B_o (€) results in an annual reduction of operating costs of a (€/year), the *internal rate of return* r_i of the investment can be derived from:

$$a \cdot I(r_i,n) = B_o \Longrightarrow a = \frac{1}{I(r_i,n)} \cdot B_0 = P(r_i,n) \cdot B_0 \Longrightarrow \frac{a}{B_o} = P(r_i,n)$$

The criterion for profitability is that the internal rate of return is higher than the stipulated calculation interest rate. The internal rate of return method is illustrated in Fig. 3.8.

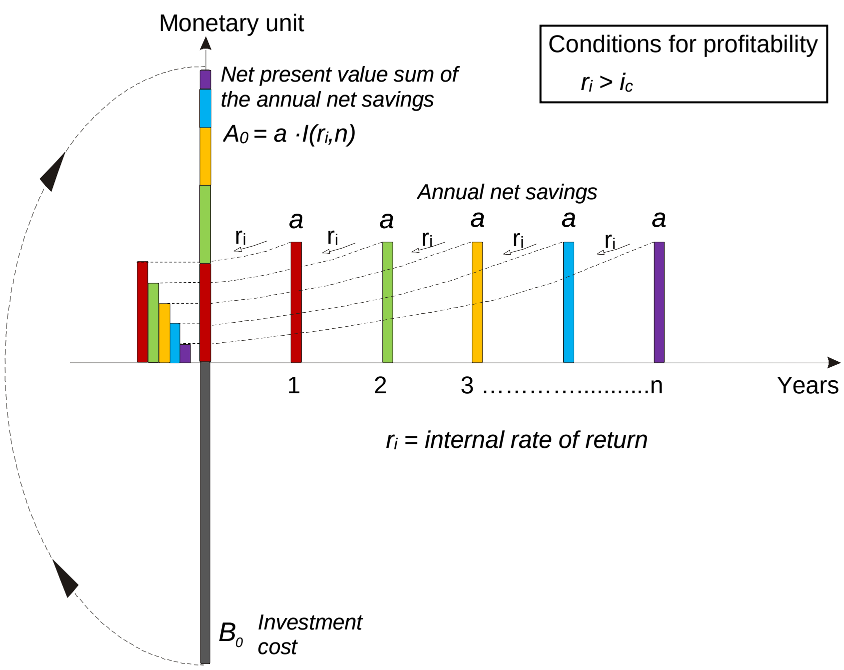


Figure 3.8 Illustration of the internal rate of return method. The internal rate of return corresponds to the interest rate at which the net present value sum of the annual net savings is the same as that of the actual investment.

The internal rate of return of an investment can also be illustrated with a help of a diagram. In such a diagram with the *x*-axes corresponding to an investment B_o and *x*-axes corresponding to annual savings *a*, for a given economic calculation period *n*, lines with slopes representing different internal rates of return can be drawn. The diagram is called an *internal rate of return diagram* and is illustrated in Fig. 3.9. The annuity factor $P(r_i,n)$ is the tangent, i.e. the slope, of a line from the origin.

If an investment and its corresponding annual savings are plotted in an internal rate of return diagram, it is possible to read off the internal rate of return that the investment results in (see Fig. 3.9). The criterion for profitability is that the internal rate of return must be higher than the stipulated real calculation interest rate.
This profitability limit can be illustrated on a diagram with an internal rate of return line corresponding to the value for real calculation interest rate. All investments that lie above this line are considered to be profitable, investments below this line are considered to be not profitable. See example on Fig. 3.9.

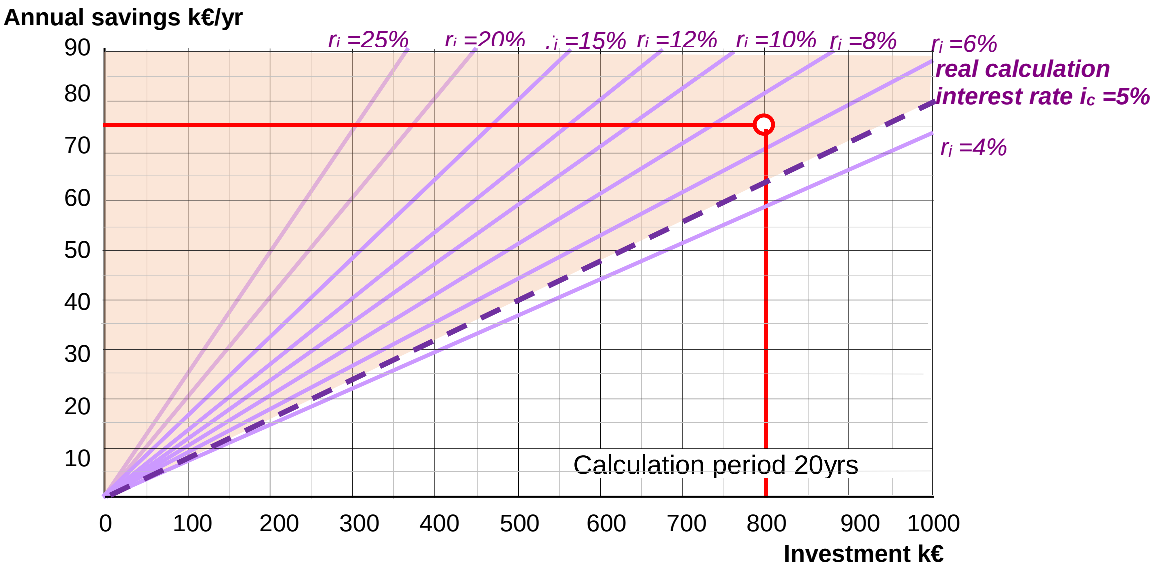


Figure 3.9 Internal rate of return diagram. The stipulated real calculation interest rate i_c = 5 % is marked with dashed line. All investments that lie above this line, i.e. result in actual yields above 5 %, are considered to be profitable.

Example
An investment of 800 000 € is calculated to give savings of 75 000 €/year for 20 years. This indicates an internal rate of return of 7%, which is higher than the real calculation interest rate stipulated by the investor i_c = *5%.* The investment is therefore profitable.

3.3.2 Relative energy price increase in the internal rate of return diagram

The internal rate of return diagram illustrated in Fig. 3.9 above is valid for savings that follow the average inflation. A future increase in the value of the saving due to changes in energy price above inflation can be taken into account in two different ways:

1) By adjusting the real calculation interest rate, reducing it by the relative energy price increase: $\boldsymbol{r_i > i_{c,adj} = i_c - q\ \%}$

2) By adjusting the diagram, so that the internal rate of return scale r_i is changed with respect to the relative energy price increase while keeping the calculation interest rate as the criterion for profitability.

Please note: These two ways described above are equally applicable when an energy saving measure leads to changes in annual energy use and power use only. When a measure leads also to changes in other annual operating costs than energy, e.g. maintenance cost, then alternative *2* should be used, as in the *Totaltool* program a relative energy price change is only taken into account for the energy part of the annual net savings.

Adjusting the internal rate of return diagram is illustrated in Fig 3.10 below. The left diagram corresponds to a *real internal rate of return diagram*, where the internal rate of return lines correspond to real interest rate lines. As a profitability criterion an *adjusted real calculation interest rate* $i_{c,adj}$ is used. In the figure, the real calculation interest rate i_c has been adjusted with a relative energy price increase of 2 % above the inflation: $i_{c,adj} = 5\% - 2\% = 3\%$. It is marked with a dashed line in the diagram.

The diagram to the right in Fig 3.10 corresponds to an *adjusted internal rate of return diagram*, where the relative price change of energy has been taken into account in the diagram itself. In this diagram the adjusted internal rate of return, i.e, the interest rate including energy price changes above inflation, can be directly taken from the diagram. As a profitability criterion the *real calculation interest rate* i_c is used. In the present example it is $i_c = 5\%$, marked with a dashed line in the diagram.

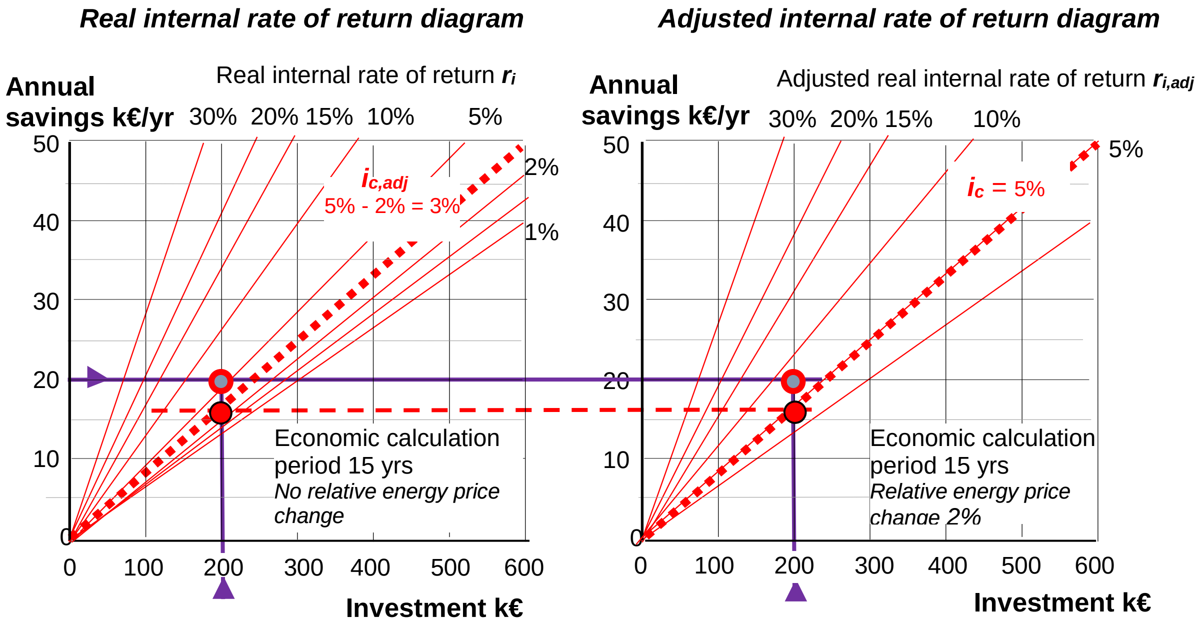


Figure 3.10 Illustration of how relative energy price changes are taken into account in an internal rate of return diagram. Left diagram corresponds to real internal rate of return diagram, right diagram to adjusted internal rate of return diagram.

3.3.3 Comparison with a cash flow

The costs and the savings of energy saving measures plotted in sequence in an internal rate of return diagram, is a useable decision-making tool. As mentioned, the profitability criterion is that the internal interest rate must not be below a given level. Yet, it is important to be aware of that this is a ground for decisions, it does not reflect in full the real profitability of the investment in question. In order to evaluate that, a following example is made demonstrating the cash flows with different calculated annual cost savings over specified calculation period, taking also into account inflation rates and relative price change of energy.

Example
An energy saving measure gives annual cost saving of a = 170 k€/yr and has an economic lifetime of n =15 years. The measure requires an investment of B_0 = 2000 k€ which will be financed with a bank loan with nominal interest rate i_n = 4% over the economic calculation period of 15 years. The estimation of annual inflation is w = 2% and energy price increases q = 2% above inflation. The nominal calculation interest rate is $i_{c,n}$ = 7%, including 3% investor's mark-up.
What would be the internal rate of return of such an investment and what would be the actual cash flow?

As discussed before, in actual amounts of money, the future annual cost saving a (€/yr) increases due to inflation *w %*. This increase is even higher if the energy price increases q % above inflation. The table 3.1 shows how the cost savings will increase in absolute value for assumptions on *w= 2%* and *q=2%.*

Table 3.1. Annual value increase of the cost savings

Year	w 2% q 2%	annual cost saving *a* (k€/yr)	Year	w 2% q 2%	annual cost saving *a* (k€/yr)
0	1,000	170	8	1,369	233
1	1,040	177	9	1,423	242
2	1,082	184	10	1,480	252
3	1,125	191	11	1,539	262
4	1,170	199	12	1,601	272
5	1,217	207	13	1,665	283
6	1,265	215	14	1,732	294
7	1,316	224	15	1,801	306

The capital cost (€/yr) on the other hand will remain the same at their nominal values during the economic calculation period. When financing the required investment cost for an energy saving measure with a bank loan with interest rate i_n = 4% and economic calculation period n = 15 years, the annual capital cost b will be:

$b = P(i_n,n)\cdot B_0 = P(4,15)\cdot B_0 = 0{,}0899 \cdot 2000 = 180$ k€/yr

With the initial investment cost of B_0 = 2000 k€ and annual cost saving of 170 k€/yr the internal rate of return of the investment will be r_i = 3.2 %. This corresponds to real internal rate of return r_i , and does not take into account relative price changes. For taking into account relative price change of energy the *adjusted real calculation interest rate* $i_{c,adj} = i_c - q$ % is used as a profitability demand. Since the nominal calculation interest rate is $i_{c,n}$ = 7 % then real calculation interest is $i_c = i_{c,n} - w$ % = 7% - 2% = 5%. The adjusted real calculation interest rate will be $i_{c,adj}$ = 5% - 2 % = 3 %. Based on the stipulated profitability demand the energy saving measure can be considered to be profitable.
Alternatively, when taking into account the annual increase in energy price of 2% above inflation directly in the calculations (in Totaltool) then the internal rate of return of the investment will be $r_{i,korr}$ =

5.3 %.In this case the real calculation interest rate $i_c = i_{c,n} - w$ % = 7% - 2% = 5% is used as a profitability demand and same result are received in terms of profitability of this energy saving measure.

To evaluate the actual profit that the investment creates during its calculation period the cash flow of this investment is illustrated on the diagram in Fig 3.11 below. In this example the cost savings will be somewhat lower than capital cost during the first year and the net cash flow will be negative. However, when calculating the sum of net cash flows during the whole calculation period the investment creates a total profit of ca 840 *k€*. The present value of this revenue with nominal calculation interest rate of 7 % (including investors mark-up plus annual inflation) would be approx 400 *k€.*

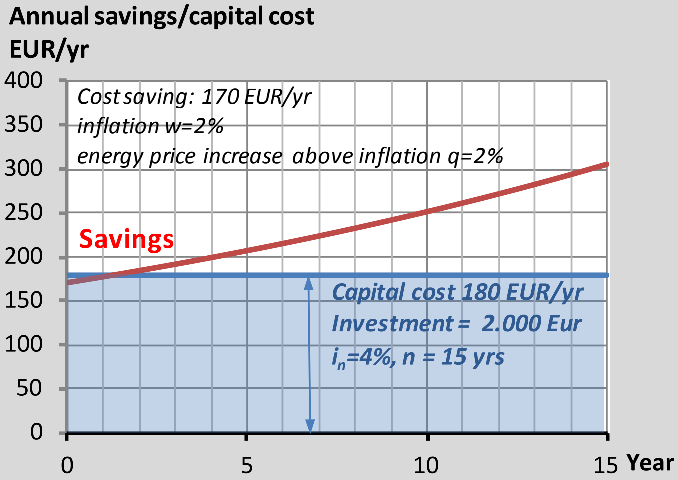


Figure 3.11 Example of cash flow that the energy saving measure creates when the annual cost saving is 170 kEUR/yr and capital cost 180 EUR/yr. Estimated inflation is 2 % and energy price increase above inflation 2 %.

If the calculated annual cost saving for the energy saving measure would be 200 k€/yr then with the same investment conditions the real internal rate of return r_i will be $r_i \approx$ 5,5 %, fulfilling the profitability demand $i_{c,adj}$ = 5% - 2 % = 3 %. The cash flow will be positive from the beginning (see Fig 3.12) and the investment creates a total profit of ca 1.460 *k€* during the whole calculation period. The present value of this revenue with nominal calculation interest rate of 7 % (including investors mark-up plus annual inflation) would be ca 770 *k€.*

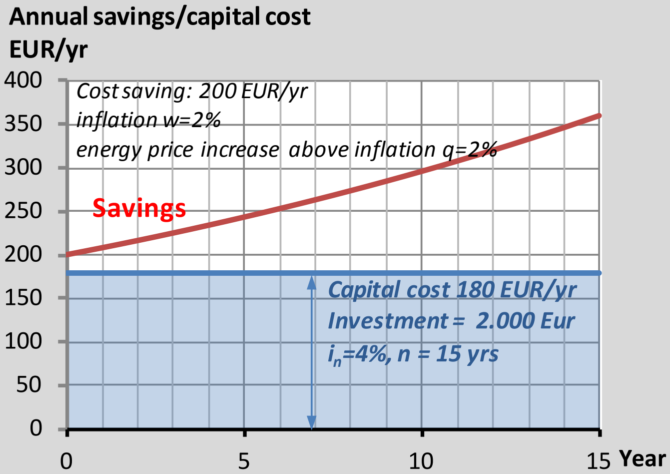


Figure 3.12 Example of cash flow that the energy saving measure creates when the annual cost saving is 200 kEUR/yr and capital cost 180 EUR/yr. Estimated inflation is 2 % and energy price increase above inflation 2 %.

3.3.4 Internal rate of return method vs. simple payback method

A frequently used economic model, the simple payback time method, is still often applied for assessing profitability of measures in the building sector, leading to false conclusions when interpreting the profitability results. Therefore it is important to clarify this method and what it means when assessing the energy saving measures.

According to the payback method, an investment is regarded as profitable if it generates incomes or savings that pay back the investment within the allowed payback time. The payback time, calculated by dividing the investment B_0 with the annual savings a, shows only how long it will take to pay back the invested amount. Therefore, it is important not to confuse the payback time method with a profitability model. The method is simple to use but gives rather rough estimates as it does not take into account interest rates, changes in energy prices, the economic lifetime of the measure or possible needs for re-investments. Also the maximum allowed payback time set in the profitability criteria is often determined randomly. Commonly a payback time less than 5-10 years is considered to be a profitable investment. But does this payback time really reflect profitability if economical lifetime of a measure is less than 5 years or more than 30 years?

The payback method encourages investments that are profitable in the short-term. If the investments to be assessed have long economic lifetimes and are expected to be in operation for a long time they will not be treated fairly using this method. Figure 3.13 illustrates the correlation between the economic calculation period, internal rate of return and payback time. For an example, an energy saving measure in a technical system, that has an economic lifetime of 20 years would need to create an internal rate of return of 20% if the requirement of payback time of 5 years need to be fulfilled. This is by far higher rate of return than commonly expected from any alternative investments in the building sector.

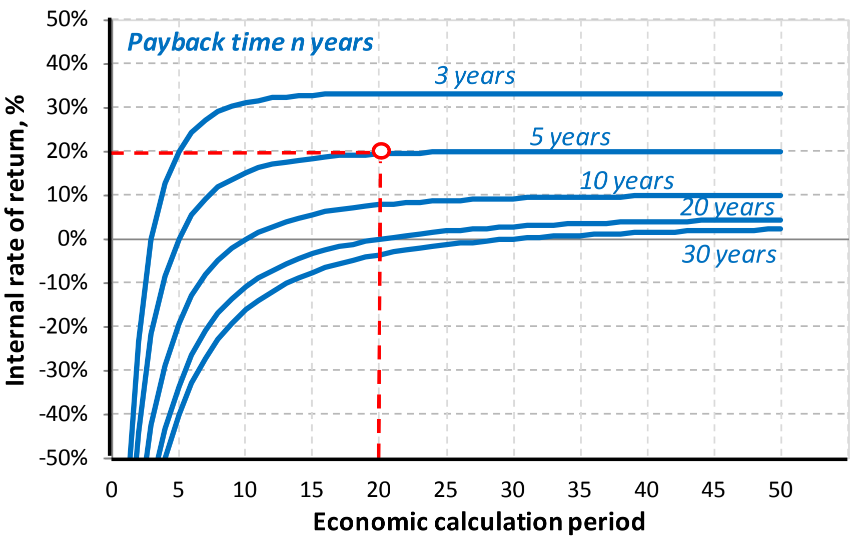


Figure 3.13
Correlation between the economic calculation period, internal rate of return and payback time.

Therefore the payback method is not suitable for use in building and property sector. Uncritical use of the payback method tends towards short-term investments without regard to quality. This is why the use of simple payback model should be limited to assessing investments, for example, in new machinery for a manufacturing industry where high profitability is required from productivity improvement investments. In this case the requirements regarding payback time could be around two to four years.

3.4 Use of internal rate of return diagram in Total Concept method

3.4.1 The creation of an action package

When a number of energy savings measures have been identified and their investment costs and annual cost savings have been calculated they can all be plotted as points in an internal rate of return diagram. From each point a line can be drawn to the origin, of which the slopes then represent the internal rates of return, see Fig. 3.14. The figure shows an example of six energy saving measures *M1- M6* plotted on the internal rate of return diagram.

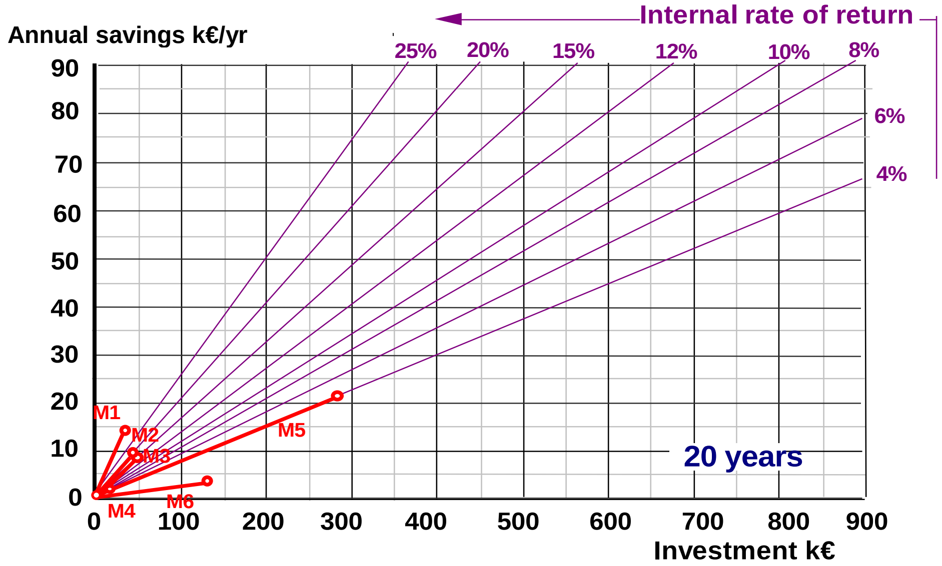


Figure 3.14 The profitability of energy saving measures presented in an internal rate of return diagram. As an example six energy saving measures *M1- M6* have been plotted as points on the diagram, representing their cost savings and investment costs. Slope of a line from each point to the origin represents an internal rate of return of the measure. The diagram is for an economic calculation period of 20 years.

By arranging all these lines according to their descending angles of slope, a basis for an action package is created, that is, a package that includes the most energy-efficient improvement measures, see Fig. 3.15. Note that when a number of measures are considered simultaneously their effects on each other must also be taken into account. If a particular measure is carried out first, then the savings potential in another measure might be reduced, compared to if they were carried out the other way round. This means that the order in which the measures are carried out can have an effect on how much a specific measure can save. In the Total Concept method it is assumed that the most profitable measures are carried out first. This means that when forming a package of measures in an internal rate of return diagram every point in the diagram takes into account the measures carried out before and shows the savings of each measure when previous measures have been carried out.

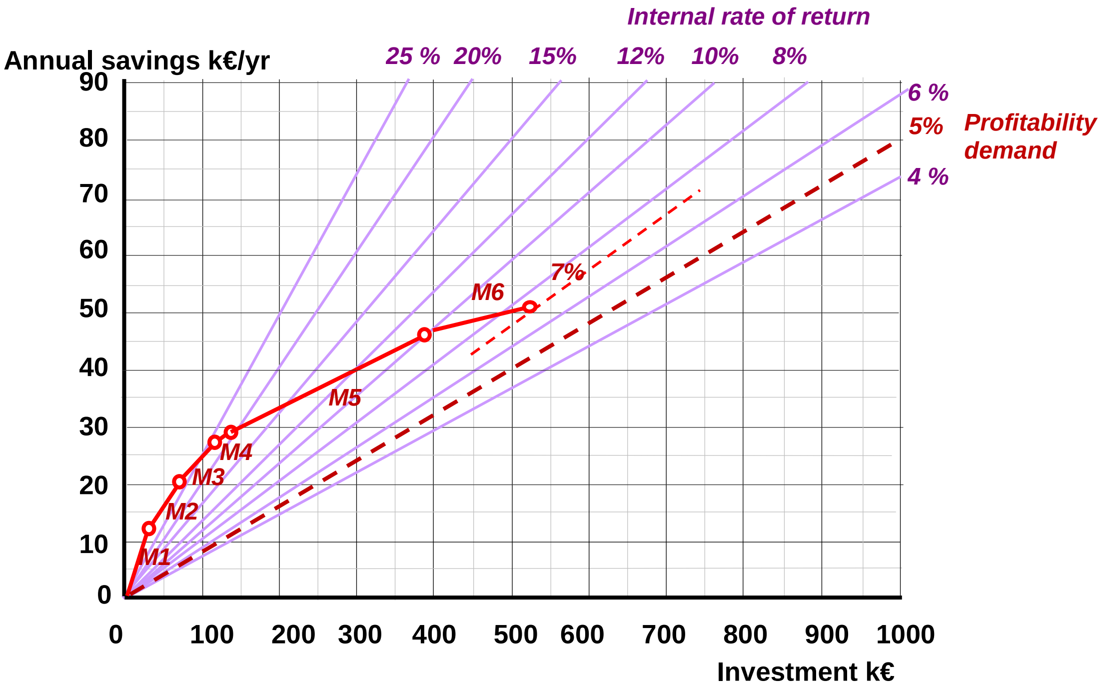


Figure 3.15 The profitability of the measures is presented in an internal rate of return diagram in order to create an action package. The stipulated profitability demand is 5 %. Note that all the measures in this example have the same economic calculation period of 20 years.

The criterion for how many measures are included in the action package is that the internal rate of return for the action package in its entirety must be greater than the stipulated calculation interest rate.

3.4.2 The effect of an economic calculation period

Every internal rate of return diagrams is valid for a specific economic calculation period. This could be the same as the economic lifetime of a measure, but property owners/clients can sometimes choose shorter periods. Energy saving measures in non-residential buildings can have different economic lifetimes. For technical installations, periods of between 15 and 20 years are often chosen, while building components might have economic lifetimes of 40 years. However, it might be desirable to be able to show them at the same time in the same diagram.

Fig.3.16 illustrates the effect of the economic calculation period on the internal rate of return. For a given investment with a given yield, the internal rate of return rises as the economic calculation period increases. The diagram shows that when the economic calculation period is longer than 15 to 20 years it has little effect on the internal rate of return. If the plotted economic calculation period - internal rate of return point lies to the right of the red dotted line for all the measures with different economic calculation periods, the differences in lengths of the economic calculation periods have little effect, less than one percent. If the plotted points lie to the left of the curve for measures with short economic lifetimes, the difference in the economic lifetimes must be taken into account.

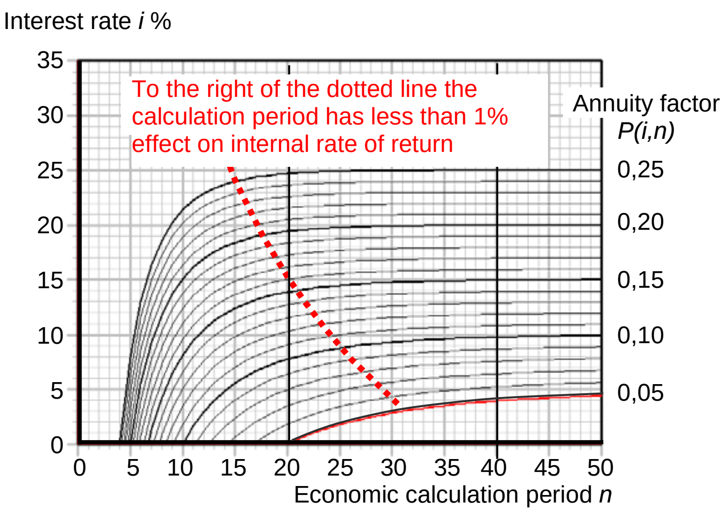


Figure 3.16 The dependency of internal rate of return of economic calculation period. To the right of the dotted line the calculation period has a negligible effect.

It would be impractical to have to use a number of different internal rate of return diagrams for different economic calculation periods. They have therefore been combined in one diagram in which the slopes of the internal rate of return curves have been adjusted to the economic calculation period of each measure. If a number of measures with different economic calculation periods are combined, this can be taken into account by correcting the savings effects of the different measures.

The common internal rate of return r_i for two simultaneous measures – B_{01} € with an economic calculation period of n_1 years and B_{02} € with an economical calculation period of n_2 years, with yields of a_1 €/year and a_2 €/year respectively – is determined when the sum of the present values of the yields covers the whole investment:

$$B_{01} + B_{02} = I(r_i,n_1)\cdot a_1 + I(r_i,n_2)\cdot a_2$$

where $I(r_i,n_1)$ and $I(r_i,n_2)$ are the net present value factors for the annual yields of a_1 and a_2.

It is quite time-consuming to do this manually but is simple to carry out using a calculation program such as the Total Concept calculation tool *Totaltool*.

Example
The economic principles of the Total Concept method are illustrated in the following practical example. An office building with a floor area of 8.500 $m^2_{\text{gross floor area}}$ is investigated, in which the Total Concept

method has been applied in its entirety, i.e. an action package has been drawn up and carried out and the energy use followed up for a whole year after handover. The values shown in the example below are the calculated annual cost savings and investment costs from Step 1 that were used as in-data for the action package.

The identified energy saving measures, their economic calculation period, their calculated investment and the expected savings have been compiled in the Table 3.2 below. The measures are shown in a condensed form: some of them actually comprise a number of separate measures. The measures shown in the table have economic calculation periods of 15 or 40 years.

Table 3.2
Examples of energy saving measures with different economic calculation periods

No.	*Measure*	*Economic calculation period* [yr]	*Investment* [k€]	*saving* [k€/yr]	*Internal rate of return* [%]
1	New communal lighting	15	35	14	39.7
2	Reduced basic heating load	15	35	7	18.4
3	Improved roof insulation	40	40	6	17.5
4	Introduction of night cooling in the summertime	15	7.5	1	10.2
5	New ventilation system	15	270	21	1.3
6	New windows	40	120	3	0.1
	Total		***507.5***	***52***	

In the Figure 3.17 below, the internal rate of return diagrams have been plotted for 15 and 40 years respectively.

Figure 3.17 Combining energy saving measures with different economic calculation periods on an internal rate of return diagram.

With the help of a Total Concept calculation tool *Totaltool* the internal rate of return diagrams for different economic calculation periods are combined and common internal rate of return for the measures in the package is calculated. The figure below shows the results of the profitability calculations, action package in Table 3.2 on an internal rate of return diagram.

Figure 3.18 The action package in Table 3.2 plotted on an internal rate of return diagram.

The property owner has stipulated that the investment must create savings that are equivalent to a real interest rate of 5% (real calculation interest rate). As can be seen in the figure above it is approximately 7 %.

3.5 Reinvestment

When applying Total Concept method a common internal rate of return is calculated for a number of simultaneous measures carried out an action package. This means that if the action package includes measures with different lifetimes it is presumed that the savings provided by those with shorter lifetime cease when their lifetime expires. Consequently, the annual cost savings will decrease gradually, if the systems or components with shorter economic lifetime are not replaced. However, in practice energy saving measures with shorter economic lifetimes than that of the building as a whole will be replaced when they can no longer perform properly. For example, a number of technical systems and its components are assumed to have an economic lifetime of 15 years, while the components in the building construction will be used 40 years or more. Consequently, these technical installations have to be replaced first after 15 years and then again after 30 years, i.e., new investments are needed after 15 and 30 years. Then new profitability assessments can be carried through for the investments needed.

However, one can take into account the future reinvestments needed by adding the present values of the future reinvestments to the initial investment and include the corresponding savings in the profitability calculation.

If two reinvestments, B_{r1} and B_{r2}, are made after n_{r1} and n_{r2} years respectively, the present value ΣB_o of the whole investment process will be:

$$\Sigma B_0 = B_0 + B_{r1} \cdot i(i_c, n_{r1}) + B_{r2} \cdot i(i_c, n_{r2})$$

The Net present value factor for individual yields, $i(i_c,n)$, *i_c is the real calculation interest rate*, can be found from the table in Appendix 2.

When calculating the present value of future investments real calculation interest rate i_c is to be used. The future relative price changes of energy above inflation should not be taken into account as that has no influence on the present value of future investments. It only influences the present value of the annual energy costs.

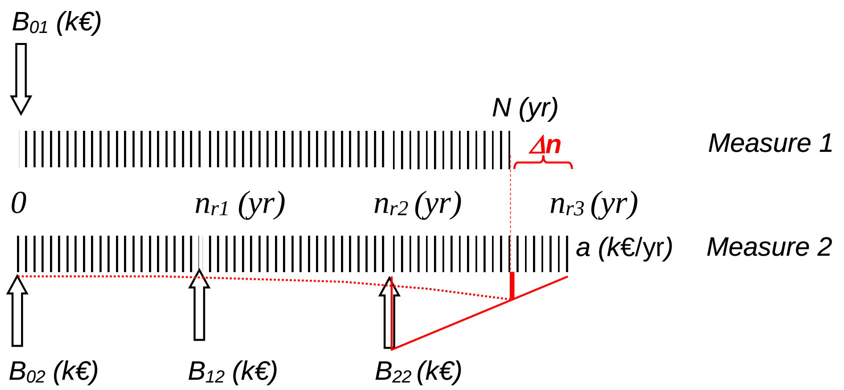
Two reinvestments imply that the whole economic process takes place over the lifetime of the measure with the longest lifetime, in this case for example 40 years. Obviously, in the case of an action package, where measures have different economic lifetimes, the measures with shorter economic lifetime can be recalculated to the time period of the measures with longer economic lifetime. In this case the action package *as a whole* will have same economic lifetime.

Additionally, the residual value of the last reinvested measures may need to be taken into account as recommended in"*European Commission C115, 19.4.2012"*[1]. This is the case for example when a reinvestment of a measure will last longer than the measure with longer lifetime. The value of the reinvestment is assumed to decrease linearly in time and the total present value of reinvestments is decreased by the present value of the residual value.

This is illustrated in the figure below. The figure illustrates the case where one measure in the action package has the economic calculation period *N* years while another measure has much shorter calculation period and needs to be replaced two times after n_1 respective n_2 years. The total present value of the investments will be:

[1] European Commission. Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012, supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings", 2012/C 115/01; Official Journal of the European Union, C 115/1 - C 115/28, 19.4. 2012

$$\Sigma B_0 = B_{01} + B_{02} + B_{12} \cdot i(i_c,n_1) + B_{22} \cdot i(i_c,n_2) - B_{22} \cdot \Delta n/(n_3-n_2) \cdot i(i_c,N)$$



Example 1
The action package includes 2 measures that require the initial investment B_{o1} and B_{o2} and have economic lifetimes of 15 or 40 years.

B_{o1} 100 k€, economic calculation period 40 years

B_{o2} 50 k€, economic calculation period 15 years

Total annual cost saving for the action package $a = 14$ k€/yr.

Real calculation interest rate $i_c = 8$ %

Annual relative price change $q = 2$ %

Profitability demand $r_i > i_{c,adj} = 8 - 2 = 6$ %

Measure B_{02} needs to be replaced after 15 years and after 30 years. If it can be assumed that the value of the reinvestments will, in real terms, be the same as the initial investment $B_{12} = B_{22} = B_{02}$. However, only 10 years of the second reinvestment can be taken into account in the profitability calculationd. There will be a residual value covering the last 5 years period. The present value of the total investments for the action package can then be calculated as follows:

$n_1 = 15$ years, $n_2 = 30$ years, $n_3 = 45$ years, $\Delta n=5$ years, $N = 40$ years.

$i(8,15) = 0{,}3152$ $i(8,30) = 0{,}0994$ $i(8,40) = 0{,}0460$

$$\Sigma B_0 = 100 + 50 + 50 \cdot 0{,}315 + 50 \cdot 0{,}0994 - 50 \cdot 5/(45-30) \cdot 0{,}0460 = 170 \text{ k€}$$

This gives an internal rate of return r_i:

$I(r_i,40) = 170/14 = 12{,}1 \Longrightarrow$ internal rate of return $r_i = 7{,}8$ % $> i_{c,adj} = 6$ %

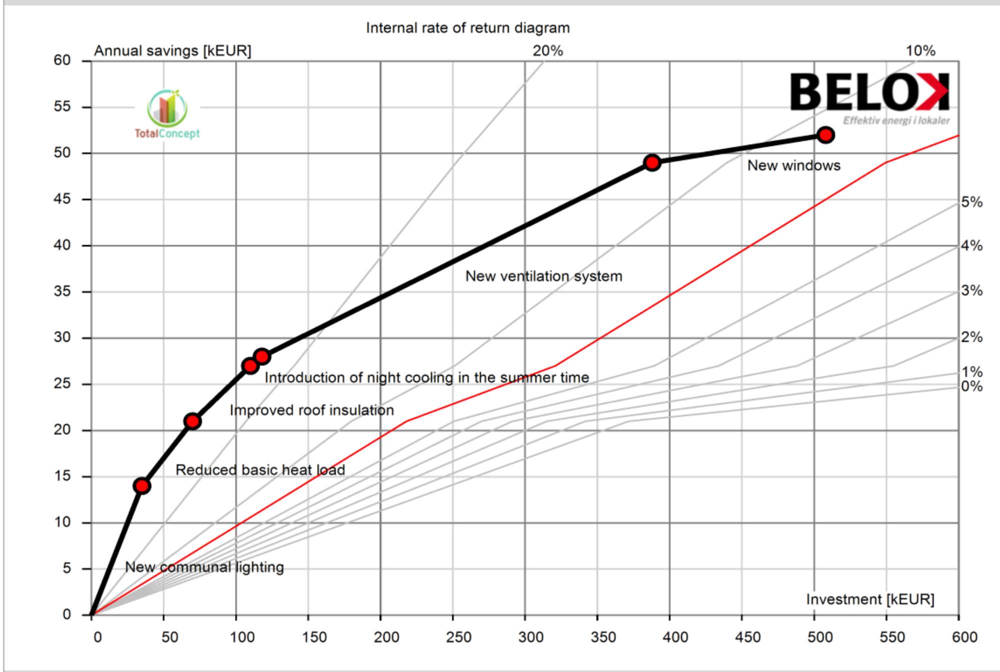
The action package is considered to be profitable and should be carried out.

Example 2
The action package includes measures with economic lifetimes of 15 and 40 years (see table 3.3). The profitability demand in terms of real calculation interest rate is $i_c = 7$ %. The annual relative energy cost increase $q = 2$ %.

Table 3.3 Examples of an action package of energy saving measures *without reinvestments*.

No.	*Measure*	*Economic calculation period* [years]	*Investment* [k€]	*Savings* [k€/year]
1	New communal lighting	15	35	14
2	Reduced basic heat load	15	35	7
3	Improved roof insulation	40	40	6
4	Introduction of night cooling in the summertime	15	8	1
5	New ventilation system	15	270	21
6	New windows	40	120	3
	Total		***508***	***52***

The action package formed with the *Totaltool* based on the Total Concept method is shown below. As mentioned before the tool calculates the combined internal rate of return for the measures without taking into account reinvestments. Measures with shorter economic lifetimes fall out after their lifetime is finished and total annual savings will decrease if these systems or components are not replaced, In this case after 15 years.



An internal rate of return of the action package in question will be about r_i = 9%. According to the profitability demand the internal rate of return must be higher than real calculation interest rate i_c = 7 %. Taking into account an assumed annual relative energy cost increase q = 2 % (this will be used as input data in the *TotalTool* to adjust the annual cost savings for energy use only). Therewith the action package above fulfills the profitability demand and should be carried out.

In the same example, when taking into account reinvestments, it is assumed that those with shorter lifetimes are to be replaced after 15 and 30 years. The present value of these reinvestments can be added to the initial investment. If even here is assumed that the value of the reinvestments will, in real terms, be the same $B_{11} = B_{12} = B_{o1}$, the present value of the total investments for the measures with shorter lifetimes will be as follows:

$\Sigma B_{01} = B_{01} + B_{01} \cdot [i(i_c,n_1) + i(i_c,n_2) - \Delta n/(n_3-n_2) \cdot i(i_c,N)]$

$\Sigma B_{01} = B_{01} \cdot [1+i(i_c,n_1) + i(i_c,n_2) - \Delta n/(n_3-n_2) \cdot i(i_c,N)]$

n_1 = 15 years n_2 = 30 years n_3 = 45 years N = 40 years Δn = 5 years

i (7,15) = 0,365 i(7,30) = 0,132 $\Delta n/(n_3-n_2)$= 5/15 = 0,33 i(7,40) = 0,071

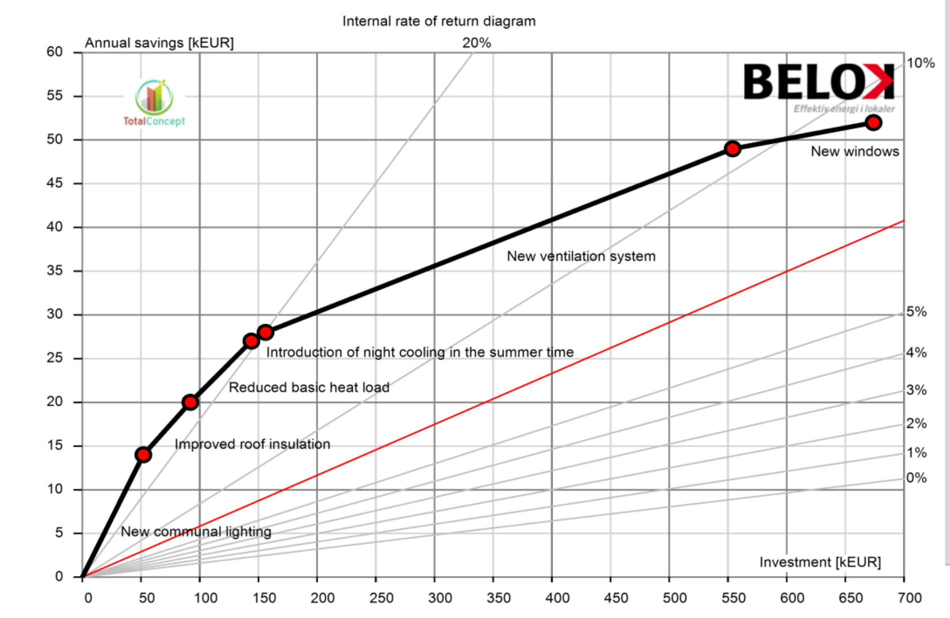
$[1+ i(i_c,n_1) + i(i_c,n_2) - \Delta n/(n_3-n_2) \cdot i(i_c,N)] = 1+ 0{,}365 + 0{,}132 - 0{,}33 \cdot 0{,}071 = 1{,}474$

By multiplying the total investment of the measures that have 15 years economic lifetime with the factor 1.474, the economic process is prolonged to 40 years.

Table 3.4 Examples of action package of energy saving measures *with reinvestments.*

No.	*Measure*	*New economic calculation period* [years]	*Initial investment* [k€]	*Including present value of reinvestments* [k€]	*Savings* [k€/year]
1	New communal lighting	40	35 (15 years)	52	14
2	Reduced basic heat load	40	35 (15 years)	52	7
3	Improved roof insulation	40	400	40	6
4	Introduction of night cooling in the summertime	40	8 (15 yearsa)	12	1
5	New ventilation system	40	270 (15 years)	398	21
6	New windows	40	120	120	3
	Summa		**508**	**674**	**52**

Profitability of the action package *with the reinvestments* is presented in the diagram below.



Even in this case the profitability will be about 9 % internal rate of return, i.e. principally the same as when the reinvestments are not taken into account.

3.6 Evaluation of annual cost savings

Estimation of annual cost savings due to the energy efficiency measures carried out, is a fundamental part of every Total Concept project. Saved energy use is calculated as annual savings in operating cost. Here it is important to keep in mind that it is the annual net savings that should be estimated. Additionally, energy prices can consist of a number of price components and can be varying over the year, depending on the season or other factors. Here some simplifications can be justified and are explained below.

3.6.1 Calculating annual net savings

It is the annual net savings, *a* (k€/yr), corresponding to changes in annual operating costs before and after a measure taken, that are taken as input data in the profitability calculations. Annual operating costs for a building and/or its systems can be divided as follows (see figure 3.19):

- Energy costs for operation of the technical systems (heat energy, electrical energy)
- Service costs for operating the technical systems/building components. This can include for example costs for planned maintenance, replacements and repairs, spare parts (replacement of filters, light bulbs, component cleaning, checking the control parts, calibration of sensors, etc.).

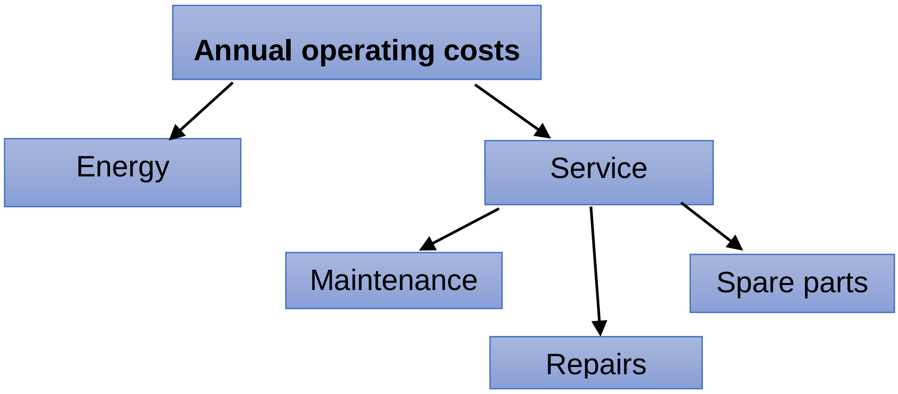


Figure 3.19 Dividing up of annual operating costs for a building and its systems.

> *Example*
> Proposed energy saving measures will decrease the annual heating energy use from 780 MWh/yr to 580 MWh/yr. The energy price for heating is 70 €/MWh. However, the annual maintenance costs for system maintenance will increase by about 500 €/yr. Thus the annual net savings of the measures is:
>
> $$a = (780 - 580) \cdot 70 - 500 = 13\,500 \text{ €/yr} = 13.5 \text{ k€/yr}.$$
>
> This will be used as annual cost savings input, *a (k€/yr),* in the profitability calculations.

3.6.2 Complex price models

Energy companies do not charge the amount of energy you buy only, but also the power demand and in many cases also how efficient the energy is distributed, e.g. district heating companies often take the amount of distribution water flow or the return temperature into consideration. Furthermore, the prices often vary seasonally and diurnally. There is a vast amount of price models and they are modified and updated regularly. It is hardly possible to foresee the situation ten or twenty years in advance. Therefore simplified assumptions might often be motivated.

If the energy simulations software used cannot handle seasonal variations of the energy price, a representative yearly average price is used. Then it is often reasonable to use a weighted mean annual price, based on the recent years' energy statistics.

However, it is important to keep in mind that since a number of measures can save energy during different parts of the year, different annual mean prices may be needed for different measures. This is illustrated in the example on Figure 3.20 below. The bars in the figure show the price of energy from a typical Swedish district heating company. Most of the energy efficiency measures save energy mainly during winter. Installing solar collectors or energy-saving water taps have a different saving profile and the value of each saved kWh may therefore differ.

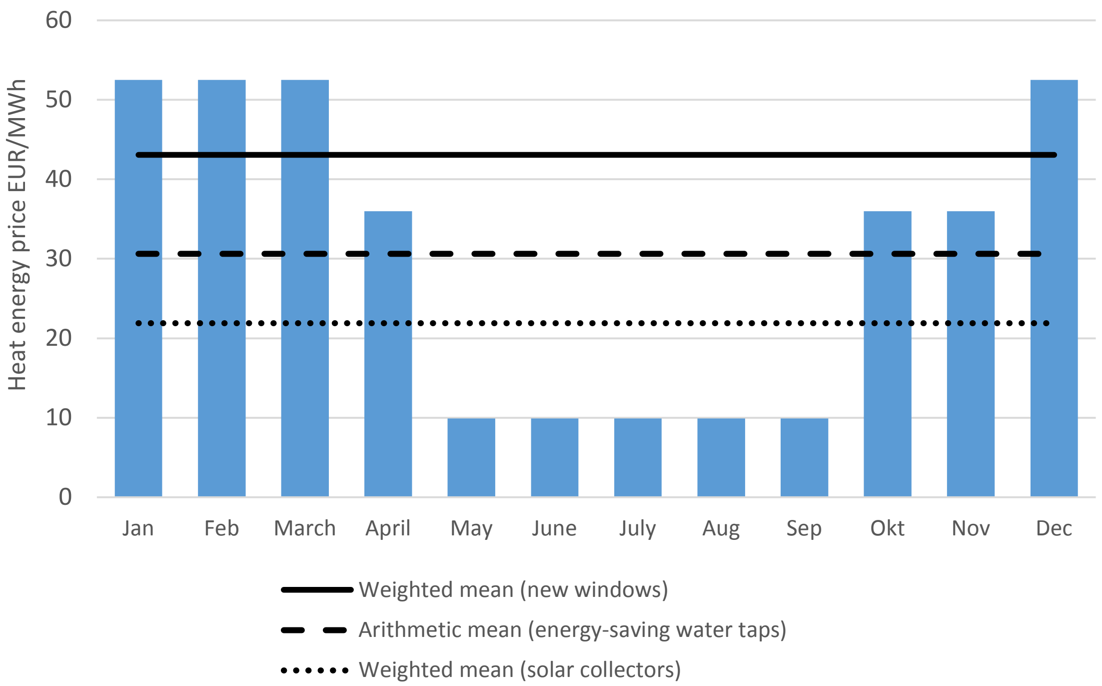


Figure 3.20 An example of how to take into account complex price models for energy when calculating cost savings.

Example
Annual district heating use in an office building in Gothenburg is 1000 MWh/yr. The district heating price is varying over the year as follows (see figure 3.20):

- January, February, March, December: 52.5 EUR/MWh;
- April, October and November: 36 EUR/MWh;
- May, June, July, August and September: 9.9 EUR/MWh

Heat energy use during each month over a year and associated energy cost per month is given in the

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Heat energy use (%)	16%	16%	14%	10%	5%	1%	0%	1%	4%	7%	11%	14%	
Heat energy use (MWh)	162	162	136	99	49	14	4	7	38	71	114	145	1000
Heat cost (EUR)	8497	8497	7120	3580	483	134	36	72	376	2571	4101	7595	43063

Energy price to be used for energy saving measures in building envelope and HVAC system (e.g. new windows) can be calculated as follows (weighted mean price):

Annual heat cost (EUR)/Annual energy use (MWh) = 43063 EUR/ 1000 MWh = 43.1 EUR/MWh

Energy price to be used for energy saving measures in a DHW system can be calculated as follows (arithmetic mean price):

Σ heat price per month (EUR/MWh)/12 months = (52.5 EUR/MWh ·4 + 36 EUR/MWh ·3 + 9.9 EUR/MWh ·5)/12 = 30.6 EUR/MWh

Saved annual energy cost with installation of solar collector system can be calculated based on the estimated monthly production during a normal year. Weighted average price can be used, calculated based on the annual production.

3.6.3 Savings in power use

For several measures, power tariffs can be taken into consideration by integrating it into the cost of energy.

Example:

Energy price (Ep): 0.05 €/kWh
Power tariff (Pp): 60 €/kW
Energy demand (Ed): 1 000 MWh/year
Power demand (Pd): 400 kW

A simple method is to find an equivalent energy price in which the power piece is integrated as follows:

$$Ep_{eq} = \frac{Pd \cdot Pp + Ed \cdot Ep}{Ed}$$

This equivalent energy price is used then to estimate the cost savings of the measure. However, this simplification should not be used when analyzing measures which are not affecting the power demand and energy demand proportionally.

3.6.4 Diversified heat supplies

Sometimes a building or a set of buildings is supplied from more than one heat source. This can make the cost saving calculations somewhat more complicated, since different heat sources are associated which different energy prices. An extreme example could be a building connected to district heating, with solar collectors on the roof, a ground source heat pump which supplies some base load and an electrical heater which helps when the other heat sources cannot cover the demand.

If the energy simulations software used do not consider this complexity into, some effort might be needed for finding the relations between measures and heat sources.

References

[1] Swedish Standard SS-EN 15459:2007 “Energy performance of buildings - Economic evaluation procedure for energy systems in buildings”

[2] European Commission. “Recommendations on measurement and verification methods in the framework of Directive 2006/32/EC on energy end-use efficiency and energy services.”

[3] P-E Nilsson. 2003 “Achieving the required indoor climate”

4 Step 1 of a Total Concept method - Creating the action package

This chapter provides more detailed insight to the process of carrying out Step 1 of a Total Concept project. The roles of the client and energy consultant, their respective responsibilities and tasks are discussed.

4.1 Introduction

In step 1 of a Total Concept project, an energy consultant carries out a technical assessment of the property to identify possible measures to improve energy efficiency and an action package is suggested. This analysis is far more thorough than that carried out for an energy certificate. However, the energy certificate can be used as a starting point if one exists. The output of this working step forms a basis for a decision making, whether or not to invest in the action package. Careful analysis is vital if the project is to be a success. The key points to consider for achieving good results and assuring quality assurance when carrying out the different work tasks in Step 1 will be discussed in detail in the following sections.

4.2 Stakeholders and key actors in Step 1

Carrying out Step 1 of the Total Concept method requires cooperation between the following main stakeholders and key actors:

- ***Property owner/client,*** who is responsible for ordering the practical work based on Step 1 of the Total Concept method from external key actors. Property owner/client is also responsible for assuring that internal resources are available for project execution, e.g. involvement of in-house personnel like property manager, maintenance staff, etc. Additionally the property owner must make sure that all the relevant background information needed for the Step 1 will be made available for the consultant.
- ***Energy consultant***, who based on the contractual agreement with the property owner/client, carries out the practical work included to Step 1 and forms a package of measures based on the Total concept method.
- ***Property manager,*** who is responsible for the buildings in question and has access to the relevant information needed for the consultant for the analysis in Step 1 or knows where this information can be obtained. Property manager is also often involved with the investment decision. It is greatly advantageous if the consultant can discuss the proposals with the property manager to eliminate measures that would, for different reasons, not be conceivable or practically possible to carry out.
- ***Facility management staff (maintenance staff),*** who are responsible for operating all the systems in a building. Maintenance staff usually has a good picture of the present condition of the building and its systems and can support the consultant with relevant information. They also possess information about any shortcomings, what they depend

on, and what could be done to eliminate them. Their collaboration in energy auditing on site is very valuable, since they are usually the ones who can show the consultant around the building for an on-site inspection and who have access to the technical rooms.

Step 1 will also require some support from the ***tenants/ building users*** when basic information about the building and its use is gathered by the consultant. They usually know best how the different rooms are used at present, what is the occupancy level and times as well as if any changes are planned in the future. It is also important to for the property owner/manager to keep the tenant´s well informed about the project and its objectives and to be responsive to their needs. Additionally, some measures may require tenant´s involvement, e.g. measures in the lighting system and machines/equipment used, and therefore the alternatives need to be discussed with them.

The stakeholders and key actors involved in Step 1 of the Total Concept method is illustrated in Fig. 4.1.

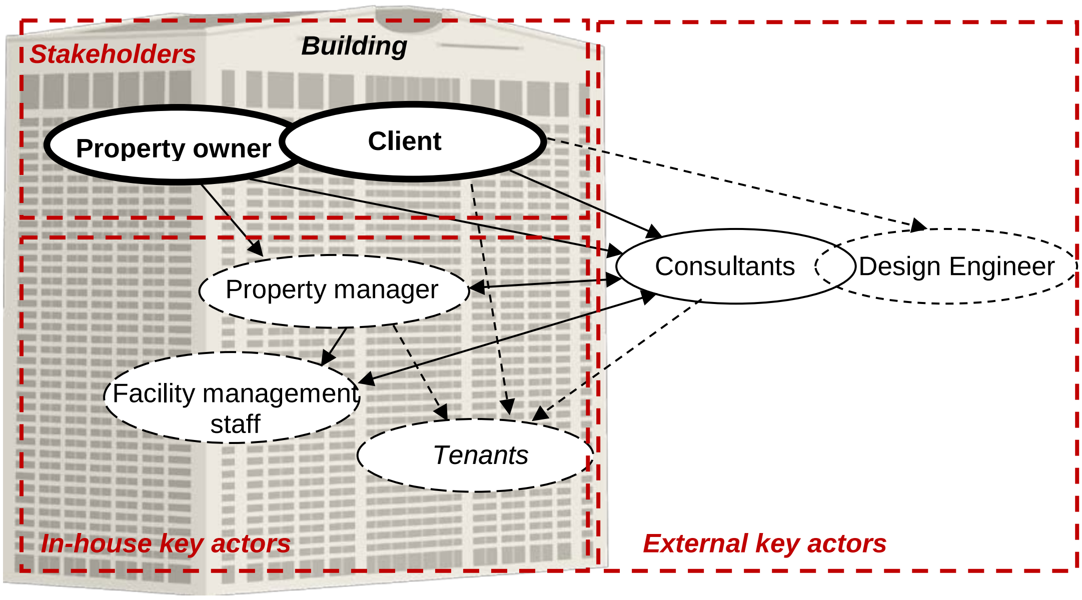


Figure 4.1 The stakeholders and key actors involved in Step 1 of the Total Concept method.

In some cases it can also be relevant to involve ***design engineers***, who will do the detail design for the proposed measurers, already in Step 1 for the assessment of design work required for specific measures as well as for estimation of investment costs. This is of course only possible when the design engineers can be appointed in an early stage of the project.

4.3 Key activities of Step 1 of Total Concept

The key activities of Step 1 of Total Concept are illustrated in Fig. 4.2. Step 1 starts with preparations needed from the *property owner/client*, and then proceeding to key activities carried out by the *consultant*.

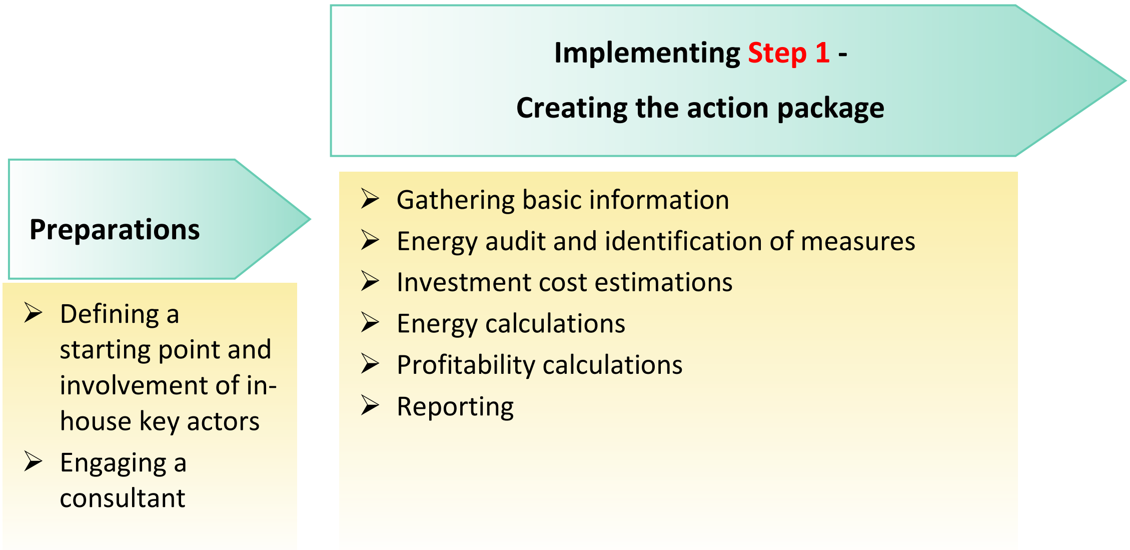


Figure 4.2 The key activities included in Step 1 of the Total Concept method.

4.4 Preparations for carrying out Step 1

4.4.1 Defining a starting point

Before any practical work is initiated it is strongly recommended for the property owner/client to clarify the preconditions for the energy refurbishment project to be carried out. It is important to be aware and think through the following questions:

- What are the general prerequisites for carrying out energy saving measures in the building in question? Is there information available about how the energy is used, e.g. heating, electrical energy for building operation, the tenant´s use of electrical energy, cooling?
- What is the property owner’s/client’s aim and expectations? Is the aim of the renovation to improve energy performance only or will it be combined with general upgrade of the building for e.g. improving the function of the building, indoor climate?
- What is the economic strategy and situation of the property owner’s/client’s company and how could possible energy measures be financed?
- How will the exchange of information and spread of knowledge be ensured between those involved, for example, the tenants, maintenance staff, managers, consultants and contractors? They all will have an affect on the work and its outcome.
- How and by whom will the follow-up be carried out and how is future maintenance and operational work ensured? What are the present resources; are they sufficient and how are they to be applied?

4.4.2 Client’s role and responsibilities

The property owner/client must clearly specify the scope of the undertaking to all involved in the project. In most cases, the property owner/client appoints an own project manager to take on responsibility for the project and provides this person with sufficient authority and resources.

The role of project manager includes:

- The engagement of an energy consultant, i.e. drawing up the tender documents, evaluation of tenders, project management and coordination.
- Supplying the energy consultant with all the necessary information about the building.
- Assisting the consultant by providing information when drawing up the proposals for the energy efficiency improvement measures.
- Coordinating internal resources/personnel, for example, the involvement of the facility maintenance staff.
- Presenting the report from Step 1 to the relevant parties before a decision to carry out the action package is made.
- Planning for Step 2, for example, the preparation of the tender documents before engaging consultants and contractors.

4.5 Engaging a consultant for Step 1

4.5.1 Drawing up the tender documents

The information that is required from the property owner/client to prepare the tender documents can vary depending on whether it is a public invitation to tender or a private one.

The property owner/client must define and formulate clearly the correct requirements so that there is no gap between what the property owner/client expects and what the consultant can deliver. It is important to clearly state the responsibilities of the consultant, as well as how the results will be followed up and checked. Information that can provide a clear picture of the scope of the work should therefore be included in the tender documents. It should be stated in this information that the assignment involves a thorough investigation and assessment of the building and identification of possible energy saving measures, as well as the costing of every measure and estimation of energy savings. In other words, this is a considerably more thorough and extensive assignment than required for energy certification.

The tender documents should include:

- Specification of the assignment.
- Demands placed on the consultant, and on the deliverables, for example, with regard to the starting date, the delivery date and the documentation that should provided.
- A general description of the property and the building in question.

It is important that the energy consultant has an adequate knowledge of the Total Concept method and how it should be applied. In existing non-residential buildings the main savings potential lies in the technical systems. The consultant must therefore be familiar with heating-, ventilation- and cooling systems (HVAC) as well as electrical and building management (BMS) systems.

The tender documents should state that the following information is required about the consultant:

- The consultancy company's and the consultant's personal experience of energy efficiency improvement work in non-residential buildings similar to that in the assignment.
- The consultant's resources and competency regarding energy calculations. Information should be provided regarding which approved calculation programs are to be used and what experience the consultant has of energy calculations similar to those required by the Total Concept method.
- The consultant's personal resources, competency and experience of costing. The person(s) who will carry out the work should be specified.

In the tender documents the methods which will be used to evaluate the tenders, other than price, can also be indicated. The evaluation method should include evaluation/weighting of the components competency, experience and price (least of all). This will give the property owner/client an opportunity to assess competency and experience in relation to price.

Checklists for creating tender documents in Step1 can be found in the Total Concept tool-kit.

4.5.2 The consultant's role and responsibilities

The assignment for the energy consultant consists of creating an action package for the specified building based on the Total Concept method and it comprises the following tasks:

- Gathering of basic information about the building and compiling technical data.
- Carrying out an energy audit and drawing up a list of possible measures. This must be carried out thoroughly and include both the building envelope and the technical installations (possibly excluding the tenant's own installations). The audit must be documented with the help of check lists, notes, photographs, measurements, etc. The consultant will normally decide if additional measurements are needed and, if so, see that they will be carried trough.

  The consultant draws up a list of *all* the technically and practically possible measures that can significantly reduce the use of energy. ***It is not only the individual and profitable measures that are to be identified but every measure that can have a reasonable effect on energy use.*** Initially, no economic evaluation is carried out.
- Carrying out investment cost calculations. Cost for each proposed measure is individually estimated based on the requirements set by the property owner/client (e.g which costs will be included) and taking into account how the implementation of measures as an action package affects the costs. Every calculation must be well-documented and conditions, assumptions, origins of input data, calculation method and the results recorded.

- Carrying out energy calculations. The energy balance of the building is simulated with the help of validated calculation software. Energy savings are calculated for each measure, taking also into account the effects that each of the individual measures have on each other when the action package is formed. Every calculation must be well-documented and conditions, assumptions, origins of input data, calculation method and the results recorded.
- The composition of an action package according to the Total Concept method. The action package is put together based on successive step by step energy calculations outgoing from the whole building and by using the Total Concept calculation tool *Totaltool*. The results are illustrated on an internal rate of return diagram. List of measures included to the profitable package, their respective cost savings and investment costs as well as other relevant economic input data used for forming the package are to be carefully documented.
- Forming of the report about Step 1. The report must include: a summary of the project; current status of the building; its indoor climate; its technical systems; an overview of the current energy performance and energy statistics; input data used in the calculations. It should also include documentation about all the individual proposed measures in the action package and the action package as a whole, in figures and diagrams. The information in the report must be sufficient to enable a decision about if the measures are to be carried out and the project should continue to Step 2. A template for the report is available.

4.5.3 Information required from the property owner/client

The property owner/client needs to provide together with the tender documents also a description of the building(s) in question. The consultant needs to evaluate the time and resources needed for the work. For example, following information can be relevant:

- The name of the property, address, area (m^2) including a definition of how it is measured, information about the building use and operation.
- When built, any major rebuilding work done previously?
- Requirements on indoor climate and current status with indoor climate.
- Energy use MWh/yr, kWh/(m^2·yr) - heat, district cooling (if any), the electricity use for building operation and the tenant’s electricity use. If the electricity use for building operation and for tenant´s is not measured separately, the estimations will be made by the energy consultant by carrying out calculations.
- Water use m^3/yr, l/(m^2·yr) - cold water and warm water (if it is measured separately).
- General description of the ventilation systems in the building(s), number and type of systems and units, type of heat recovery in the units, type of flow control (CAV, VAV).
- General description of comfort cooling, type and number of cooling systems (type of production), distribution (air based, water based)

- General description of heat production systems (for example, district heating, bio fuel boiler, heat pump), number of systems/substations
- Description of the building envelope and condition.
- Any planned rebuilding/refurbishment work - can they be coordinated?
- Information sources available for the auditing, e.g. drawings, technical descriptions, energy statistics, access to BMS system, etc. and quality of the information (for example, hourly/monthly measurements, measurements from sub-meters, as-built drawings).

A template for gathering basic information about the property is available in the Total Concept tool-kit. It is up to the consultant to request complementary information about the building in order to evaluate the time and resources needed for the work. And it is up to the property owner/client to make sure that this information is forthcoming.

It can happen that a building, in which energy saving measures are to be carried out, is technically complex and in order to get an overview of the present functioning of the building and its systems as well as analyse the energy saving measures will require more time and resources. In order to make a correct estimation of the resources required for the work a preliminary study may be necessary. This would help to avoid problems if the time budgeted in the contract is not enough to carry out the project to a high standard and with good results. It is important to discuss the prevailing conditions with the consultant before starting the project.

4.6 Determining the baseline

4.6.1 Baseline for energy savings

For assessing the total saving potential with identified measures it is necessary to define an energy use baseline or a reference level for what the savings are compared to. Commonly this baseline is set based on the measured energy use in the building. It is the client´s responsibility to make sure that this data is available for an energy consultant. If for any reason there is not sufficient data for establishing a baseline based on energy statistics then the client should plan additional resources needed for acquiring it.

However, there can be a number of cases where determining a baseline for energy savings requires more careful consideration than just taking the measured values from energy statistics. These situations are for example:

- **Minimum requirements, functional or legal, are not fulfilled before renovation,** e.g. indoor climate requirements are not fulfilled. If, for example, the premises do not fulfil the minimum requirements with regard to indoor climate, the building’s HVAC systems must be upgraded first. This can lead to changes in energy use in the building compared to the initial situation before renovation.

- **Buildings characteristics and function will be changed** as part of the planned renovation process, e.g. changes in the use of a building and occupancy levels, new tenant adjustments, reorganizing the floor plans, rebuilding atrium/entrance areas, etc. This can lead to changes in the technical properties of the building, its technical systems and its use. Changes in the building characteristics and its use often leads to changes in the energy use of the building regardless the planned energy saving measures.
- **Minimum requirements from the building code**, e.g. when carrying out a major renovation project national building codes or other requirements might require some minimum level of quality after refurbishment.

In the described situations a new baseline needs to be determined by using an energy simulation tool. After calculating the new baseline based on the planned changes the effects of proposed energy saving measures can be analysed.

Discussion should be carried out at the beginning of the project and an agreement made with a property/owner/client about how the baseline will be set. There must be a common understanding how the baseline is determined and which input data will be used.

4.6.2 Methods for determining the baseline for energy use

There are three different methods for setting the baseline for energy use in order to evaluate an impact of a package of energy saving measures.

1) Fixed baseline based on the existing energy statistics.
Existing energy statistics is used as baseline when the minimum requirements set on a building and its function are fulfilled and when building characteristics, its function and use will not be considerably changed after renovation.

Commonly this baseline is set based on the measured energy use taken as average of the recent years’ energy statistics, temperature corrected to a normal year.

Example
An energy inspection has been carried out in a school built at the end of the 1960s. The school has 6 buildings with total heated area is 5.386 m² heated area. The energy use for district heating and electricity is measured monthly bases and according to the data from energy statistics the buildings' total energy use in 2011-2014 was in average about 186 kWh/m² år (corrected to normal year). Indoor climate requirements are fulfilled in the building and no other major changes in the use of the building or renovations are planned.

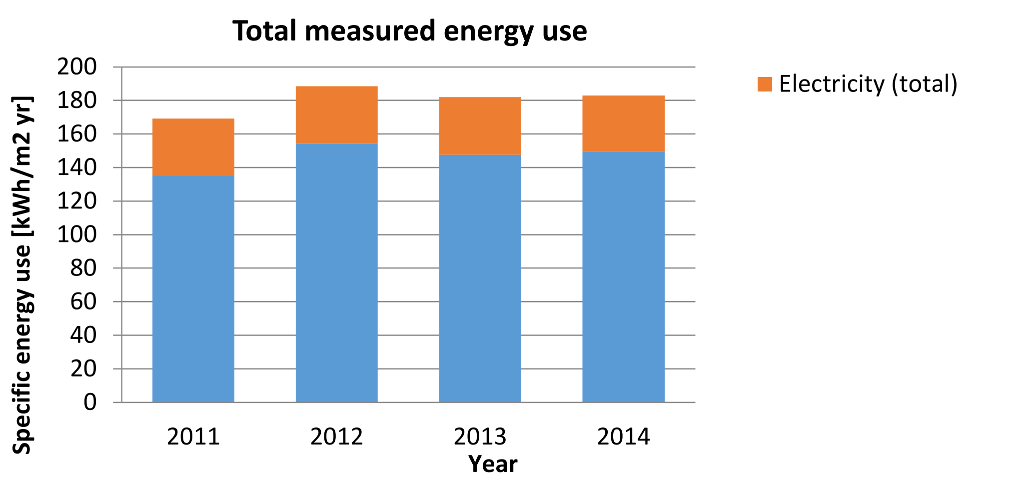


Figure 4.3 Measured energy use of the building based on energy statistics.

In this case, the mean energy use before refurbishment is used as the baseline for the energy calculations in Step 1 of the Total Concept method.

2) Fixed baseline based on energy simulations

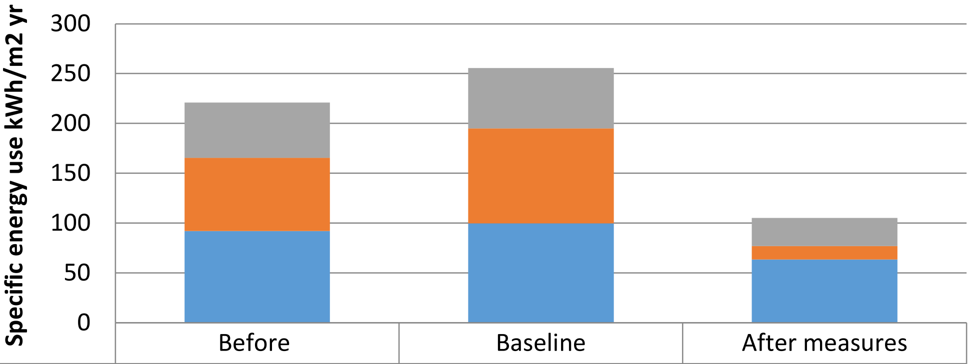
This method is used when a building is functioning poorly, for example regarding indoor climate, and the functionality and use of the building will improve substantially after renovation.

In this case the baseline energy use is based on calculated energy use with the prospective new (required) conditions (e.g. occupancy density, ventilation air flow rates after retrofitting) and with existing and/or upgraded systems. The baseline can easily be determined by:

- first calibrating the energy simulation model based on the conditions before renovation,
- Secondly adjusting the model based on the planned use or needed upgrade of the system(s).

Thereafter the effects of possible energy saving measures can be analysed.

This is illustrated in figure 4.4. The first pillar represents energy use before refurbishment. This energy use is based on measured values and is temperature adjusted to normal year. The second pillar represents the new baseline, for instance the energy use is recalculated with the new airflow rates/upgraded systems for improved indoor climate. The energy use after energy refurbishment is evaluated based on the baseline and the savings achieved with the energy saving measures. The corresponding energy cost reduction should only balance additional investments costs for doing energy measures beyond improved ventilation.



	Before	Baseline	After measures
District cooling	55	60	28
District heating	74	95	13
Electricity	92	100	64

Figure 4.4 Fixed baseline based on energy simulation

Example
An energy inspection has been carried out in a school built at the end of the 1960s. Its heated area is 9.472 m² A_{temp}. After auditing on site it was found that the air flows to the classrooms and group study rooms were too low to meet the property owner's requirements for an acceptable indoor climate, i.e. a maximum CO_2 concentration of 1000 ppm. In order to improve the indoor climate in all the rooms, the air flows need to be increased by approximately 25 %. The existing supply air units and extract air fans are separate units and have insufficient capacity to achieve this. Furthermore, the ducting cannot manage higher air flow rates.

Measure 0 means that the indoor climate is improved so that it fulfils existing requirements but for as little cost as possible and without taking energy efficiency into account. The simplest solution possible has therefore been chosen without taking energy efficiency into consideration. The existing supply air units and extract air fans will be replaced with bigger units. Also new ducting with new terminal devices will have to be installed. The upgrade means that the school's energy use increases, primarily due to the increased air flow rates without heat recovery:

	Before upgrade	*After upgrade(Measure 0)*	
District heating	126	138	kWh/(yr·m²) A_{temp}
Electricity	46	47	kWh/(yr·m²) A_{temp}

In this case, the energy use after ventilation system upgrade (*Measure 0*) is used as the baseline for the energy calculations in Step 1 of the Total Concept method. When calculating the required investment costs of energy improvement measures, e.g. addition of the heat recovery to the ventilation system, implementing DCV system, only the costs related to improving the energy efficiency are included and not the total cost needed for upgrading of the ventilation system.

3) Dynamic baseline based on energy simulations

When a specific energy saving measure is carried out, national requirements can set some minimum level of quality for a system/building component after refurbishment. This minimum requirement is then set as a baseline and energy saving potential of an additional energy measure, e.g. up to passive house standards, is evaluated based on this level. Necessary investments up to minimum level of quality, is considered in the baseline and not part of the energy saving of a measure. This means that the baseline must be dynamic, adjusted for each energy measure with the minimum level identified and subtracted for both energy and investment.

This dynamic adjusted baseline consists of several steps:

- The first step is to identify relevant energy measure.
- The second step is to split the costs into what is required for the minimum level and additional cost to reach an even higher energy ambition level, e.g. up to passive house standards.
- The third step is to calculate energy savings for every single measure.
- The fourth step is to rank the measures after profitability to identify the most profitable measure. You can use the *TotalTool* to do this (more information can be found from Chapter 4.11.2).
- The fifth step is to recalculate energy use with the most profitable energy measure fixed. This is set as the new baseline. Step three to five are repeated until all measures are ranked and fixed. This will include several energy calculations, and it is important to have an efficient tool to carry this out in a fast manner. However, it is important to do this to find the correct rank order of the measures with the exact energy reduction for each measure. If you skip this procedure, you risk that several measures saves the same kWh energy. This again can misguide the decision makers to make wrong decisions.
- The sixth step is to form the action package that fulfills the profitability requirements set by the building owner. You can use the Total Tool to do this.

A stepwise procedure is developed and shown in figure 4.5.

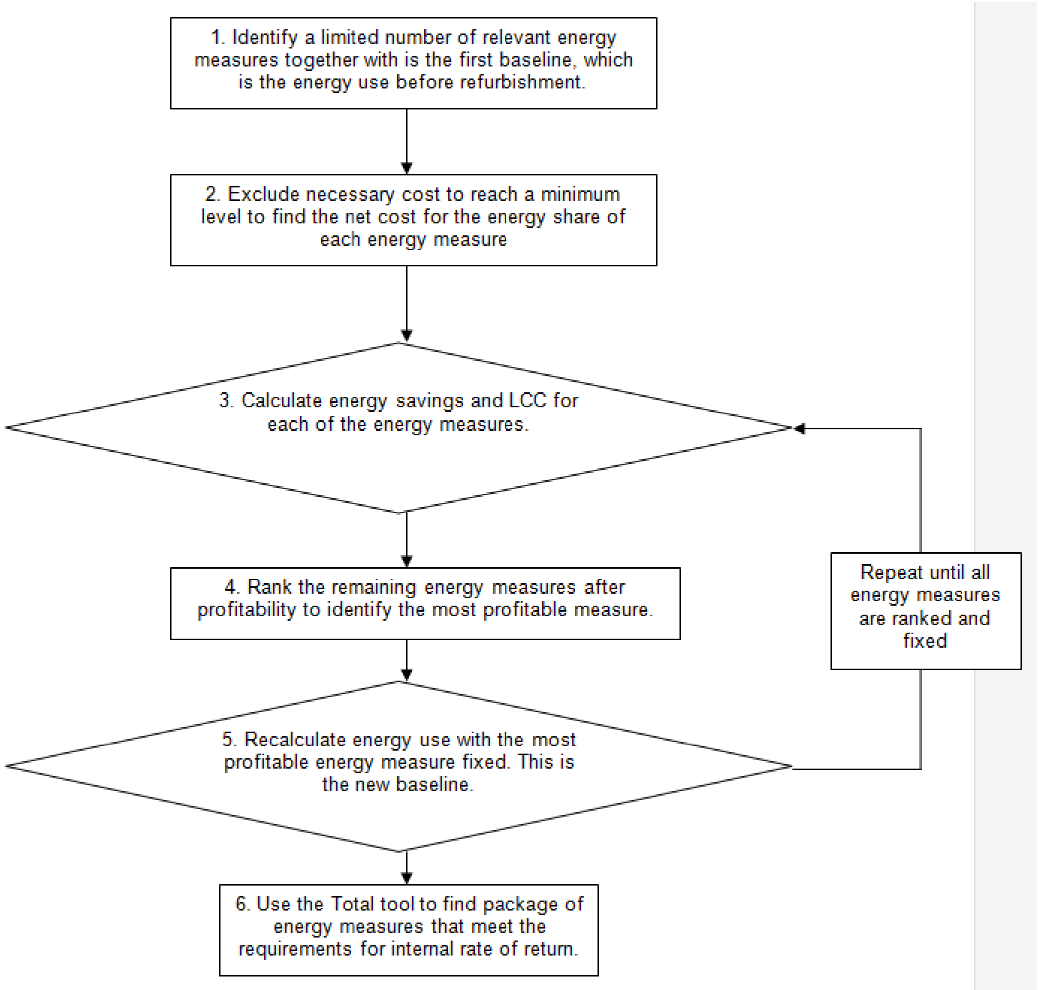


Figure 4.5 A stepwise procedure for Dynamic Adjusted Baseline

Example
A building owner needs to improve ventilation and replace windows, walls and roof due to old age. He wants to see if is profitable with energy ambitious upgrading to passive house level of less than 85 kWh/m². The energy measures are ranked and presented in the table. Four of the measures have a national minimum requirement that is not optional for the building owner. Let us take windows as an example. If windows need to be replaced, the U-value of the new windows must be less than 1,5 W/m²K due to national requirements. Replacements of the old windows with 1,5 W/m²K windows will reduce energy from 204 to 197 kWh/m². This is included in the baseline. An alternative is to use windows with U-value of 0,8 W/m²K. This will reduce energy use to 188 kWh/m². The difference between 1,5-windows and 0,8-windows for both investments and energy savings are consider as an energy-measure and analysed for profitability.

Energy measure	**Base-line kWh/m²**	**Minimum kWh/m²**	**Ambitious kWh/m²**	**Rank**
Windows		197	188	1
Roof	188	175	165	2
Ventilation	165	150	138	3
Artificial lighting	138	No minimum	114	4
Walls	114	104	94	5
Heat pump	94	No minimum	84	6

4.7 Start of the project

The different tasks in Step 1 can often be quite time consuming and require the work to be well structured with careful planning. It is therefore recommended after start of the project to draw up/ specify in more detail a time schedule for the execution of the project.

An initial meeting should be held to discuss the details of the project and how the practical work will be managed. To ensure an effective exchange of information and to simplify the consultant’s work during its execution, all the key people involved in the project should participate. In addition to the consultant and the property owner/client, the property manager, the maintenance manager, and if possible even the tenant’s representative(s) should be invited.

The following points should be discussed at the initial meeting:

- The scope, time plan and activity schedule of the project.
- Information required from the property owner/client for carrying out different tasks in Step 1.
- Clarifying all the relevant in-house and external key actors involved with the project and their contact details.
- Reporting the work.

When discussing the time and activity schedule it must be made clear to those involved how the work will be carried out and what level of involvement is expected of each of them. Details for future meetings and on-site inspections are also to be agreed upon. How the tenants are to be informed about the project and if there will be any interruptions when carrying out inspections of the premises, carrying out indoor climate measurements, etc.

The initial meeting also provides an opportunity for the consultant to discuss what information will be required from the property owner/client for carrying out different tasks in Step 1. Also, the property owner’s/client’s requirements regarding the building, its indoor climate and energy efficiency improvement work as well as their plans on maintenance measures can be brought up. The more questions that can be sorted out early on, the more rationally and efficiently the consultant will be able to carry out the assignment.

The consultant should also clarify with the client all the contact persons who will be involved with the project from the client side (in-house key actors) and draw up a list with their contact details and specify which type of information and support can be received from the different key actors. All relevant communication paths should be discussed at the initial meeting. This includes information about contact persons, who can provide relevant information and documentation about the building, e.g. technical documentation, energy statistics, system schemes, etc. Even people who are not directly involved can be put on the contact list, for example, contacts in drawing archives, previous suppliers and those in charge of the control and monitoring (BMS) systems. Also previous energy and environmental inspections might be of importance and details of contacts needed.

Finally, it should be decided how the follow-up and the final reporting of the consultant's work should be done.

4.8 Gathering basic information about the building

The first key activity for the energy consultant in Step 1 is to gather basic information about the building and other relevant input data for the work in Step 1. A separate information checklist template is available in the Total Concept tool-kit that lists the information needed for carrying out Step 1.

Normally, the property owner's/client's personnel supply the major part of the relevant basic information, as they know where this information is to be found or can, reasonably easily, find out where it is. Property owner/client must therefore provide information about these contact persons, who can support the consultant with the required information and documentation. The information checklist template can be sent to these appointed persons for them to fill it in and complementing it with the relevant documentation. Alternatively it can be filled in during the meeting with in-house key actors and used as a discussion base.

In practice, not all the information described in this checklist is readily available. Nonetheless, a clear and comprehensive picture should be strived for with regard to:

- The building.
- How the building is used.
- Indoor climate requirements.
- The technical systems
- The energy use.

4.8.1 The building

The basic information about the building such as the name of the property, its address, year built (originally and any rebuilding or extensions) and data about the different areas of the building - gross floor areas, non-residential areas, heated areas, etc.- are important for the energy audit, especially with respect to reference values and energy calculations. If more than one building will be inspected as part of the project then this data should be specified for each building.

Additionally, it can be important to study drawings, primarily the architect's drawings. Overview/layout drawings, floor plans, elevations and sectional drawings usually suffice to obtain a general picture of the building. Structural drawings illustrating construction of walls, ground slab, roof or technical descriptions of structural details can be of great value. All documentation should be as-built documentation, and a short description of the structural changes or renovation work during the last 10 years would contribute to establishing a good overall picture of the building.

4.8.2 Information about how the building is used

In most cases, the property manager and maintenance staff can supply sufficient information about how the building is used. However, it can sometimes be necessary to contact the tenants regarding occupancy times/working hours and the number of occupants or people present in the building. Information about occupancy rates and use of space in different parts of the building will provide a picture of the current ventilation requirements and if these are met by the systems installed at present.

4.8.3 Indoor climate requirements

The energy efficiency improvement measures in a building must never impair the function of the building, its indoor climate or its technical standard. These are basic requirements that must always be taken into account when planning and carrying out energy measures and it must therefore be made clear what the indoor climate requirements are. Every identified measure must be assessed individually to determine whether it entails any long-term impairment of the indoor climate or the usefulness of the building or its standard.

It should always be investigated what indoor climate requirements apply for the building(s) and whether or not these indoor climate requirements are fulfilled at the starting point of the project. Also any previous indoor climate assessments that have been carried out can be relevant to the project.

If for any reason the indoor climate requirements are not fulfilled it is important to identify what deviation and problems occur and what would be the relevant actions needed for improving indoor climate conditions and how this can be combined with energy saving measures.

It is important that the consultant and the property owner/client discuss this matter and agree on what baseline can be regarded as a starting point for the energy efficiency improvement project (see Chapter 4.6.2).

4.8.4 Technical systems

When carrying out an audit work the consultant should look at the main features of the building's HVAC systems. Principle system schematics for ventilation, heating and cooling systems will provide an overview. Reports from previous mandatory ventilation inspections will provide information about the condition of the ventilation system, whether it has been approved, how large the air flows are, etc.

Operating and maintenance instructions will provide information about how the systems were planned to be controlled and regulated. From the systems for control and monitoring (e.g. a building management system, BMS) it can be possible to check control parameters and operating times for different technical systems including ventilation, heating, cooling, lighting and other technical systems. The BMS will provide valuable information in the form of logs of selected parameters over time.

The as-built drawings for the ventilation, heating, cooling, domestic hot water system systems are important. When the energy balance in a building is to be calculated and the energy measures identified it might be necessary to look at the floor plans and sectional drawings so that the possibility and cost of replacing ventilation plant, supply air terminal devices, additional ducting, etc., can be investigated.

An initial assessment of the electrical power required for lighting can be carried out with the help of updated drawings in which the number and type of fittings can be seen.

Information about other electrical power consuming equipment and machines can be of great importance. It would be good to have an inventory list or to create one during the inspection.

A short description of the replacement technical systems and/or renovation work that has been carried out over the last 10 years will contribute to creating a clear overall picture. Maintenance staff can provide information about any changes made to the technical systems and, if so, why they were made. They can also report any shortcomings or problems regarding the current functioning of the systems and whether there are any obscurities in the present documentation, for example, if the drawings do not agree with the actual conditions.

4.8.5 Energy and resource use

The following details about the building's energy and resource use are required for the energy audit:

- Heat energy use (MWh/yr or kWh/m^2·yr). If the heat energy use is not measured separately or can be easily identified then information about the bought fuel/energy source for heat production (e.g. bio fuel, gas, oil, electricity) together with the performance factors of the heat production system should be given.
- Electrical energy use (MWh/yr or kWh/m^2·yr), in many cases the use of electricity can be divided up into electricity used for the building itself and tenant's electricity, then data about both types of energy end-users is relevant. It is important to get overview of the total electricity use in the building.
- District cooling energy use, if any, (MWh/yr or kWh/m^2·yr).
- Power demand for electricity (kW), building´s total power demand and power demand for end-users (kW) if available (e.g. cooling plants)
- Cold water use (m^3/yr or l/s·m^2·yr).
- Warm water use, if measured separately (m^3/yr or l/s·m^2·yr).

This energy use data should be extracted from energy statistics and it should be clear whether the heating data has been adjusted to provide an average annual use in a normal year. The statistics should be at least from the last year and preferably from three or more previous years.

If the property comprises a number of buildings, the annual energy use in each and every building should be investigated. The energy use can then be studied at an individual building level, i.e. energy mapping carried out to see where energy is actually being used. It is greatly advantageous if there is separate metering of heat, cooling and electricity in each building. The more detailed the statistics, the better. If sub-meters have been installed in the building for different energy end-users, then readings from these should also be reported. It must be clear which end-users the meters cover, for example tenant's electricity/property electricity, cooling units, lighting system, etc.

Information about previous energy analyses, for example, energy certification, can also provide important information for the energy audit.

In order to make comparisons of energy use in similar buildings, it is practical to use key indicators expressed in kWh/m^2. For making this comparison it is important to have a clear picture of which area categories have been used for the reference values, i.e. gross floor area, non-residential area, heated area, etc.

4.9 Energy audit and identification of measures

This chapter highlights the issues that are important to take into account from a quality point of view when carrying out an energy audit in a Total Concept method.

4.9.1 Energy audit - the basics

In general, energy audits can be carried out at three levels (categories):

- **Level 1**: This is in principle a 'desk audit' in which previously documented information is examined. A visual inspection might also be carried out.
- **Level 2**: This includes, besides a Level 1 audit, a thorough investigation of the building and its installations. Only simple, momentary measurements are made, if deemed necessary.
- **Level 3**: This includes, besides a Level 2 audit, a more comprehensive analysis of the building by carrying out, for example, additional measurements of the functions of the different systems in the building and gathering all necessary information for the energy simulations and the investment cost calculations.

The Step 1of a Total Concept method requires a Level 3 audit to be carried out.

4.9.2 Carrying out a ´desk audit´ and planning an audit on site

Planning the audit ahead is important in order to ensure efficient and successful energy audit on site. Detailed preparations and careful planning of the audit work will contribute to keeping the number of site visits to a minimum.

Before the practical inspection work on-site is carried out a certain amount of ‘desk audit’ work should be done. The person who will then inspect the building will hereby obtain a first insight into the building and gets some understanding about its operation and technical systems.

Based on the outcomes of the ‘desk audit’ a checklist can be formed with relevant points to be checked and analyzed in detail when site visits are done as well as questions to be raised to the relevant in-house key actors. It will also give a preliminary insight what measurements may be needed.

4.9.3 Carrying out an energy audit on site

The main key points to consider for efficient and successful energy audit on site:

- Conduct the audit in collaboration with the property manager and maintenance staff. Maintenance staff usually has a good picture of the present condition of the building and its systems and can support the consultant with relevant information. They are usually the ones who can show the consultant around the building for an on-site inspection and who have access to the technical rooms. In Appendix 4 there are examples of useful questions that the consultant can put to the property manager, the maintenance staff and the tenant’s representative.
- Inspect the building based on building *as a whole* approach. It is the building function and use that sets the demands and requirements on technical systems. Check the status and condition of the building and all of its technical systems that have an impact on building’s energy balance. Use the ***Demand – Distribution – Production*** method when auditing; see the Chapter 4.9.4 for details.
- If there is a central control and monitoring (BMS) system check the control and regulation principles and operating parameters (if access to the system cannot be provided beforehand).
- Document in detail and take photos, make documentation traceable.
- Plan and carry out additional measurements when needed; see the Chapter 4.9.5 for details.
- Plan ahead which input data is needed for carrying out energy simulations in the next step and what data needs to be collected/confirmed on site. Gather as much of the in-data as possible. Relevant input data for energy simulations include for example room temperatures, power demand and operating times of the technical installations, airflow rates, occupancy times and occupancy levels, assessment of the air tightness of the building, etc.

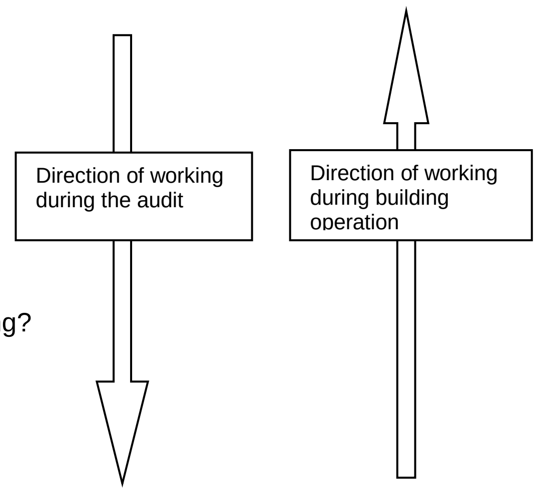
- Make a list of *all* possible energy saving measures: all obviously profitable measures are to be included as well as those which might appear economically doubtful. It might be possible to include them in an action package that is profitable when regarded as a whole.
- Check whether identified measures can actually be carried out from technical point of view:
  - *Are there architectural limitations?*
  - *Is there enough space for new systems/equipment?*
  - *How do the measures affect other systems?*
  - *How will implementation of the measures affect the use of the building?*
  - *How much refurbishment/rebuilding work will be required?*
- Assess the factors that affect the cost of a particular measure.

4.9.4 A Demand – Distribution – Production energy audit method

The person carrying out the auditing work must have a clear and overall picture of the building and its systems and at the same time be able to identify and study important details. The chances of being able to do this are greater if the *Demand – Distribution - Production*[2]method is followed when analysing the different systems in the building.

The basic question to be answered during the auditing work is: *what are the demands/requirements and how are they met?* In principle the demand for energy/media is met in three steps, in which the following can be analysed:

- Demand (to be met)
  - Quality?
  - Amount/volume?
  - Point in time?
- (via) Distribution
  - Do the demands – quality/amount/ point in time – vary in different parts of the building?
  - Is distribution efficient?
- (from) Production
  - Adapting to demands?
  - Is production efficient?



The demands are usually determined by the indoor climate requirements in the different spaces in the building. Investigate, for example, whether the air flows, heating capacity and cooling capacity are correct – not too low, so that requirements are not met, and not

[2] **Production** refers to production in central units/supply systems in the building.

unnecessarily high, for energy use reasons. When it comes to lighting (lighting sources, lighting fittings, lighting systems), the quality must be correct at the same time as the power demand should be reasonably low.

When analysing *distribution*, it is investigated whether for example, air, heating and cooling media is delivered and distributed between the different rooms according to the demand. Are demands (quality/amount/point in time) different in different spaces in the building? It might be the case, for example, that in certain parts of a building heating is required while at the same time cooling is needed elsewhere. Is distribution efficient? Check the control of flow rates and temperatures damper and valve functions and settings, insulation of the air/water distribution system, efficiencies of pumps and fans.

When analysing *production*, the efficiencies of different types of production are investigated. These can include the production of certain air flows at certain temperatures or the production of cooling and heating media flows at certain temperatures. Are these produced in an efficient way and do they have effective control, is there heat recovery in ventilation systems?

Examples of questions to be asked when inspecting a ventilation system

When analysing *Demand*:

- *Quality:* Has the supply air the correct temperature, cleanliness and humidity content[3] to meet the requirements?
  - *Suggested measures: Adjust the temperature of the supply air, improve the purification process, improve the humidification/dehumidification process[2]*
- *Amount:* Is enough air supplied to meet the requirements?
  - *Suggested measures: Adjust the air flow rates or adapt the flow rate according to the load (DCV)*
- *Point in time:* Can the correct amount of air be supplied with the correct quality at the right point in time? Investigate variations over time, for example, when premises are occupied/unoccupied, summer/winter, etc.
  - *Suggested measures: Adjust the operating times*

When analysing *Distribution*:

- Do demands regarding quality, amount and point in time vary in different parts of the building?
  - *Suggested measures: Install additional units to meet varying demands, e.g. after-treatment with heating/cooling/filters. Sectioning of the system using dampers. Insulation of air distribution system*
- Is distribution efficient? What types of motors and fans are used and how large are the pressure drops?
  - *Suggested measures: Check the air terminal devices and dampers if pressure drops can be reduced and choose more efficient fans/motors on replacement. Install variable speed control.*

[3] In certain non-residential premises, such as museums and hospitals, humidification can also be needed.

When analysing *Production*:

- How are adjustments made in the central ventilation unit to adapt to the demands: temperature, cleanliness, air flows, operating times?
  - *Suggested measure: Adjust their control to variations in demand.*
- Is production efficient? Is there any heat recovery? Primarily air to air heat exchangers, secondarily air to water to air heat exchangers.
  - *Suggested measure: Replace fluid heat exchangers with rotary heat exchangers. Note: Make sure that extract/exhaust air is not contaminated by process air.*

4.9.5 Measurements on site

It might turn out during auditing that some relevant information is missing and that it can only be gathered by making measurements on site. It can happen that the information about the use of energy in the building is not complete or more detailed information is required about some large energy users, for example, for process cooling or restaurant/catering kitchens. It might then be reasonable to carry out separate electrical energy use measurements for a short period of time. Additionally, measurements of temperature and flows are often needed to confirm that the requirements are met or identify possible measures for energy saving.

Examples of system parameters that could require additional measurements:

- Room temperatures.
- The temperature of the supply air at ventilation units and at the air terminal devices/ room units.
- Supply and return water temperatures (room units, coils, chillers/boilers, etc).
- Flow rates (ventilation, cooling and heating system).
- Pressure drops over components in air handling unit.
- Electric power rating and air flows of the fan systems
- Electrical power demand in the building, if separate measurements are not available.
- Electrical power demand for a cooling plant, if separate measurements are not available.
- The temperature efficiency[4] of heat/cooling recovery system.

The number of additional measurements required is usually determined by the information gathered from the ‘desk audit’ work and from the first on-site visit.
If these measurements are to be carried out efficiently, and are to provide useable results, the work should be carefully planned. The following questions should be asked:

- What is to be measured?
- Why is it to be measured?
- How is the work going to be carried out?

[4] The temperature efficiency of a heat recovery system must be measured when it is working at maximum capacity, that is, when the outdoor air temperature is so low that after-heating of the supply air takes place. It is also possible to carry out the measurements at higher outdoor temperatures by raising the supply air temperature until the after-heating unit is switched on. This must normally be done after working hours.

  - *Short-term random spot checks?*
  - *Long-term logs, e.g. several days?*
  - *Types of instruments?*
  - *Data gathering system?*
- Can existing control and monitoring systems be used?
- How will the data be handled, processed and presented? By whom?
- How long will it take to complete the work?
- What will the measurements cost? Will the cost be covered by the budget?

4.9.6 Identifying energy saving measures

In many buildings, it is quite easy to identify measures that can result in significant savings and that do not require large investments. It is often only a question of just adjusting set points and operating times, balancing, etc. In other buildings – especially those which already have low levels of energy use – it can be difficult to find energy saving measures that would also be cost-effective, but some are usually found. In most buildings, however, potential improvement measures have a large span when it comes to profitability.

In non-residential buildings there are often large savings to be found in the different technical systems, such as those for lighting, ventilation, heating and cooling. To achieve these savings, it is necessary to implement even measures in the control and regulating systems.

The layout and design of the building envelope and other aspects of the building's structural design are of vital importance from the very beginning, when the building is planned and built. When a building has been completed it is difficult to find measures connected to the building envelope that do not cost too much in relation to the resulting energy savings. The Total Concept method can, however, offer an opportunity to carry out some of these measures, as the total profitability of the project can be upheld by the more profitable measures connected to the technical installations.

When inspecting the building to identify energy saving measures building *as a whole* approach should be applied. It is the building function and use that sets the demands and requirements on technical systems. The status and condition of the building and all of its technical systems that have an impact on building's energy balance needs to be checked during the audit. The essence of the Total Concept method is to try and find as many measures as possible that can result in reasonable energy savings and not to focus only on those that are profitable as individual measures. The chances of succeeding will increase if you can think outside the box and challenge existing solutions:

- Ask the question "Why?" as often as possible.

- Existing systems can either be controlled or used in more efficient ways (short-term approach) or you can think in a new and bold way and discard the old solutions, which is a more long-term approach to improving efficiency.
- Visits to the building at night or on weekends can often provide information about the unnecessary use of energy.
- Planned maintenance and building function improvement measures can often be combined with energy efficiency improvement measures.

The idea is to gather a range of measures in a profitable action package. This is why measures that do not appear to be profitable should not be disregarded during the energy audit. If they are unprofitable, then this will be shown in the economic analysis when the *whole* of the action package is considered in its entirety.

A checklist of common energy efficiency improvement measures within different technical categories is given in Appendix 5. Sometimes it can be greatly useful to engage specialist consultants who can give advice about different aspects, such as lighting solutions, control systems and restaurant/catering kitchens.

It is important that the final report from Step 1 can be used as a basis for Step 2 when design and construction work is undertaken. This is why every measure included in the action package must be described very accurately.

System boundaries

When planning energy saving measures it is extremely important to decide from the very beginning which *system boundaries* are to apply. How the boundaries are chosen is not important but it is important that a deliberate choice is made. If the aim of the project is to reduce the amount of bought energy, then the supply equipment, such as cooling plant, boilers and heat pumps, must be included in the analysis. If, on the other hand, the aim is to reduce the energy demands of the building itself, then these units can be disregarded. Fig. 4.6 shows how boundaries for energy-saving measures in a building can be drawn.

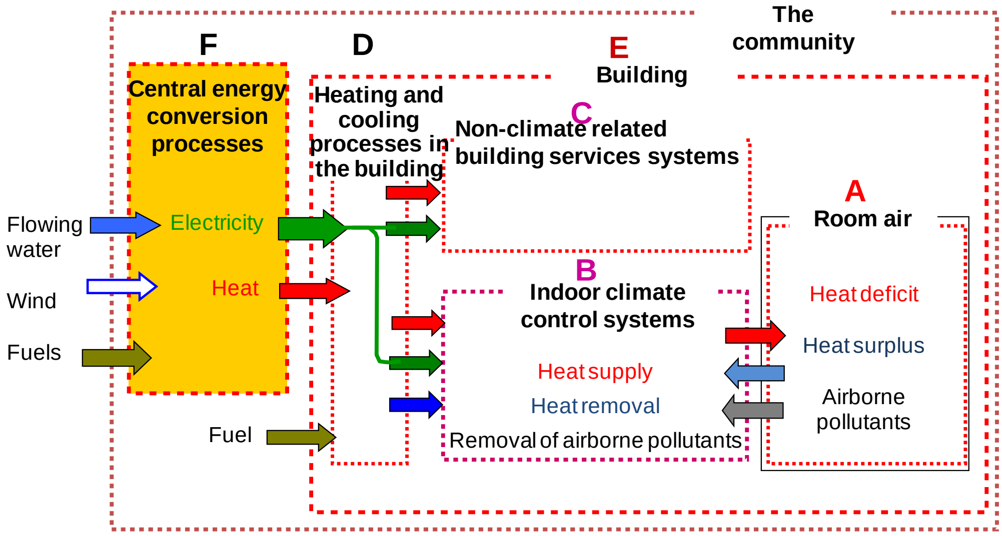


Figure 4.6 System boundaries that can be applied when analysing the energy behaviour of a building.

The Total Concept methods that have been carried out by BELOK members have focused on reducing the heat, cooling and electrical energy demands by improving building components and installations. Focus has often been on the *actual demand* and not how the demand is met. The system boundary has therefore been placed often around the systems **A**, **B** and **C** in Fig. 4.3. But in some cases also improvements in the supply systems, **D**, have been included.

Of course, the system boundary **E** could have been chosen, and this will mean that 'everything' within the building is included. Choosing this system boundary would have then meant focusing on 'bought energy' and including measures such as the replacement of oil-fired or electric boilers by heat pumps which also are important energy measures. Again, it is not important how the energy system boundaries are chosen but that a deliberate choice is made early on in the project.

It is therefore worth mentioning that if the system boundary is drawn far outside the building, **F**, then it would include the whole of society or even the world and this would mean including terms such as primary energy. Reasoning this case would be difficult because there is the risk of implementing measures that might be seen as 'wrong' in the future, as the definition of primary energy could be changed as a result of political decisions or technological advances.

When identifying energy saving measures in a building and determining their effects on each other and on total energy use it is possible to use the above described system boundaries. Hence the improvement measures can be categorized into three groups according to their effects on energy use and cost of energy supply (see Fig. 4.7):

1. Measures in a building to reduce loads on and thereby also the energy demand in the technical systems. These are measures that influence the loads from system boundary *A* in Fig. 4.6.

2. Measures in a building's technical systems to decrease their energy use and increase their energy efficiency. These are measures that are carried out in system boundaries *B* and *C* in Fig. 4.6.
3. Measures that reduce the cost of energy supply. These are measures that are carried out in system boundary *D* in Fig. 4.6 and influence the bought energy.

The three principally different improvement measure categories are shown on Figure 4.7.

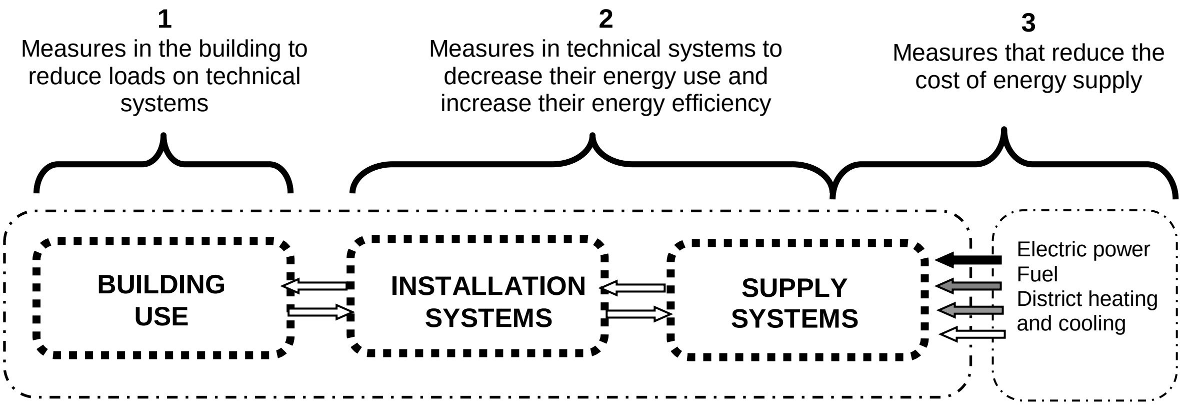


Figure 4.7. The three principally different improvement measure categories arranged according to their effect on energy use, cost of energy and possibly, the size of the initial investment.

Power demand improvements

Improving energy efficiency is often about reducing the use of energy but decreasing the power demand of the building can be just as important: savings in costs for charges based on input power demand will also contribute to paying for the investments for energy-saving measures.

Reducing peak power demand, both for heat and electrical energy, can result in considerable cost savings. Power peaks are not only the result of large single power peaks but also the sum of all power peaks. It is therefore important to take all uses of power into consideration. An analysis is required of what the basic power demands are and what demands depend on different points in time, such as start-ups of ventilation units, lighting, machinery, etc.

The reduction of the peak power use requires numerous measurements to be carried out on machines/apparatuses having high power demands. Measurements made over a period of one to two weeks will reveal how machines/apparatuses are used and how they are controlled and regulated.

Improving power demand can often be achieved by changes or improvements in the BMS system. Changes in operational routines can also contribute, for example, by avoiding the simultaneous start-up of ventilation units, lighting, machinery, etc.

4.10 Investment cost calculations

4.10.1 General principles

The cost of each measure (capital cost) must be calculated individually. However, how the simultaneous implementation of the different measures in the action package affects the costs must also be taken into account. For example, if measures are carried out at the same time then the design work and construction work might be lower.

When assessing the costs for each measure the following cost items might need to be considered:

- Dismantling costs.
- Investment costs for the specific product or system.
- Labour costs, installation costs.
- Additional building costs, for example, for drilling holes, installing fire seals, replacing ceilings and carrying out groundwork.
- Cabling and power connections.
- Control and regulation, and reconnections to the BMS system
- Costs for system balancing
- etc.

Preliminary costs involved with Step 3 should also be assessed already in Step 1 if possible, including cost for additional energy meters, measurement system, etc.

Investment cost calculations can be carried out in different ways: by using one’s own or hired cost engineer, using available cost books (e.g. *Sektionsfakta* in Sweden), tenders from technology providers /contractors or a combination of sources.

It is always the property owner/client who decides on the financial terms as well as the conditions for the investment cost calculation. Among other things, the property owner/client has to decide on whether the design costs or client’s project management costs are to be included in the investment cost calculation. Design work that is required for the implementation of the action package can also be included in the contract with the building contractor. It must be clearly stated in the report which costs have been included.

The property owner/client should be aware of that investment cost calculations made at an early stage has certain inaccuracy. Step 1 of the Total Concept method is a pre-study phase of a building process in which a requirements specification and consequence analysis for identified measures are carried out. Detailed planning and design is carried out in Step 2 and this will result in the basic documentation and data that are required so that contractors can be engaged. Only when equipment is purchased and contracts actually awarded will the size of the costs be known in detail. Complete certainty will be achieved first when a contractor has been appointed or when the contract has been completed.

4.10.2 Determining the baseline for investment costs

It is not unusual for a property company to carry out energy saving measures at the same time as a building is generally refurbished or upgraded to minimum required level. In the calculations for a Total Concept method, only investment costs which are directly related to the energy efficiency improvement measures should be included. This is defined here as an *energy investment cost* of a measure. In principle, it is only the additional costs exceeding the baseline level that should be considered.

For cost allocations following recommendations apply:

1) When a measure is carried out only for energy saving purposes, all of the investment cost is included to the energy investment cost. If, for example, the energy saving measure is carried out only for saving running cost for energy use and not for any other reason, e.g. maintenance or upgrade, then the investment is motivated only from energy saving perspective and should be included 100 % to the energy saving action package.

2) When a measure is part of upgrading the building and its systems for fulfilling minimum requirements, only the additional costs exceeding the baseline level should be considered. If, for example, the premises do not fulfil the minimum requirements with regard to indoor climate, the building’s technical systems must be upgraded first. New baseline for energy use is calculated based on the prospective new (required) conditions. A cost estimation is based on the minimum investment required for upgrading the systems for fulfilling these requirements and this investment cost is not considered as part of the energy saving action package. Only the additional investment cost for doing energy measures beyond improved ventilation is considered.

3) When a measure is part of upgrading the building and its systems for maintenance reasons and/or tenant adjustments, divide the investment cost**.** Some measures may be carried out also for maintenance reasons and therefore not all of the investment cost for the measure can be considered as an energy investment cost. How the cost will be divided in between investment for building maintenance and investment for energy saving measures must be agreed with the client as they can have more detailed plans and budget for maintenance measures.

4) When minimum requirements from the building code apply for the measures, use cost adjusted or dynamic baseline. In some Nordic countries when carrying out a major renovation project, national building codes or other requirements might require some minimum level of quality after refurbishment. In this case dynamic baseline for energy use can be calculated (see chapter 4.8). The costs for fulfilling the minimum requirements are not included to the energy investment for a measure, but only the cost to reach a higher energy ambition level, e.g. passive house level.

Example

- If the windows in a building are due for replacement because of their poor condition or because the indoor climate is not satisfactory in winter, only the extra costs incurred by choosing especially energy-efficient windows are to be included in the Total Concept calculations.
- If a ventilation system has to be replaced, because it is in poor repair or it does not fulfil current requirements regarding air quality, only the extra costs incurred to achieve a significantly higher level of energy efficiency are to be included in the Total Concept calculations.
- One of the measures in a Total Concept method is to add extra insulation to a cellar wall. At the same time the drainage around the building is to be improved as part of a renovation project. The costs must then be apportioned between the two projects. The cost of the excavation work is referred to the renovation project, while the material cost of the extra insulation and the labour required is referred to the Total Concept method.

4.11 Energy calculations

4.11.1 Introduction

Energy calculations are very important part of the Total Concept method. One of the basic requirements that must be fulfilled so that it is practically possible for property owners/clients to decide whether or not to carry out an energy savings project, often quite costly, is that the data on which the decision is made is reliable. Primarily, this concerns the calculated energy savings.

Energy calculations help to establish which the different energy end-users are in the building and where the greatest potential for energy savings lies. Energy calculations are also needed to calculate the energy savings of the identified energy saving measures in order evaluate the final annual cost savings. Also, when measures are implemented as a package then often different measures affect each other. For example energy savings achieved from lowering the set point temperature for heating from +22 °C to +21 °C will be somewhat lower when also the climate scale is renovated. Decreasing the average airflow rates in the ventilation system leads to less savings when also the fan system is exchanged to more efficient one. The combined effects of identified energy saving measures needs to be estimated during the calculations.

The energy saving measures can be divided into two main categories, based on their impact on other systems:

- Measures in which the energy savings are only results of the measures themselves and the measures do not otherwise affect other systems.
- Measures in which the energy savings, in addition to the direct savings, also have indirect effects on the energy use of other systems.

An example of the first type of energy saving measures is the installation, or replacement, of heat/cooling recovery system in the ventilation system. This will only affect the heat and electrical energy demands in the ventilation system. The same is true for the replacement of pumps and fans, etc. Here it is quite easy to calculate the change in total energy use after implementing each measure and advanced energy simulations may not be needed.

An example of the second type is the installation of more energy-efficient lighting. This will directly reduce the electrical energy demand but might increase the heat demand. Additionally, if a chilled beam system is installed, the cooling demand during working hours can be reduced. Another example is the conversion of a CAV system to a VAV system. The heat and electrical energy demands of the ventilation system are reduced considerably but, in addition to this, the heat demand by the radiators is also reduced, as it is no longer necessary to compensate for the cooling effect of the supply air during working hours in empty spaces. However, a measure that aims to reduce air flows, with the intention of reducing the need for electrical energy to run the fans, will reduce the savings that a more efficient heat recovery unit would have provided with the original air flow.

4.11.2 Carrying out energy simulations

For analyzing the effects of energy saving measures that have indirect effects on the energy use of other systems and for taking into account combined effects of different measures more detailed energy simulations are required. Commonly a calculation model for the building with its existing structure and operations is made with the help of energy calculation software or tool.

The building is modeled according to the existing layout of the building, its current operational data and building use. The input-data for energy calculations are based on data that has been obtained from documents gathered at the beginning of the project and on-site inspections and should be detailed documented for each energy calculation. As a result of the calculations building demands for heat energy, cooling energy and electricity is obtained as well as division of energy use between different end-users. These results are then compared to the building’s energy statistics. The aim is to ensure that the deviation from the measured energy values is not greater than about 10 %.

If the calculations and the energy statistics are markedly different, the input data will have to be re-checked and adjusted if possible. Deviations could occur because some of the assumed input data was incorrect when compared to actual use and prevailing condition of the building. This could, for instance, be due to incorrect assumptions about the heat gains from occupants and machinery/ equipment.

After the deviations from measured values are decreased to an acceptable level the calculation model can then considered to be calibrated according to the actual conditions and will be suitable for studying the effects of the different energy saving measures in the building.

When carrying out energy calculations the following points should be taken into account:

- The background/input data must be correct, including a correct assessment of the existing conditions in the building and its systems.
- If the results from the building model do not agree with the energy statistics check the background data and determine what affects the result the most – assumed room temperatures, air leakage into the building, operating times, etc. – as all these can have considerable effects on the results. Determine whether more measurements are needed to correct the assumed values.
- The conditions and assumptions used in the energy calculations must be properly documented, for example, the basic data regarding the building and the input data for calculating the effects of energy saving measures.
- The comparison of energy use before and after the implementation of the energy saving measures must be understandable and reasonable. Make sure that agreement has been reached with the property owner/client regarding the initial conditions and ensure that the effects that the energy saving measures have on each other have been included.

Calculation tools

In order to evaluate the effects of energy saving measures which, in addition to the direct savings, also have indirect effects on the energy use of other systems, the calculation tools or simulation software's used need to be able to calculate the total energy balance of the building. These calculation tools or simulation programs need to consider the effect of heat storage in building fabrics, internal heat loads as well as their impact on thermal climate.

Also a considerable number of calculations or simulations can be needed to obtain a reliable understanding regarding the effect of each measure on future energy use. It is essential, when investigating non-residential buildings, that the calculation tools or simulation programs are actually designed for such buildings (e.g. include possibilities to calculate different types of technical systems) and that it is possible to analyse the effects of individual measures using a reasonable amount of work input.

Additional requirement is that the programs that are used for energy simulations must have been validated and the person carrying out the calculations must understand how the calculation model relates to the building in question.

In some cases, special programs and/or the use of reference data based on experiences are required to determine the use of energy and the savings potential for certain measures and systems. Among other things for:

- Measures affecting the central heating/cooling units.
- Measures affecting the control and regulating (BMS) system.
- Measures affecting the compressed air systems.

- Demand Controlled Ventilation systems.
- Measures that reduce air infiltration, for example, the replacement of windows, adjustments to the ventilation system and balancing air flows.
- Humidification and dehumidification in special premises.
- etc.

Main steps in building´s energy simulations

The simulation model that is used to calculate the energy savings of identified measures must, as far as possible, resemble the actual operation of the building. A calibrated model of the specific building must therefore be created. This is done by following main steps:

- Documentation of input data.
- Evaluating input data – uncertainty assessments.
- Division of building into zones (if needed)
- Feeding of the input data into the simulation program.
- Initial calculations.
- Comparing results to measured values.
- Adjusting uncertain input data.
- New calculation(s).
- Establishment of the basic building model.

Documentation of input data

Input data for energy calculations depends on the requirements of the energy calculation program being used. The input data for energy simulations is commonly collected when compiling already documented building information and carrying out auditing work on site. It is recommended to document all the input data required by a specific program, for example, by using Excel tables, to increase the traceability of the whole calculation process. It is then easy to check which basic data is being used, whether the input data has been fed in correctly and to make ant necessary adjustments to the input data.

Evaluating input data – uncertainty assessments

When all the input data for the energy calculations has been gathered and documented, an uncertainty assessment should be carried out. In an uncertainty assessment, all the input data and its effect on the use of energy are evaluated.

The purpose of carrying out an uncertainty assessment is to identify input data that can be used to adjust the calculation when the results are compared to the actual readings for heat and electricity. However, the degree of uncertainty for each piece of input data is not enough to find input data that can be adjusted. Every piece of input data must also be assessed based on the effect that it has on the use of energy. It is suggested that an assessment regarding uncertainty and its effect on energy use is graded using a three level scale, i.e. having a *small*, *medium or large* uncertainty or energy effect.

The assessment of the degree of uncertainty and energy effect is illustrated with examples in Fig. 4.8.

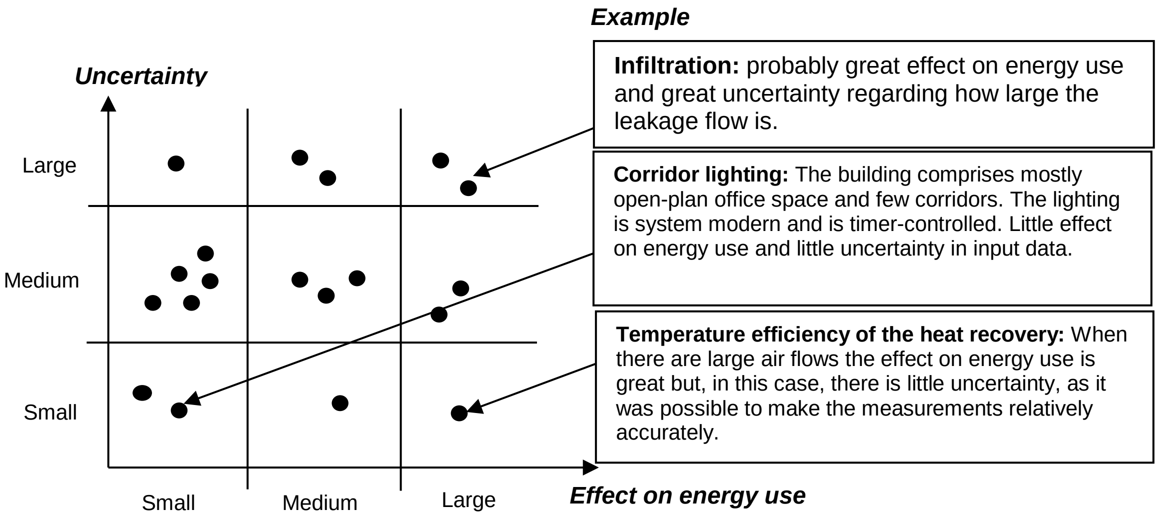


Figure 4.8 Assessing uncertainty and effect on energy use. The points in the diagram represent input data with a certain degree of uncertainty and effect on energy use.

Example: Assessment of air leakage into the building through the facade. The building is subject to wind, and is old and unrenovated. No air-tightness measurements have been carried out. The assessment of how large effect the air leakage has involves a large degree of uncertainty and, at the same time, it most likely has a large effect on energy use.

Division of building into zones (if needed)

When carrying out energy calculations the building might need to be divided into different zones depending on how it is used and its different technical installations. This supports receiving more accurate results of simulations. For example, the divisions can be made according to:

- Different uses of the building zones (e.g. office area, shop, restaurant).
- Different indoor climate requirements (e.g. different requirements on room temperatures).
- Different indoor climate control systems (e.g. air conditioned areas and non air-conditioned areas, air cooling, water based cooling).
- Different operating times of the systems (e.g. AHU units)

How the calculations per zone are done depends on the simulation software used. Often the calculations for each zone will be first done separately and thereafter combined together to achieve results for the entire building.

Feeding of the input data into the simulation program

This step requires great accuracy, as the feeding of data is itself a source of uncertainty. To reduce the risk of incorrect values being fed into the program, all input data is noted separately, for example, on an Excel spreadsheet. This will increase the traceability of the whole calculation process. It is then easy to check which basic data has been used, whether feeding of the input data has been correct and, if necessary, to make adjustments to the input data. Do not forget to double-check all input data which has been fed into the program.

First calculation

Carry out the first calculation and save the result separately. As an example the first results are illustrated on a heat/electrical energy diagram for comparison in the next step (see Fig.4.9).

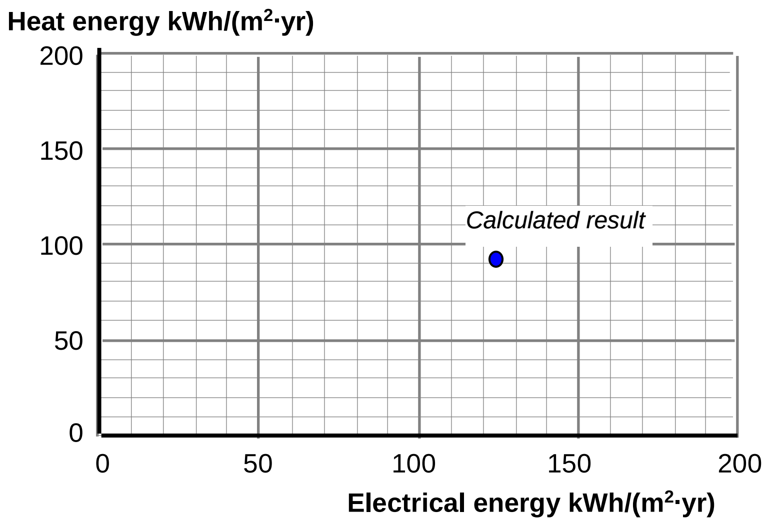


Figure 4.9 The result of the first calculation in the energy calculation process: heat and electrical energy.

Compare the results to measured values

The results of the first calculation in an energy calculation process are now compared to the measured values of the energy use in the building supplied by the property owner/client. Check whether the measured values have been adjusted to annual use of a normal year. The comparison between the calculated and measured values is illustrated in Fig. 4.10.

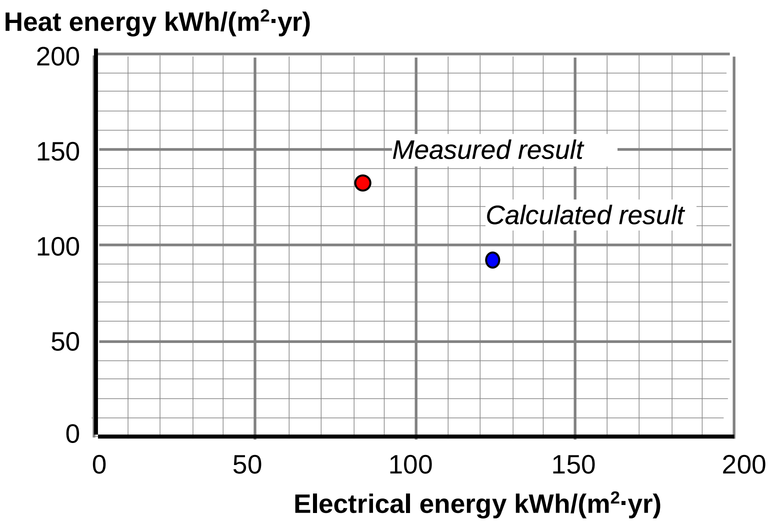


Figure 4.10 Comparison of the results from the first calculation in the energy calculation process with the measured energy statistics.

Adjusting uncertain input data – new calculation

If the calculated result differs greatly from the measured values, an adjustment should be made to the previously assessed uncertain input data and a new calculation carried out. Check the background data and determine what affects the result the most. Assess whether more measurements are need to correct the assumed values.

After the assumptions have been adjusted, new calculations are then carried out until the difference between the calculated energy use and measured energy statistics is not more than about 10 %. An example of such a comparison is shown in Fig. 4.11.

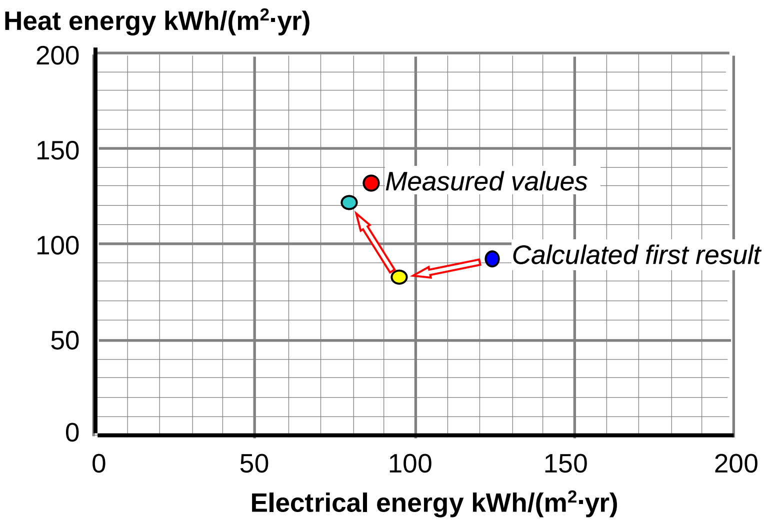


Figure 4.11 Comparison of the results of energy calculations with measured energy statistics after adjustments to uncertain input data.

Establishing a basic model

When the difference between the calculated energy use and the measured energy statistics is not greater than about 10 % the basic model can be established. The calculation model can then be said to be calibrated and ready for use to study the effects of the different energy saving measures in the building in question. This is illustrated in Fig. 4.12.

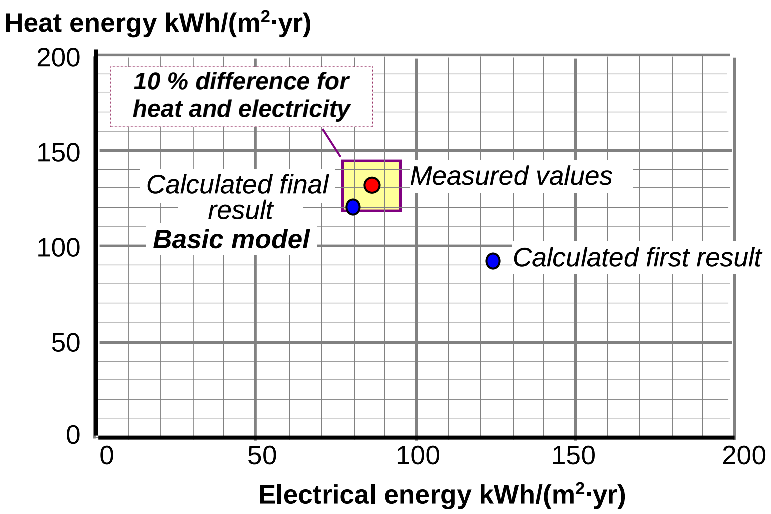


Figure 4.12 Comparison of the results of energy calculations with measured energy statistics and establishment of a basic model shown in a heat/electrical energy diagram.

It is important not to forget to document the final input-data used and assumptions made for the energy calculations when establishing the basic model as well as when analysing the identified energy saving measures in the next step. These conditions and assumptions must be stated in the report given to the property owner/client.

4.11.3 Credibility of the calculations

Credibility of calculations in Step 1 is one of the crucial elements in the implementation of the BTC method. Poor reliability of assessments in energy savings and necessary investments has a direct influence on project outcomes. There are several factors influencing the quality of calculation results in Step 1. The most important ones are illustrated in Figure 4.13.

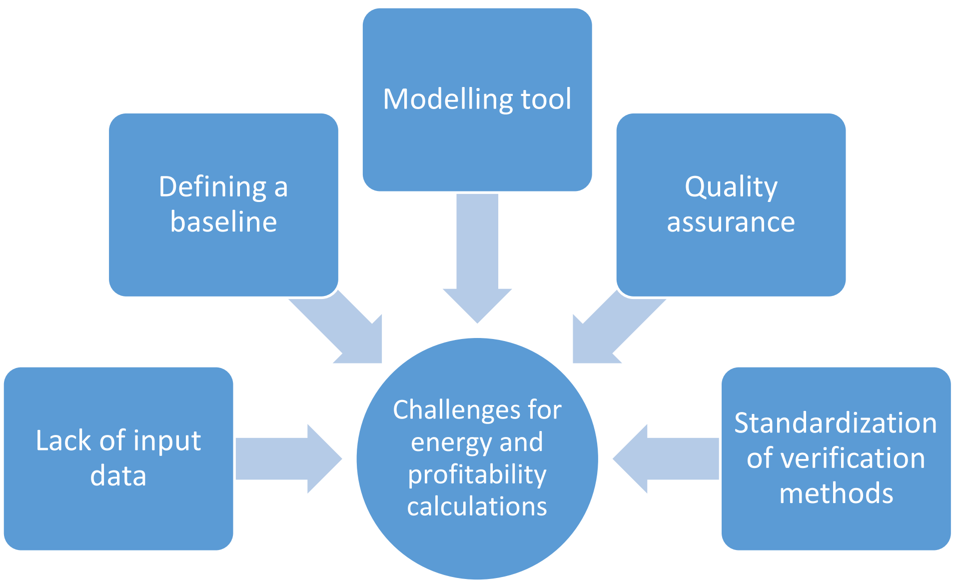


Figure 4.13 Factors influencing quality of calculation results in Step 1.

Lack of input data

Lack of input data is a very frequent problem when performing calculations for existing buildings. It is an energy consultant's task to gather as much precise data as possible and it is the responsibility of the in-house key actors to make sure that the information about the building and its use is available for the energy consultant. When some of the data that is not available this should be clearly marked as an assumption when documenting the input data t. The input parameters that are often difficult to find are thermal bridges, infiltration rates, some set points in the climate control systems, etc. Table 4.1 below gives a brief guidance on how to evaluate these parameters.

Table 4.1 Guideline for evaluation if the input data is not available

Parameter	Evaluation
Thermal bridges	If thermal bridges are difficult to evaluate, for instance because of a lack of drawings with structural details: Use thermography to identify heat leakages Evaluate values on the basis of a database with existing buildings or an official guideline (e.g. in DK: "Handbook for energy consultants" - Bekendtgørelse om Håndbog for Energikonsulenter)
Infiltration	Infiltration rates can be evaluated on the basis of national guidelines or by air leakage test if necessary. The test should be scheduled during a weekend to not disturb tenants' activities.
Set points	If set points are not available from BMS system or are varied a lot during operation times for example by the maintenance staff, then agree with the property owner/client what set points should be used in calculations.

Defining a baseline for calculations

Determining a baseline is often not an easy task. This is often because major renovation are not carried out just for energy savings and renovations can also include general upgrade of the building, changes in the building layout, improvement of indoor climate, etc. The energy performance of an existing building based on energy statistics cannot always be used then as a baseline for calculating the effects of the identified energy saving measures. Defining the new baseline must be established in dialogue with a building owner/client.

A new baseline is often calculated on the ambition levels for indoor climate, new technical characteristics of the systems that needs to be replaced, minimum renovation requirements defined in the building codes when carrying out major renovations, etc. The methodology how to determine the baseline for calculations of energy savings is described in chapter 4.6.

Modelling tool

A modelling tool used for energy calculations depends on an individual user/company. In Sweden the different software commonly used for calculation of buildings energy performance and energy saving measures are: IDA ICE, VIP Energy and BV^2 and some others with different pros and cons.

It is essential, when investigating non-residential buildings, that the calculation tools or simulation programs are actually designed for such buildings (e.g. include possibilities to calculate different types of technical systems) and that it is possible to analyse the effects of individual measures using a reasonable amount of work input. Use of the more complex software is often very time consuming when establishing a base model for a building and for carrying out step by step energy calculations when forming an action package. One calculation step can take more than 12 hours for completion, making the whole calculation procedure very long. Therefore for keeping the pre-study phase of the project (Step 1) in a reasonable cost level, more complex programs should be avoided if possible.The engineering companies who are using more complex tools for calculations, e.g. IDA ICE, are usually using it for the design work on daily basis.

It should also be noted, that hardly any available software for energy calculations are yet customized for the calculations needed in the Total Concept method and some manual work is normally needed for step by step calculations of the action package. Step by step calculations are needed for taking into account the different measures have on each other.

It is important that the background/input data used in the calculations is correct, including a correct assessment of the existing conditions in the building and its systems. Assessment of the uncertainty of the input data and its impact on the results is therefore crucial for quality assurance.

Standardization of verification method

Commonly a calculation model for the existing building is made with the help of an energy calculation software and verified with the existing data from the energy statistics, often corrected to a normal year. The weather data used in a simulation software is commonly based on the weather data of the normal year. A more accurate method of data verification would be simulating the base model with the actual weather data for a specific year and compare it with collected data from energy meters for the same year. However, the biggest barrier for this solution is the price of getting the weather data.

4.12 Profitability calculations and the creation of an action package

4.12.1 Introduction

The possible energy saving measures that were identified during the energy audit will be studied in detail with the help of the calibrated simulation model and other relevant calculation methods. At the same time an action package will be formed whereas taking into account the effects that each of the individual measures has on each other.

The measures will be graded according to profitability based on the internal rate of return method. Principles of this method were described in detail in Chapter 3. The profitability of each measure is assessed based on its calculated annual net cost saving, investment cost (capital cost) and the economic calculation period. Special consideration should be given for the accuracy of the results - there is always an uncertainty in both savings and investment costs assessments for different measures. The accuracy to which the results are shown should always take into consideration the uncertainty that is included in the calculations.

When annual savings for each measure are evaluated also other cost savings/cost increase should be included to the calculated annual cost savings. It is also important to remember that it is the annual net savings that are used as an input data in profitability calculations. Some of the measures might not only affect annual energy use but also other costs, such as maintenance costs and other resources. For example, the measures concerning domestic hot water might reduce water usage and the replacement of light fittings could save in maintenance costs for light sources (e.g. due to longer lifetime). Or it might be the other way round and carrying out some of the measures might lead to increased operating costs, for example, when introducing heat recovery or demand control. However, it is up to the property owner/client to decide how large a portion of the changes in costs is to be included in the profitability calculation.

For profitability calculations it is essential to know the profitability requirements, defined by calculation interest rate, that have been stipulated by the property owner/client in addition to any other conditions affecting the calculations, for example, energy prices, estimated energy price increases, economic calculation periods, etc. A checklist for information needed can be found in Appendix 6. How to take into account complex energy price models was discussed in Chapter 3.

4.12.2 Investigating the measures and the creation of an action package

As a first step energy savings of each identified measure is calculated separately using the calibrated calculation model and savings for heat energy, district cooling energy and electrical energy are specified.

As a second step an action package is created taking into account the effects that each of the individual measures has on each other. In order to avoid complex calculations of all the possible combinations of measures and how each individual measure affects the energy use in these combinations a simplified method will be used. This method has been proven to give equally good result in the profitability calculations of an action package.

This evaluation is based on the estimation that measures with the highest profitability will be carried out first, determining the cost savings and profitability of each following measure.

At first ranking based on individual profitability is done, based on the internal rate of return that each individual measure has. This is assessed based on each measure´s calculated individual annual net cost saving and investment cost (capital cost), without taking into account any other measures. The economic calculation period is decided by the property owner and is often taken the same as economic lifetime of a measure.
After establishing the first most profitable measure then the annual net saving of the second measure is calculated based on the estimation that the first measure has already been carried out. In principle the energy calculations are carried out step by step based on the profitability ranking:

- Measure 1
- Measure 1+2
- Measure 1+2+3
- etc.

It is common that measures affect each other's annual savings but sometimes also the investment cost. This should be taken into account similar way as when estimating combined effects on energy savings. An example below illustrates how a package of measures can be formed.

After package of measures is formed and impact of each individual measure in this package is assessed based on the method described above then all of the measures can be plotted on an internal rate of return diagram by using the Total Concept calculation tool *Totaltool*. The program takes into account different economic calculation periods for different measures and automatically adjusts the action package curve.

The criterion for how many measures are to be included is that the internal rate of return for the package *as a whole* is not less than the calculation interest rate. This means that the calculated internal rate of return for the whole package must not be lower than the property owner's/client's yield requirements expressed as a calculation interest rate. This will determine the size of the action package.

Example
An old office building uses a lot of energy and the consultant has identified following five energy efficiency measures and specified how they affect the energy demand.

- **New windows**
  Replacing the old windows with new ones will decrease the thermal transmittance, the solar gain coefficient and the air infiltration.
- **New lighting system**
  A new lighting system will decrease the total installed power of lighting as well as the utilization time.
- **Heat recovery**
  A heat recovery system will recover heat from the exhaust air and cause an increased pressure drop in the ventilation system.
- **Demand controlled ventilation**
  Controlling the airflows according to the actual demand will decrease the average airflow.

- **Balancing the heating system**
  Balancing the hydronic heating system makes it possible to decrease the average indoor temperature without jeopardizing the thermal comfort in the coldest part of the building.

The first step is to identify the single most profitable measure. Following table presents investment costs, calculated annual net savings, economic calculation periods and internal rate of return of each measure if only that single measure is carried out.

Measure	Investment cost [€]	Annual saving [€/year]	Economic calculation period [years]	Internal rate of return [%]
New windows	85 000	3 500	30	1
New lighting system	90 000	5 800	20	3
Heat recovery	130 000	12 000	20	7
DCV	120 000	15 500	20	11
Hydronic balancing	**5 000**	**2 100**	**10**	**41**

Hydronic balancing yields the highest internal rate of return and is thereby the single most profitable measure. Following table shows the values for the other measures under the presumption that the hydronic balancing is already carried out. Note how the annual savings differ from previous table.

Measure	Investment cost [€]	Annual saving [€/year]	Economic calculation period [years]	Internal rate of return [%]
New windows	85 000	3 200	30	1
New lighting system	90 000	6 000	20	3
Heat recovery	130 000	11 800	20	7
DCV	**120 000**	**14 800**	**20**	**11**

Demand controlled ventilation appears to be the second best measure. In the following table not only the annual savings are different but also the investment cost of the heat recovery. This is because it is cheaper to install DCV together with heat recovery than it is to only install DCV plus only install heat recovery.

Measure	Investment cost [€]	Annual saving [€/year]	Economic calculation period [years]	Internal rate of return [%]
New windows	85 000	2 900	30	0
New lighting system	**90 000**	**6 200**	**20**	**3**
Heat recovery	80 000	4 700	20	2

New lighting system is ranked third despite the reduced cost of heat recovery.

Measure	Investment cost [€]	Annual saving [€/year]	Economic calculation period [years]	Internal rate of return [%]
New windows	85 000	3 200	30	1
Heat recovery	**80 000**	**4 700**	**20**	**2**

Heat recovery is ranked fourth and since new windows and heat recovery does not affect each other's annual savings the last table is just a cut-out from the previous.

Measure	Investment cost [€]	Annual saving [€/year]	Economic calculation period [years]	Internal rate of return [%]
New windows	**85 000**	**3 200**	**30**	**1**

By entering the bold values from previous five tables into the *Totaltool* an internal rate of return diagram is plotted.

The diagram presents five packages of measures, and it is easy to identify the package that saves as much energy as possible while still fulfilling the requirement for profitability. The diagram is a graphic version of following table.

Package	Investment cost [k€]	Annual saving [k€/year]	Internal rate of return [%]
Hydronic balancing	5	2.1	41
+DCV	125	16.9	12
+New lighting system	215	23.1	8
+Heat recovery	295	27.8	7
+New windows	380	31.0	5

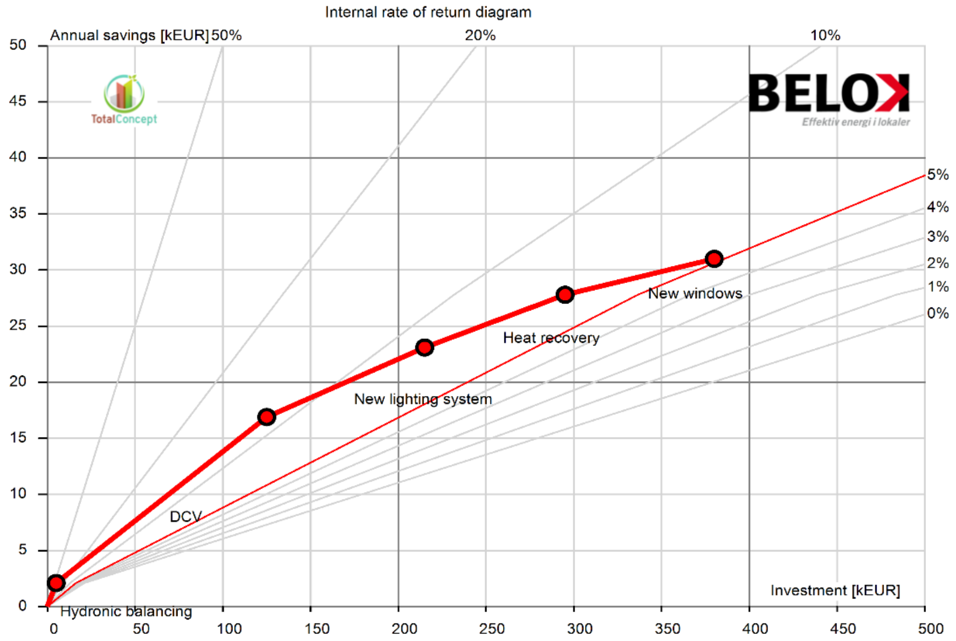


Figure 4.14. Example of the profitability of the different measures presented in an internal rate of return diagram, and the creation of an action package. For example the property owner's/client's profitability requirements are 7 % and the estimated relative energy price rise 2 %. This means that the profitability requirement is that the action package must have a greater yield than 7 % - 2 % = 5 %.

4.12.3 Finding the action package with maximum cost saving

When creating an action package the point of departure is the profitability of the individual energy saving measures. After calculations for all of the measures have been carried out some of the measures can fall below the profitability curve in the internal rate of return diagram and must therefore be excluded. At the same time, a particular measure might partly touch the curve and should also be excluded. Cases like these can result in the action package having a much higher internal rate of return than stipulated, although the energy saving aspects of the package would be greatly reduced.

In order to find the most energy saving action package within the profitability frames different sequences of measures in the package should be tested. For example, remove some of the measures close to the profitability line and see if the total energy saving of the package would be higher if the measures from the very end of the package line are included. If an expensive measure is found to be the last measure in the action package to fall outside the profitability curve, it could be worthwhile to replace it with smaller measures that might be less profitable but together would fulfil the profitability requirements of the action package. In this way a greater energy saving can be achieved while still fulfilling the profitability requirements.

Example

An audit using the Total Concept method was carried out in a school building built in the 1950s. There were just over 300 pupils and the total heated floor area was 4000 m^2, A_{temp}. There was no heat recovery in the mechanical supply and exhaust air ventilation system. The building envelope was poorly insulated. The annual energy demand was around195 kWh/m^2 for heat energy and around 60 kWh/m^2 for electrical energy. A number of energy efficiency improvement measures were identified and simulated to calculate the profitability and form the action package. The calculated cost savings and investment costs for the identified measures are presented in Table 4.2.

The energy prices used for the calculation were 0.05 €/kWh for heat energy and 0.09 €/kWh electrical energy. The property owner's/client's profitability requirements were 7 % and the estimated relative energy price rise 2 %. This meant that the profitability requirement was that the action package had to have a greater yield than 7 % - 2 % = 5 %. Figure 4.15 shows the measures plotted on an internal rate of return diagram together with the profitability requirement (marked as a thick line). As it can be seen from the diagram, the last two measures fall outside the profitability line. In order to find the most energy saving action package within the profitability frame different sequences of measures in the package were tested. On recalculation it was found that the most cost saving package would be when measure 8 "Façade insulation" was excluded. The results of the profitability calculations are shown in figure 4.16.

Table 4.2.
The calculated cost savings and investment costs for the identified measures for a school building.

Identified measure (M)	Invest. cost k€	Calcu-lation period yrs	Heat energy saving kWh/m^2·yr	Heat energy saving k€/yr	El. energy saving kWh/m^2·yr	El. energy saving k€/yr	Other savings k€/yr	Savings in total k€/yr
M1. Ventilation heat recovery	70	20	65	13	-2	-1	0	12
M 2. Hydronic balancing and new thermostats	10	15	15	3	0	0	0	3
M3: New heat system pumps	5	15	0	0	3	1	0	1
M4: DCV system	100	15	5	1	20	7	-0,5	7,5
M5: Improved roof insulation	60	40	15	3	0	0	0	3
M 6: New outer doors	10	40	3	0,5	0	0	0	0,5
M 7: New lighting	80	15	-5	-1	10	3,5	0,5	3
M8: Facade insulation	120	40	10	2	0	0	0	2
M9: New windows	100	40	20	4	0	0	0	4

The energy decrease with the proposed action package was about 120 kWh/m^2 for heat energy and about 30 kWh/m^2 for electrical energy. This corresponded to total energy decrease for about 60% and the action package resulted in annual savings of approx 35 k€ and required the total investment of 435 k€.

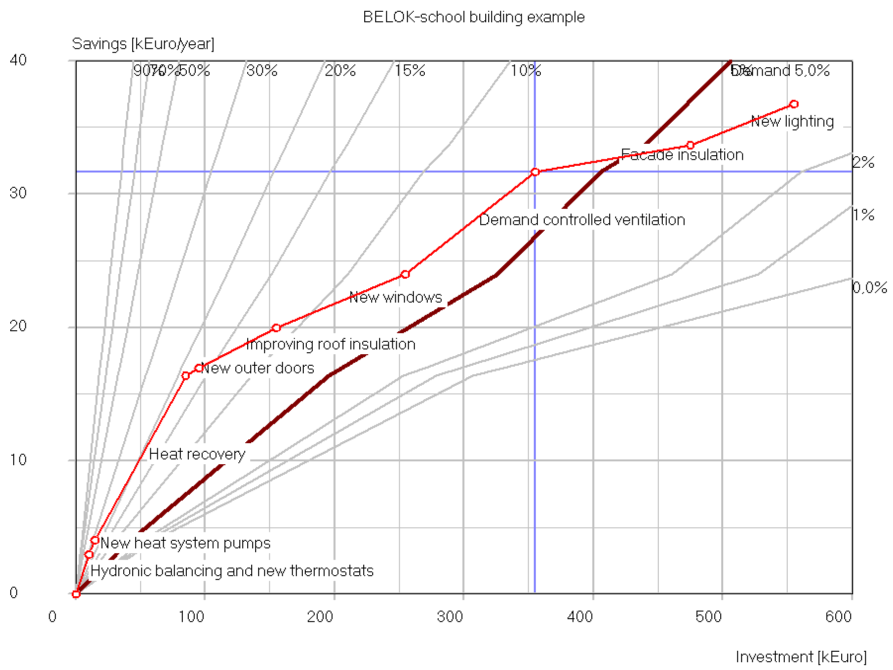


Figure 4.15 The different identified measures presented in an internal rate of return diagram, and the creation of an action package. The profitability requirement is that the action package must have a greater yield than 7 % - 2 % = 5 %. As it can be seen from the diagram, the two last measures fall outside from the profitability line.

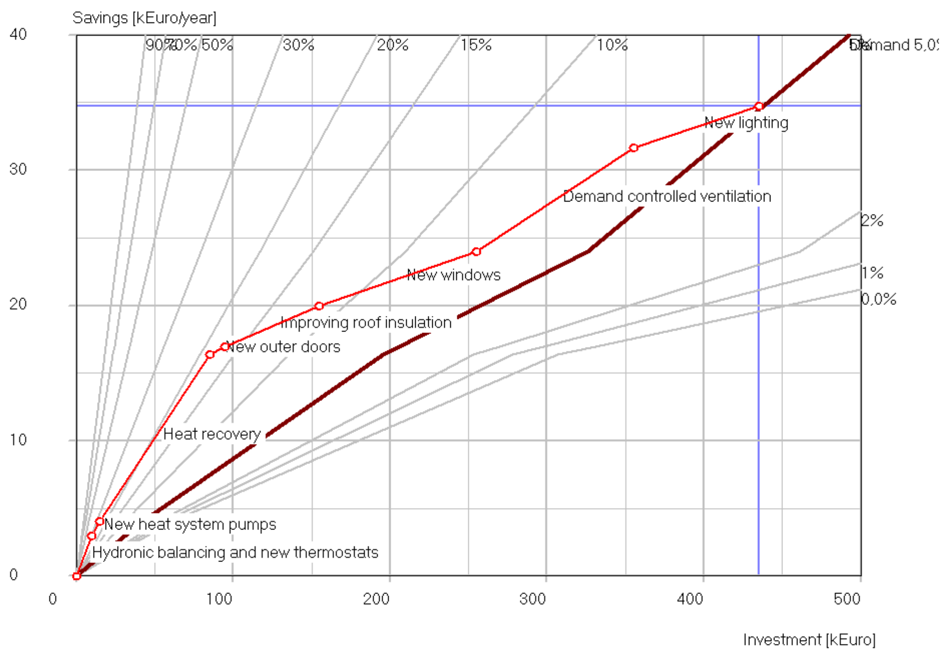


Figure 4.16 The final action package for a school building. The final profitability of the action package is 5.1 %. The action package results in annual savings of approx 35 k€ and requires the total investment of 435 k€.

4.13 Including replacement of heat supply in the action package based on the Total Concept method

When a replacement of the heat supply should be included in the Total Concept, there are three thinkable approaches.

1) First of all the energy need of the building is to be decreased. Then the most energy efficient heat supply alternative is to be chosen. This approach is often referred to as the Kyoto-pyramid originally formulated by SINTEF Byggforsk.
2) A new heat supply alternative is already decided upon and should be regarded as one of the energy saving measures in the package.
3) A replacement of the heat supply should be dealt with clearly materialistically as cost saving measure only.

From analysis point of view, the first approach is simplest and the third most laborious. The following example illustrates the three approaches.

Example

A building has an annual demand of 350 MWh district heat and 20 MWh electricity. The price of heat is 0.08 €/kWh and the price electricity 0.12 €/kWh. Six energy efficiency measures have been identified. None of these measures is influencing any of the others. The measures are presented in the table below. Figure 4.17 shows the corresponding internal rate of return diagram.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]	Economic calculation period [years]
New lighting	13	14	-2	20
Energy efficient DHW-system[5]	7	0	13	30
Improved roof insulation	15	0	9	40
New windows	72	0	40	30
Improved insulation of facade	110	0	38	40
Heat recovery ventilation	78	-4	106	20

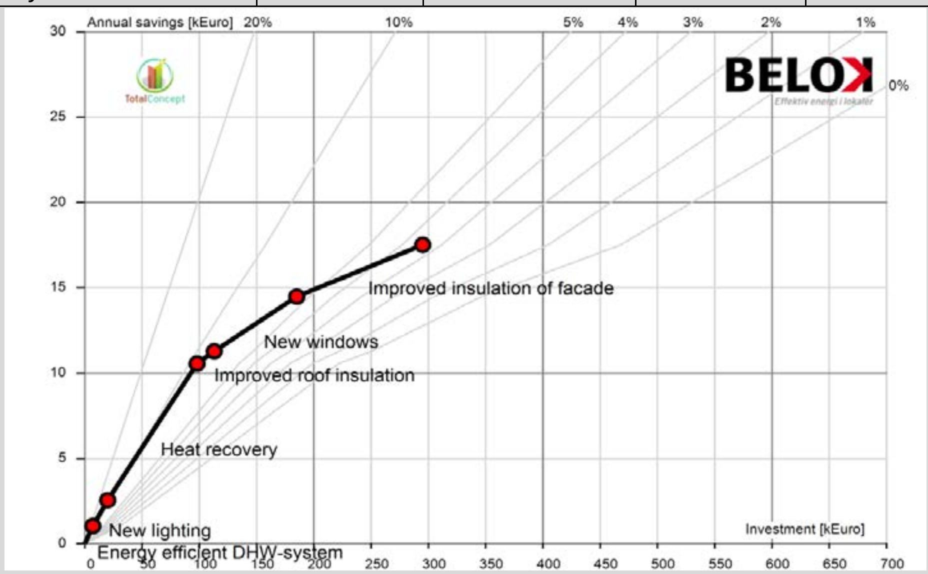


Figure 4.17 The IRR diagram with the six identified energy saving measures

[5] DHW = Domestic hot water

A ground source heat pump for heat supply is to be included in this project. The specific total cost, the performance and the economic calculation period are according to the table below. The seasonal performance factor is the ratio of heat output during one year to the electricity input.

	Investment cost [€/kW]	Seasonal performance factor [-]	Economic calculation period [years]
Ground source heat pump	850	3,1	25

The heat power demand of the building before energy saving measures is 135 kW. The energy efficiency measures will reduce the power demand according to the table below. This is used only to determine the size of the heat pump. (Hot water storage tank is taken into account.)

	Heat power reduction [kW]
New lighting	0
Energy efficient DHW-system	12
Improved roof insulation	4
New windows	11
Improved insulation of facade	9
Heat recovery ventilation	27

Approach 1

The heat pump is added on top of the energy efficiency measures. When calculating the cost and the savings, the heat pump is handled as the six energy saving measures had already been carried out.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]
Heat pump	61	-47	146

The internal rate of return diagram according to approach 1 is presented in figure 4.18.

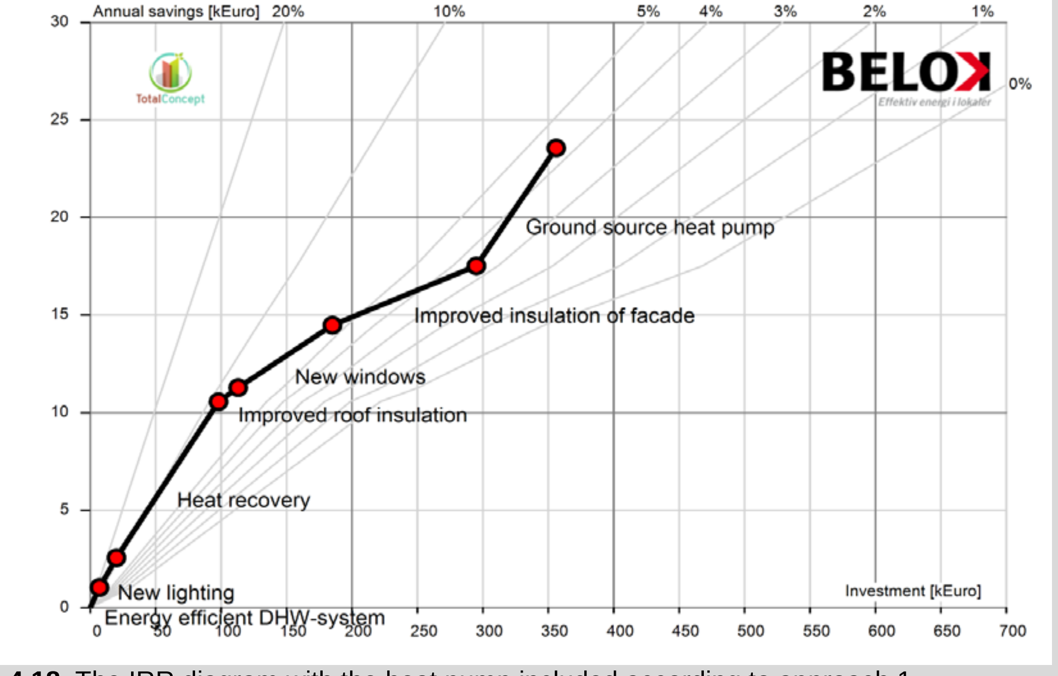


Figure 4.18. The IRR diagram with the heat pump included according to approach 1.

Approach 2

In the second approach, the installation of the heat pump is predetermined and its cost and savings do not take other measures into account.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]
Ground source heat pump	115	-113	350

Instead, the reduction of its size and the following cost saving is taken into account as reductions of the costs of the six energy saving measures in the building. Note that the measures now save electricity only.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]	Reduction in heat pump cost [k€]
New lighting	13	13	0	0
Energy efficient DHW-system	7	4	0	10
Improved roof insulation	15	3	0	3
New windows	72	13	0	9
Improved insulation of facade	110	12	0	8
Heat recovery ventilation	78	32	0	23

The reduction in heat pump cost is simply subtracted from the investmet cost and the resulting internal rate of return diagram is presented in figure 3. Concerning the replacement of DHW system, the influence on the heat pump cost is somewhat higher than the cost of the DHW replacement itself. This appears as a negative investment cost and a twist in the IRR diagram.

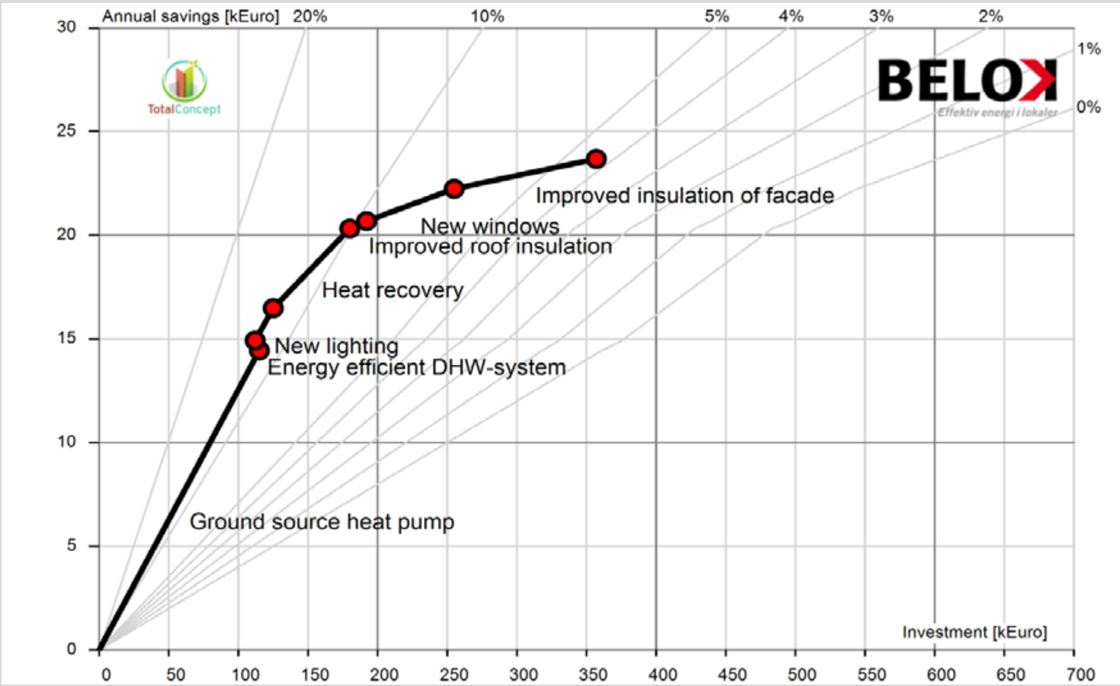


Figure 4.19. The IRR diagram with the heat pump included according to approach 2.

Approach 3

The heat pump is treated as any other energy efficiency measure. This guarantees a correct order in the diagram but requires careful monitoring of how the heat pump is influenced by the other measures and vice versa. The procedure is as described in chapter 4.11.2.
As shown in following table, the new domestic hot water system is found to be the single most profitable measure.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]	Internal rate of return [%]
New lighting	13	14	-2	10
Energy efficient DHW-system	**7**	**0**	**13**	**15**
Improved roof insulation	15	0	9	4
New windows	72	0	40	2
Improved insulation of facade	110	0	38	0
Heat recovery ventilation	78	-4	106	8
Ground source heat pump	115	-113	350	12

The next step is to redo the calculation taking into account that the first measure is implemented already.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]	Internal rate of return [%]
New lighting	13	14	-2	10
Improved roof insulation	15	0	9	4
New windows	72	0	40	2
Improved insulation of facade	110	0	38	0
Heat recovery ventilation	78	-4	106	8
Ground source heat pump	**105**	**-109**	**337**	**13**

The heat pump gets the second place and the calculations are redone again.

	Investment cost [k€]	Electricity saving [MWh/year]	Heat saving [MWh/year]	Reduction in heat pump cost [k€]	Internal rate of return [%]
New lighting	**13**	**13**	**0**	**0**	**10**
Improved roof insulation	15	3	0	3	1
New windows	72	13	0	9	-2
Improved insulation of facade	110	12	0	8	-3
Heat recovery ventilation	78	32	0	23	3

So it continues and the internal rate of return diagram is presented in figure 4.20.

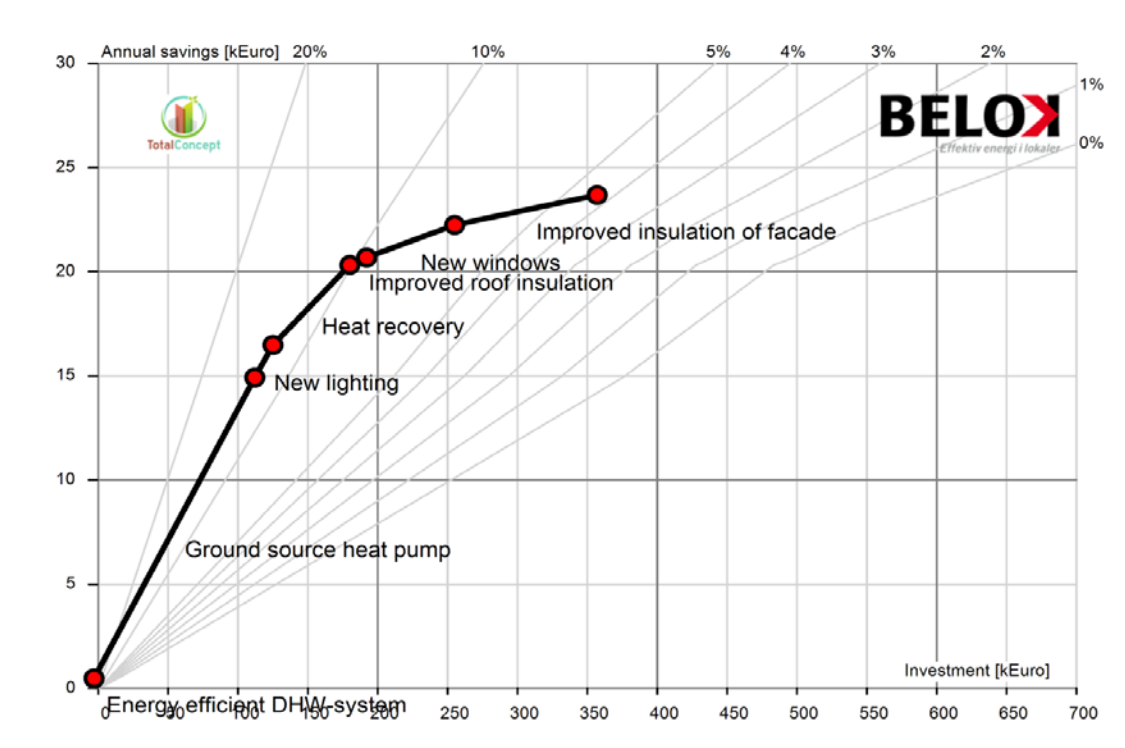


Figure 4.20. The IRR diagram with the heat pump regarded equally with the other cost saving measures according to approach 3

Regardless of the approach chosen, the endpoint of the curve will be the same. However, if the endpoint doesn't fulfill the profitability required, the choice of approach influences the design of the package which must be kept in mind when choosing the applicable approach.

4.14 Summing up and the report

It is up to the property owner/client and the energy consultant to agree about what is to be included in the report from Step 1. The information in the report must be sufficient to enable a decision about if the measures are to be carried out and the project should continue to Step 2. It must therefore be easily understood, both from a technical and financial point of view.

The report should include at least the following details:

- The procedure used.
- Input data in the form of technical details about the building and other assumptions made as well as energy statistics, calculated energy use before carrying out any improvement measures, input data for the feasibility calculations.
- A detailed description of the measures. The report will form the basis for the design work of the project.
- Partial results in the form of calculated energy and investment cost savings for each measure.
- Final results of profitability calculations including summarizing the list of measures included in the action package, the total investments and total savings, the action

package plotted in the internal rate of return diagram and the energy use before and after implementing the action package.

An example of results showing the energy use before and after implementing the measures in the action package can be seen in Fig. 4.21. Separate specifications are drawn up for energy savings regarding heat, cooling, electricity used in the building itself and the tenant's use of electricity.

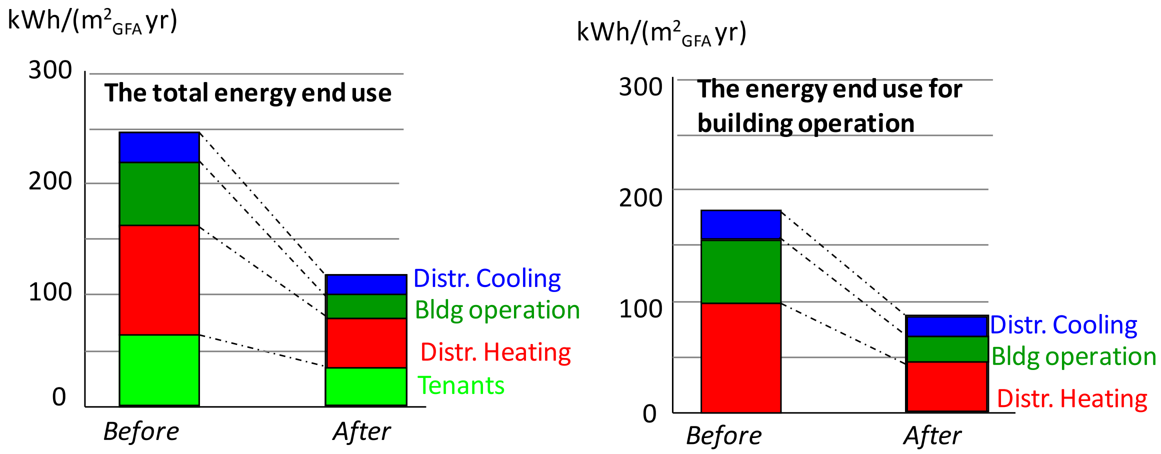


Figure 4.21 Example of the results showing the energy needs before and after carrying out the measures in the action package, kWh/m^2 (gross floor area).

A template for reporting Step 1 of the Total Concept method can be found from the Total Concept tool-kit.

4.15 Sensitivity analysis for the results

When investment decisions are made based on the Total Concept method it is advisable to carry out some form of sensitivity analysis. In fact, sensitivity analyses should be carried out no matter what method is used to provide a basis for investment decisions, especially if they are large.

Examples of questions that could be relevant include:

- What will happen if the energy savings have been overestimated?
- What will happen if one of the measures is more expensive than estimated?
- What will happen if the energy price increase is only half that assumed?

One way in which the sensitivity of the different estimations and calculations can be studied is illustrated in the example below. If the initial calculations, using the chosen assumptions, provide results according to the figure below, i.e. an internal rate of return of about 5 %, by how much will the results be affected if the annual savings differ by ± 10 % from the calculated value, or if the investment differs by ± 10 % from the calculated value?

Fig. 4.22 shows that the worst result with regard to the internal rate of return can be about 2.5 % (indicated by ✸), while the best possible result could be about 7.5 %.

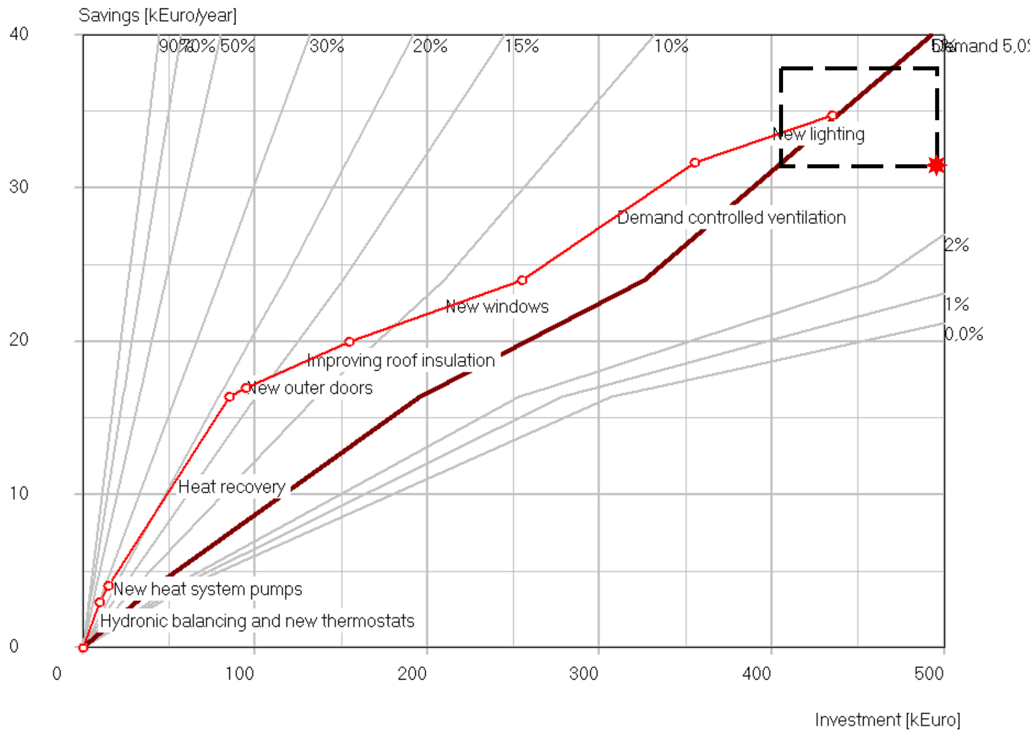


Figure 4.22 Sensitivity analysis. ± 10 % differences for both annual savings and amount invested.

If the property owner/client requires a 5 % yield on invested capital within the scope of the sensitivity analysis, this means that the action package must be limited, so that the worst case yield will be greater than 5 %. If the last two measures are excluded from the action package, then the sensitivity analysis, as shown in Fig 4.23, shows that the internal rate of return will be in the interval 5 to 10%, which agrees well with how the Total Concept model is structured. Every individual measure that is added to an action package contributes to reducing the annual costs but with a somewhat reduced total profitability of the action package. Consequently, if the property owner/client in this example stipulates a yield on invested capital corresponding to at least 5%, at the same time as the calculations have to fulfil the sensitivity analysis, the last two measures in the action package will have to be excluded.

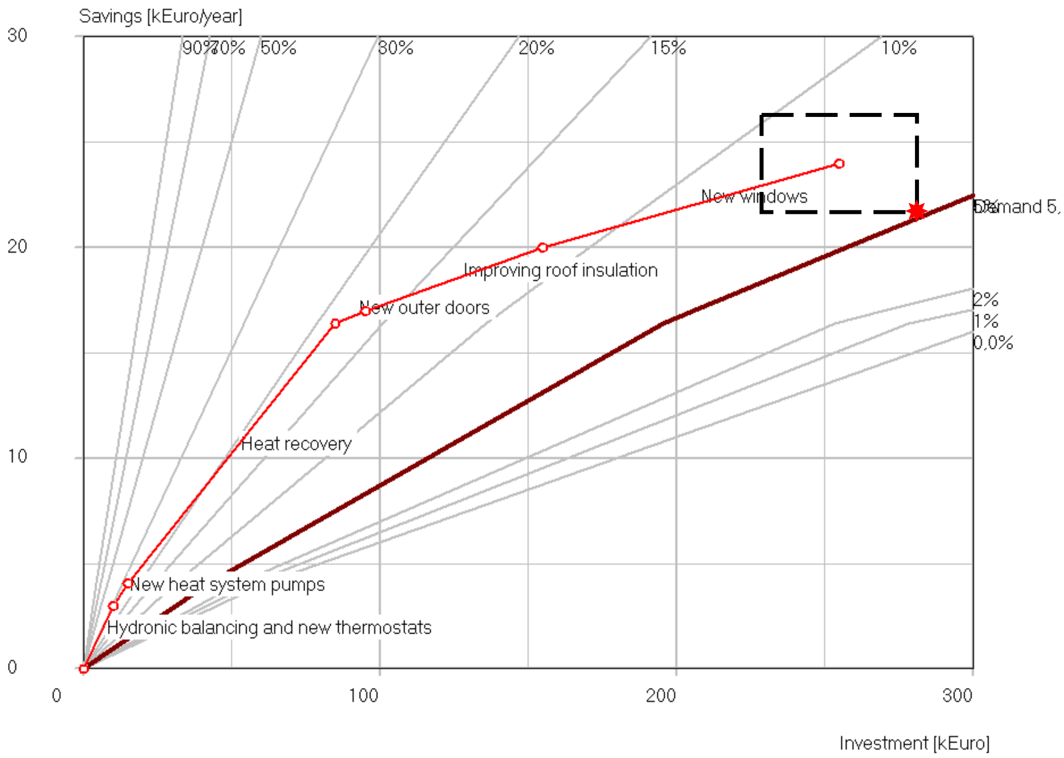


Figure 4.23 Sensitivity analysis. ± 10% differences for both annual savings and amount invested. Two measures excluded compared to before.

5 Step 2 of a Total Concept method – Carrying out the measures

This chapter discusses the issues which the client should be aware of when carrying out Step 2 of a Total Concept method, i.e. when implementing the action package drawn up in Step1. Among other things, the role of the client and the information and basic requirements that should be stipulated in the tender documents are discussed.

5.1 Introduction

In Step 1 of a Total Concept method, an action package of energy saving measures is identified which will create the biggest energy savings within the profitability range stipulated by the client. In Step 2 the accepted action package is carried out in its entirety.

Step 2 is based on careful procurement, design work and construction work. Basically, these stages are the same as in any normal reconstruction project. However, mistakes must be avoided at all costs as the expected energy savings, and the whole point of carrying out a Total Concept method, could otherwise be lost.

The work of Step 2 is finalized by carrying out thorough functional performance checks. Among other things, this is important in order to make sure that all the measures function correctly. If, for example, an upgraded ventilation system does not function as expected, a large part of the energy savings and, thereby, the cost savings, can be lost. Therefore, before the effect of the action package can be evaluated, it is very important that functional performance checks are performed so that any faults can be rectified.

It is also especially important to ensure that the use of energy in a building can be measured afterwards. This means that extra meters for electricity and heat might be needed. Some form of monitoring system as part of the Buildings Management System (BMS) is often already in place. Some additions might have to be made and these should be carried out at the same time as the energy saving measures.

The key points to consider for achieving good results and assuring quality assurance when carrying out the different work tasks in Step 2 will be discussed in detail in the following sections.

5.2 Stakeholders and key actors in Step 2

Carrying out Step 2 of the Total Concept method requires cooperation between the following main stakeholders and key actors:

- ***Property owner/client,*** who is responsible for ordering the practical work based on Step 2 of the Total Concept method from external key actors and coordinating the work between the parties involved. Property owner/client is also responsible for assuring that internal resources are available for project execution, e.g. involvement of in-house personnel like property manager, maintenance staff, etc.

- ***Design engineers (including architect)***, who based on the contractual agreement with the property owner/client, will do the detailed design work for the proposed measurers.
- ***Contractors and technology providers***, who, based on the contractual agreement with the property owner/client, will participate in carrying out the cost-effective package of energy saving measures according to detailed design.
- ***Property manager,*** who is responsible for the buildings in question and will be involved in coordinating the renovation work and functional performance checks within the building.
- ***Facility management staff (maintenance staff),*** who are responsible for operating the systems in a building. Their cooperation with the design engineer and contractor is valuable since they know how the systems work and what must be taken into account when renovation work is carried out. They will also be responsible for carrying out measures involving adjustments of settings in the control and regulating systems as well as following up the function and quality of improvement measures with regard to future operations and maintenance.

Step 2 also requires involvement of ***tenants/ building users*** as the renovation work needs to be coordinated with them and their use of the building(s). Furthermore, some measures may be tenant´s responsibility to carry out, e.g. measures in the lighting system and machines/equipment used.

It is also recommended that the ***energy consultant*** from Step 1 is available during Step 2, as the person involved in the detailed design work must have a good understanding of the purposes and backgrounds of the different measures.

The stakeholders and key actors involved in Step 2 of the Total Concept method is illustrated in Fig. 5.1.

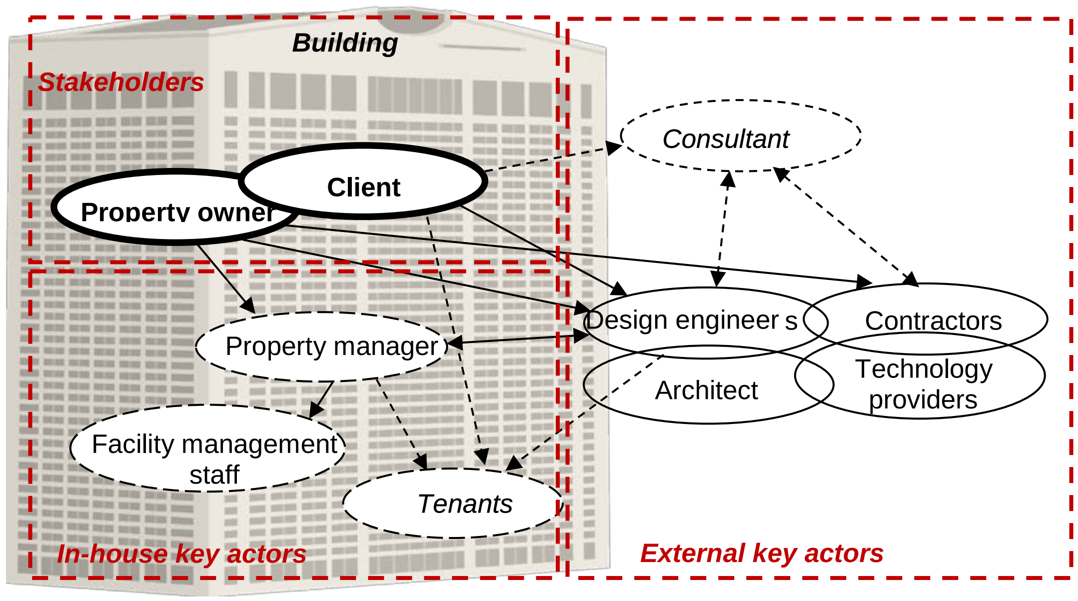


Figure 5.1 The stakeholders and key actors involved in Step 2 of the Total Concept method.

5.3 Key activities of Step 2 of Total Concept

The key activities of Step 2 of Total Concept are illustrated in Fig. 5.2. Carrying out Step 2 requires a number of preparations from the *property owner/client*, such as involvement of relevant in-house key actors for the project and engaging a design engineer and contractor(s). The key activities involving practical work are commonly carried out by the *design engineers, architect, contractors* and *maintenance personnel.*

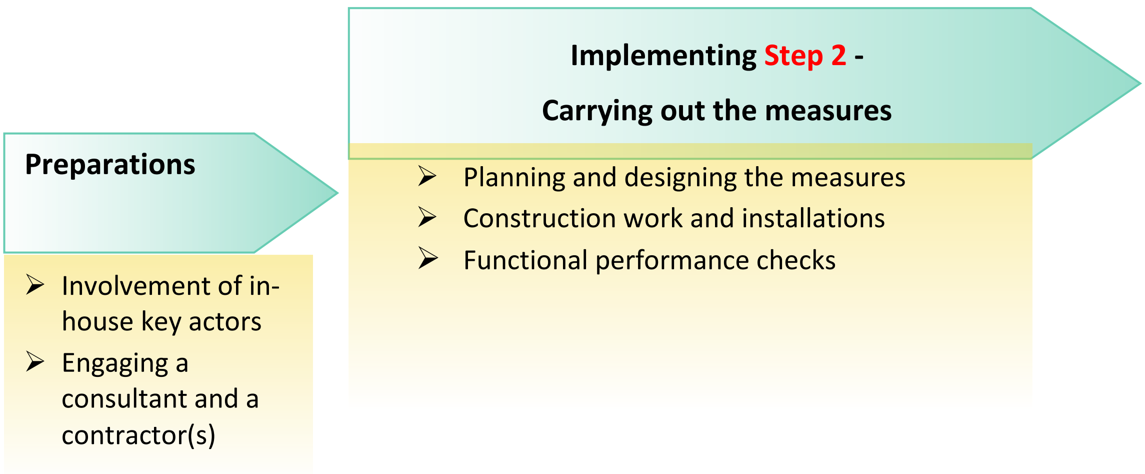


Figure 5.2 The key activities included in Step 2 of the Total Concept method.

5.4 The client's role and responsibilities

It is important that the client or client's representative follows the project actively. Preferably, this should be done by engaging an internal project manager, for example, a technical property manager, a maintenance manager or an energy and environmental manager. The project manager makes sure that sufficient communication channels are established between the design group, the contractors, the tenants and other parties involved. If project management cannot be carried out using internal own personnel, which would be preferable, a consultant can be engaged.

Experience from previous projects has shown that to actually achieve the savings in energy and, thereby, the assumed profitability, it is important to stipulate clear requirements with regard to the functioning of the completed project when engaging a design engineer and contractors. This means that demands are made on the procurement and design work as well as on the execution of the contracts. Furthermore, functional performance checks should also be included in the final inspection. Everything included in the action package must work properly when contractor hands over the building to the client.

It is also important to take into account how the implementation of the measures will affect the tenants and users and coordinate the whole operation accordingly. Furthermore, depending on the terms of the lease some of the measures might even be the responsibility of the tenants, for example, the replacement of light sources and other measures concerning lighting. The tenants might also be responsible for the investment costs and design of certain equipment/machinery. It is therefore important to have a dialogue between the tenant and the client and that agreement is reached on areas of responsibility and the possibility of coordinating some of the investments.

To be able to carry out Step 3, some of the planning work for this step should begin already in Step 2. It is the client's responsibility to make sure that the tender documents in Step 2 describe the preparations that the different parties involved must make before Step 3 is commenced. These include, for example, measuring points, measuring systems and data handling as well as the documentation of costs that are included in the calculations.

The primary roles of the client or client's representative when carrying out Step 2 include:

- Coordinating internal resources/personnel, for example, the involvement of the facility maintenance staff.
- Drawing up data for the tender documents and engaging the design engineer and contractors.
- Coordinating the contacts between the parties involved: the tenants, maintenance staff, design engineer, contractors and others.
- Plan how the functional performance checking of the improvement measures and final inspection is carried out.
- Ensure that the work is quality assured by scrutinizing documents and checking execution.
- Planning for Step 3, for example allocation of responsibilities for the preparations of detailed measurements.

5.5 Engaging design engineers and contractors for Step 2

5.5.1 Drawing up the tender documents

It is important to clearly specify the design engineers´ and contractors' assignments and what final result is expected in the tender documents. The client should also specify the responsibilities of the design engineers and contractors and how their work will be verified. Many property companies have their own guidelines and requirements when it comes to design work, construction and quality demands during the building process. Factors like these might have to be taken into account in a Total Concept method.
In the tender documents, the client should:

- Specify the assignment in detail and the areas of responsibility that the design engineers, contractors and others will have, for example, concerning project management, design work and all-in contracts.
- Specify the demands placed on these parties and what they are contracted to deliver, for example, experience, competence, resources, starting date, completion date, documentation and reports.

When drawing up the tender documents it should be specified how the final inspection and functional performance checks are to be carried out. Everything included in the action package must work properly when the contractor hands over the building to the client. This means that a final inspection is necessary and this will, among other things, include the checking of important functions.

To further emphasize the importance of a fully functional building on completion there is reason to define the economical responsibility connected to this, so that the expected energy savings are verified *before the contractors work is approved*. It could therefore be advantageous to procure the detailed design and contractual work from the same company, i.e. as a type of all-in contract. A combined design engineer and contractor partnership could then be held economically responsible for achieving the expected savings. This could involve extra expense for the client but experience shows that this extra cost, in reality, can be both well motivated and profitable.

When drawing up the tender documents in Step 2 the client should take into account how the results of the measures will be evaluated in Step 3. If careful follow-ups are planned, then it must be ensured that energy use can be measured in sufficient detail and that the actual costs of the energy saving measures are documented. This is needed in order to verify that the investment in the Total Concept method has been successful.
If the consultant who is engaged in Step 2 is responsible for the preparations for detailed measurements, then he/she must already specify, during the design work, which measuring points are required, what data is to be gathered and how, etc. Costs involved with Step 3 should be included to the offer.

5.5.2 The design engineer's role and responsibilities

Some of the measures may require relatively detailed design. The design work will result in documents required for procuring the contractors.

The design engineers who are to be engaged in Step 2 are to take responsibility for the following:

- Carrying out the design work for specified measures based on the documents from Step 1 and according to the project manager's/client's directives.
- Following the client's quality assurance routines and ensure that the quality goals are met.
- Establishing contacts with all the relevant parties regarding the design work, for example, tenants, maintenance personnel, contractors and others, to quality assure the design of the improvement measures. Contact with the consultant who carried out Step 1 is recommended in order to check the details of the measures and ensure that the results reach high standards.
- Make a plan for measurements and follow-up in Step 3, including planning for extra meters so that energy use (heat, cooling, owner's electricity use and tenant's electricity use) can be followed up.

As a large proportion of the saving measures are normally connected to the technical installations, it is important that the design engineer has a good understanding of how they work in the building in question. It is also important that the design engineer is fully aware of the main goals of the project – to reduce the use of energy.

5.5.3 The contractor's role and responsibilities

The main role of the contractor is to carry out the specified improvement measures according to the design engineer's documentation. In addition, the contractor should be responsible for making sure that the measures that have been carried out function correctly from the very start. The client should stipulate that the contractor must not leave the assignment until an approved functional performance checking has been carried out.

The contractor who is to be engaged in Step 2 is to take responsibility for the following:

- The practical implementation of the specified measures according to the design engineer's documentation.
- Assure that the measures that have been carried out function correctly before functional performance checking and final inspection is carried out.
- Following the client's directives regarding the construction work and commissioning the different systems.
- Following the client's quality assurance routines and ensure that quality goals are met.

- Compiling the documentation of the contract costs for the energy measures if required by the client.

5.6 Design work and quality assurance

The information contained in the Step 1 report forms the basis for decision-making regarding the implementation of the savings measures. It also forms the basis for the detailed design required.

A number of the measures in the action package will be so simple that they can be carried out without any special preparations being made. Others must be designed and planned in detail and carried out by contractors. Here also the influence on the tenants and building users need to be taken into account.

In the design phase, the detailed design work takes place and drawings, system schematics and technical descriptions are produced. The design work results in the documents that are needed so that a call for tenders from contractors can be made.

When in the design stage it may be discovered that some of the measures are not possible to carry out according to the proposals formulated in Step 1. For example, it might not be possible to install new device or some system component in a loft due to lack of space. It is important to have a discussion with the property owner/client on how to proceed. In this case, the action package as a whole should be investigated, to see what effect this would have and to make adjustments, if possible, before the actual reconstruction work is commenced.

How can design mistakes be avoided?
The risk of making design mistakes can be greater when carrying out reconstruction projects than new construction work, as it is a question of integrating new solutions in existing systems. It is therefore important to have an overall view and understanding of how the different systems will interact and be aware of the effects of all the proposed improvement measures.

Example
When only certain parts of a ventilation system are to be improved while others are to be left unchanged, the design engineer must be especially careful when planning the installation of new supply air terminal devices:

- No old devices which were designed to work at a considerably different pressure than the new ones are to be left in the system. If any of the old devices cannot deal with the working pressures required by the new ones, the functioning of the system will be impaired. If the new working pressure is considerably greater, then both the functioning and the energy savings will be at risk.

- If the system is to be upgraded from a constant flow system to a variable flow system, no devices that require a considerably higher discharge temperature than the new devices can be left in place. Otherwise, there is a danger of the demand-control function being knocked out as the whole system will operate at a high supply air temperature and the VAV devices will be fully open as the cooling capacity of the supply air will be small. In temperature-controlled systems this would lead to the system working at full air flow capacity for most of the year and the VAV advantage would be lost.

5.7 The building process and functional performance checks

The contractor must carry out the action package measures according to the documents drawn up by the design engineer and the client's guidelines. It is essential for the profitability of the action package that all the parts of the building, the technical systems and the technical components included in the action package exhibit the properties and functions that were assumed when the package was drawn up.

To ensure good results and high standards throughout a project based on Total Concept method and before the evaluation of the action package can be commenced, care must be taken to check the function of all the improvement measures and, if necessary, remedy any shortcomings. Incorrect balancing, function adjustments and wrong connections might have significant effects on energy use and ruin the profitability of the whole project. All control systems must function as intended.

Guidelines on how the functional performance checks should be carried out in Step 2 can be found from the BELOK focus project report "Coordinating Functional Performance Checks"[6].

---

[6] Göran Andersson, GICON Installationsledning, 2015 "Samordnad funktionskontroll"

5.8 Commissioning and maintenance after the construction process

Keeping energy use at a low level on a long-term basis requires the involvement of the maintenance staff, the property manager and the tenants. The maintenance staff who are responsible for the running of all the systems in the building can directly influence the use of energy and also the result of the energy efficiency improvement measures carried out in the building.

Some of the measures in the action package in the Total Concept method can be in fact quite simple, such as adjusting the set point values, operating times, valve settings and alike. These measures can be easily carried out by property management or maintenance staff.

In addition, the maintenance staff and property management staff will be responsible for following up the function and quality of the improvement measures with regard to future operations and maintenance. It is therefore important that operations and maintenance plans are revised to take into account all the changes.

In Step 2, the property management staff and/or maintenance staff must:

- When necessary, complement the operating and maintenance routines, so that they accommodate the new additions or alterations. Additionally, assist during implementation of the measures in the action package that involve adjusting the set point values, operating times, valve settings and alike.
- Cooperate with the design engineer and contractors during the practical execution of Step 2. The maintenance staff knows how the systems work and what must be taken into account when reconstruction work is carried out.
- Ensure that the measures that have been carried out work in the long-term and revise the existing operating and maintenance routines if needed
- Ensure that energy use can be measured in Step 3. New operating routines are to be implemented if necessary.

5.9 Planning for follow-up in Step 3

As discussed before some preparation work for Step 3 needs to be started already in Step 2. It is the client’s responsibility to make sure that the tender documents in Step 2 describe the preparations that the different parties involved must make before Step 3 is commenced.

A plan for measurement and follow-up is commonly made in Step 2. A template for a plan for measurements and follow-up can be found from Total Concept tool-kit.

In addition to measuring the energy use for heat and district cooling (if any) it is important to follow up the electricity used by the tenant’s operations/activities and electricity used for building operations, for example lighting in communal areas, lifts, etc. Extra meters may need to be installed for these measurements and need to be planned already in the design process. Also a special agreement might be required so that the tenant's electricity bills can be inspected. In non-residential building where there is a more than normal use of domestic hot water (restaurant kitchens, hospitals, etc) this should also be followed up. If there are no or too few meters in the building, then additional meters should be installed.

In order to follow up the results of a project based on the Total Concept and to verify that the investments have been successful, the true costs of the improvement measures must be documented in Step 2.

More details for planning for Step 3 can be found in Chapter 6.

6 Step 3 of a Total Concept method – Following up

This chapter discusses issues that are important to take into account when carrying out Step 3 of a Total Concept method. Among other things, the preparations necessary before carrying out Step 3 are discussed in more detail and the allocation of responsibility, following up of costs, measurement of energy use and assessment of profitability results are also discussed.

6.1 Introduction

The purpose of Step 3 is to follow up the energy use after the action package has been carried out and check the profitability of the action package. When the correct functioning of the measures has been confirmed in Step 2, the energy use in the building can be followed up by taking readings every month for at least a whole year. The results are used in a final profitability analysis. It is, of course, up to the client to decide on the scope of Step 3 and how detailed the work will be.

The key points to consider for achieving good results and assuring quality assurance when carrying out the different work tasks in Step 3 will be discussed in detail in the following sections.

6.2 Stakeholders and key actors in Step 3

Carrying out Step 3 of the Total Concept method requires cooperation between the following main stakeholders and key actors:

- ***Property owner/client,*** who is responsible for involvement of in-house key actors for carrying out Step 3 of the Total Concept method, e.g. maintenance staff, property manager, etc. Alternatively engaging a suitable ***consultant*** who will manage/ carry out practical work based on Step 3.
- ***Property manager,*** who is responsible for the buildings in question and will be involved in the follow-up work in Step 3.
- ***Facility management staff (maintenance staff),*** who are responsible for operating all the systems in a building. They often handle the follow-up work and gather measurement data, as this work is best done with the aid of the operating and monitoring (BMS) systems.

Step 3 will also require some support from the ***tenants/ building users*** when basic information about the building's use is gathered during the measurement period in Step 3. The purpose of this is to see whether there are any differences in the operating conditions and usages, compared to those in the assumptions made during Steps 1 and 2.

The stakeholders and key actors involved in Step 3 of the Total Concept method is illustrated in Fig. 6.1.

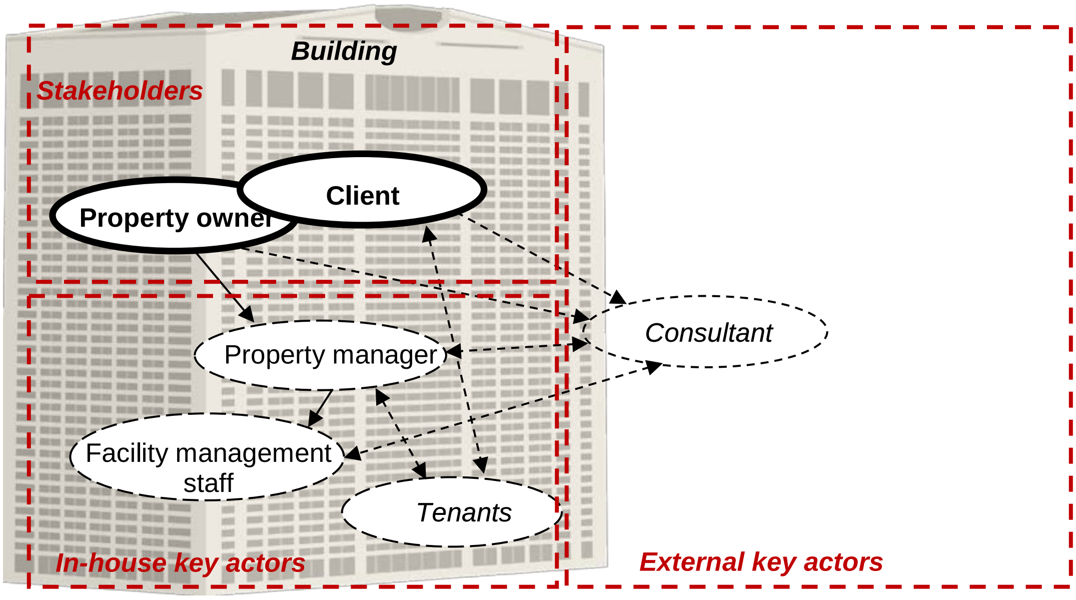


Figure 6.1 The stakeholders and key actors involved in Step 3 of the Total Concept method.

6.3 Key activities of Step 3 of Total Concept

The key activities of Step 3 of Total Concept method are illustrated in Fig. 6.2. The main activities in follow-up process in Step 3 include measuring energy use and checking the profitability results. In order to carry out these tasks preparations are required.

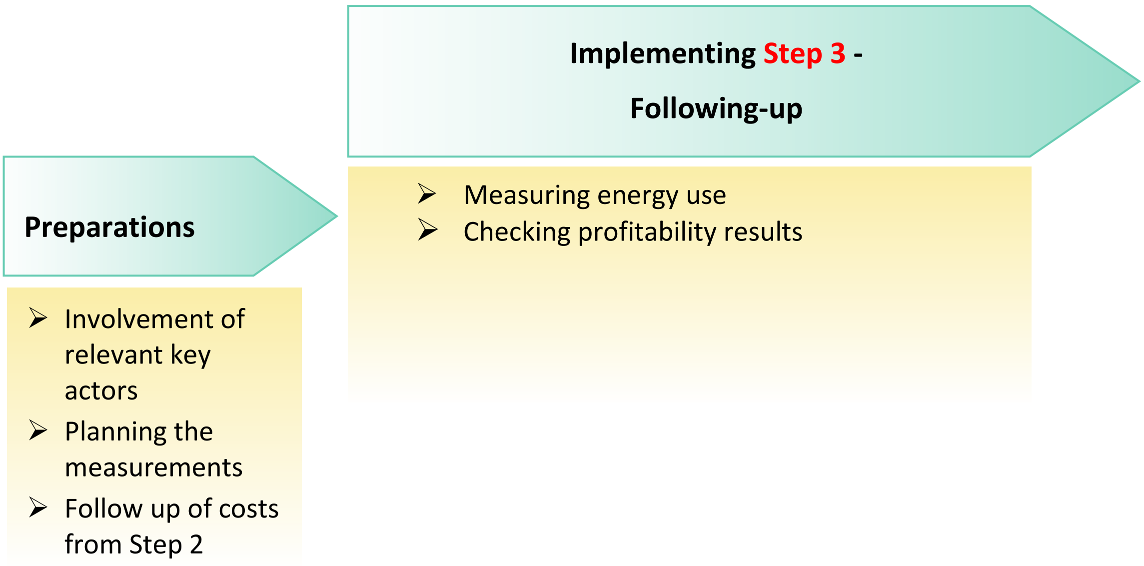


Figure 6.2 The key activities included in Step 3 of the Total Concept method.

6.4 Preparations for Step 3

6.4.1 Allocation of responsibility

Step 3 can be carried out by the client or by engaging a suitable consultant. If careful follow-ups are planned, then it must be ensured that energy use can be measured in sufficient detail and that the actual costs of the energy saving measures are documented. This is needed in order to verify that the investment according to the Total Concept method has been successful.

To be able to carry out Step 3, some of the planning work for this step should be begin during Step 2 when preparing the tender documents. It is the client's responsibility to make sure that the tender documents in Step 2 describe the preparations that the different parties involved must make before Step 3 is commenced. These include, for example, identifying measuring points, installation of additional meters and adjustments in data handling system as well as the documentation of costs that are included in the calculations. It is recommended, that the additional measurement points are to be identified by the design engineer and meters installed by the contractor.

Quite often, the maintenance staff will handle the follow-up work and gather measurement data, as this work is best done with the help of the operating and monitoring (BMS) systems. The maintenance staff should therefore be informed about this future assignment so that they have sufficient time to prepare for the involvement.

6.4.2 Planning the measurements

To plan and carry out measurements in the most efficient way, it is essential that the following points are taken into account:

- What measured data is required?
- What sort of results need to be studied?
- How should the measurements be carried out, what sort of instruments are needed and what sort of data gathering system is required?
- How will the data be processed?

In order to carry out the energy follow-up, the uses of heat energy, electrical energy and district cooling energy (if any) need to be measured on a monthly basis during at least one year period of time.

Guidelines on how the energy follow-up should be carried out in Step 3 can be found from the BELOK focus project report "Coordinating Functional Performance Checks" [4].

---

[4] Göran Andersson, GICON Installationsledning, 2015 "Samordnad funktionskontroll"

6.4.3 Following up costs

In order to check the profitability results of the action package the actual investment costs of the energy measures must be carefully documented in Step 2. It is always the client who decides both the economic conditions and the assumptions made in the investment cost calculations. It must be clear whether or not planning and design costs and client costs are included in the calculations. For more information about the investment cost calculation see Chapter 4.

Sometimes, together with the energy saving measures, other measures are also carried out, for example, during a general refurbishment of a building. In this case it is important to differentiate between costs for the energy saving action package and costs which refer to the upgrading work.

6.5 Measuring energy use

When the functional performance checks in Step 2 have been finished the measurement of the energy use can begin and data registered, suitably on a monthly basis, during at least one year of operation.

To make sure that data is gathered correctly, it is important to analyse the collected data carefully, especially at the beginning of a measuring period. Both verifying that the building and its installations are working in the intended way and ensuring that the measured values are registered in the intended way are important aspects. If measured values differ from the expected values, corrective measures must be taken as soon as possible and the measurements repeated. This means that data gathering has to be carried out with the systems functioning as intended during the whole of the evaluation period.

While gathering data, the operating conditions and use of the building must also be followed up. The purpose of this is to see whether there are any differences in the operating conditions and usages, compared to those in the assumptions made during Steps 1 and 2. For example, the occupancy times of the building might have changed or parts of the building might have been left unused or unoccupied, although this was not planned from the start.

Alternatively, it can happen that the building was un-occupied before the project based on Total Concept was started and new tenants have moved in after renovations were finished. Follow-up investigations on occupancy patterns are then necessary for estimating the actual savings if for example simulations were used for determining baseline. Follow-up investigations are also needed for analysis if any differences occur between expected and actual results.

6.6 Checking the profitability results

When following up profitability calculations the figures from the measured energy use and the approved final costs for the action package are commonly used, i.e. the costs resulting from Step 2.

The actual profitability result is calculated in the form of an internal rate of return for the whole action package. This is then compared to the internal rate of return that was calculated in Step 1.

Example

The results from a completed Total Concept method are shown below. The building comprises 8,500 m^2_{GFA}, in which the Total Concept method was implemented in its entirety, Step 1, 2 and 3.The energy use in the building was followed up over a period of one year after completion. The bar chart below summarizes the measured specific energy use before the measures were implemented and the measured energy use after completion. The action package resulted in a halving of the energy needs. The energy use was reduced from 180 kWh/m^2 yr to 80 kWh/yr excluding the tenant's use of electricity.

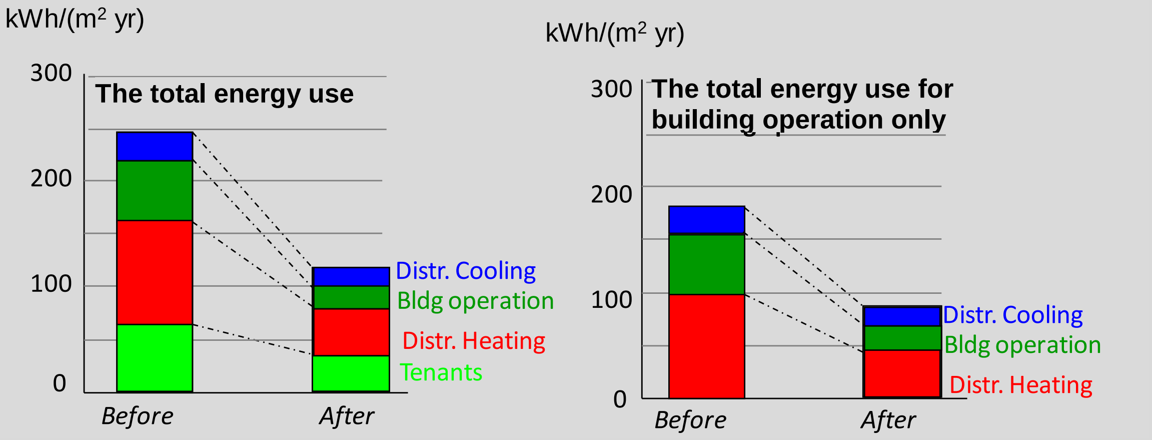


Figure 6.2 Measured energy use after carrying out the action package.

The diagram below shows the calculated profitability for the action package together with the true profitability that was calculated after Step 3. The calculated profitability for the package was 7 %. The profitability calculated using the actual costs for the rebuilding work and the measured savings was around 13 %, which is considerably higher than the owner's profitability stipulation of 5 %. During the building process, the actual costs were followed up and the results showed that they had been 25 % lower than calculated. This was partly due to a fall in the market and partly due to the margins allowed for when estimating the costs in the preliminary stages.

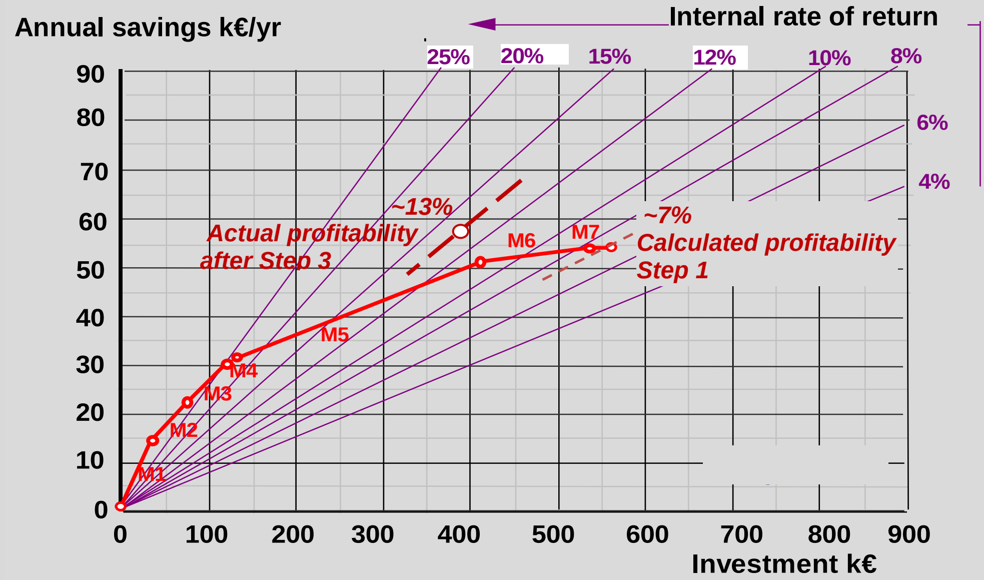


Figure 6.4 The calculated profitability of the action package together with the actual profitability that was calculated after Step 3 plotted on an internal rate of return diagram.

If there are differences in the expected and actual savings, and profitability results, the following points should be analysed:

- Does the building and its technical systems function as intended? Be careful to check functions and, if necessary, remedy any shortcomings.
- Have the operating conditions and use of the building changed since gathering the information used in Step 1?
- Do the actual costs differ significantly from those calculated in Step 1? What could be the cause? Is there anything else that could have affected the calculated energy savings, for example, if other works were carried out at the same time that were not connected to the Total Concept method, for example, a general upgrade of the building? If this was the case, it is important to keep the costs of the energy saving action package and the building upgrading work completely separate.

Appendix 1. Three examples of projects that have used the Total Concept method

1) Pennfäktaren, Vasagatan, Stockholm
Built in: 1975; Completely refurbished in 2008 – 2010
Offices, restaurant. A_{temp}12 600 m^2 (heated area)
A project based on Total Concept method was carried out together with the complete refurbishment work

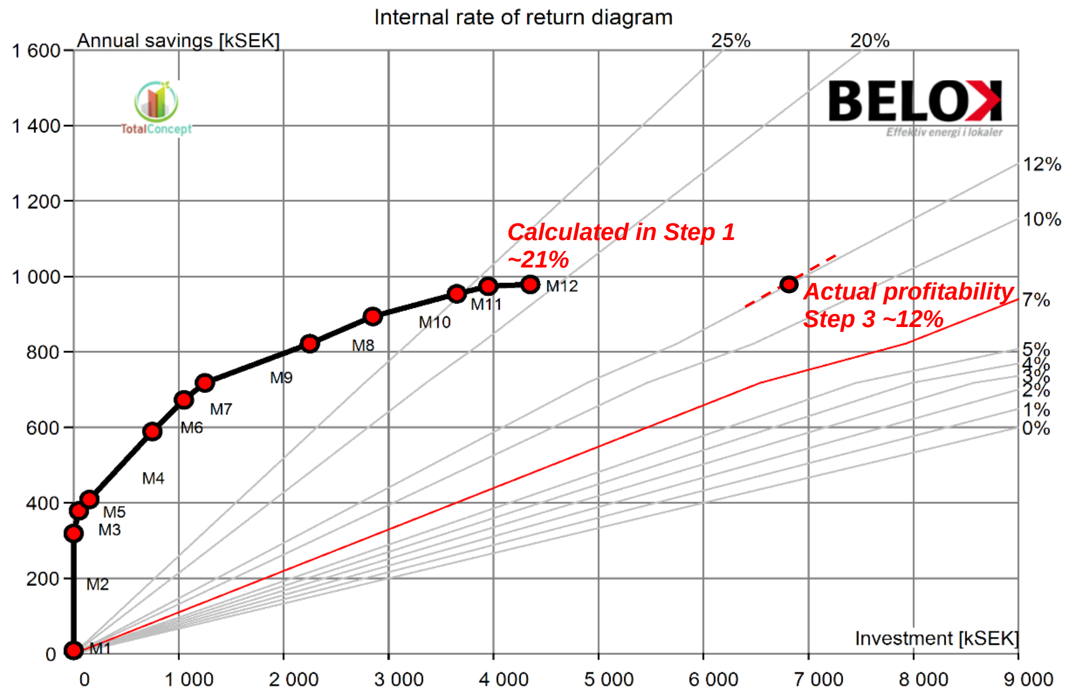
Before ***After***

Energy use measurements carried out September 2011 – August 2012. Following measures were included to the profitable action package:

- Optimizing the cooling system operation (M1)
- Demand Controlled Ventilation (M2)
- Installation of modern tap fittings (M3)
- Installation of new cooling unit (M4)
- New energy efficient pumps in the cooling system (M5)
- New ventilation unit with heat exchanger (M6)
- Replacement of district heating heat substation (M7)
- New lighting in the garage (M8)
- Replacement of windows towards the inner yard (M9)
- Installation of solar collectors (M10)
- Replacement of halogen spotlights (M11)
- Solar panels 50 m^2 (M12)

The estimated saving potential with the action package was 55 % (exckl. tenants' electricity) and the internal rate of return approximately 21 %, based on the calculations in Step 1. In Step 3 the measured energy use of the building was about 124 kWh/m^2, yr (excl. tenants´ electricity). Total energy saving was about 57 % and actual profitability about 12 %. A number of measures needed more time to implement and optimizing the system performance after renovation was more time consuming than expected.

Energy use	***Measured 2006 before action package***	***Measured 2011–2012 after action package***
Heat energy [kWh/m² Atemp]	**122**	**69**
Electricity for the building operation (excl. tenant's electricity) [kWh/m² Atemp]	**55**	**36**
District cooling [kWh/m² Atemp]	**110**	**19**
Total	**287**	**124**



2) Getholmen, Skärholmen, Stockholm
Built in: 1975
Offices, A_{temp} 7 600 m^2 (heated area)
A project based on Total Concept method was carried out 2007 – 2010

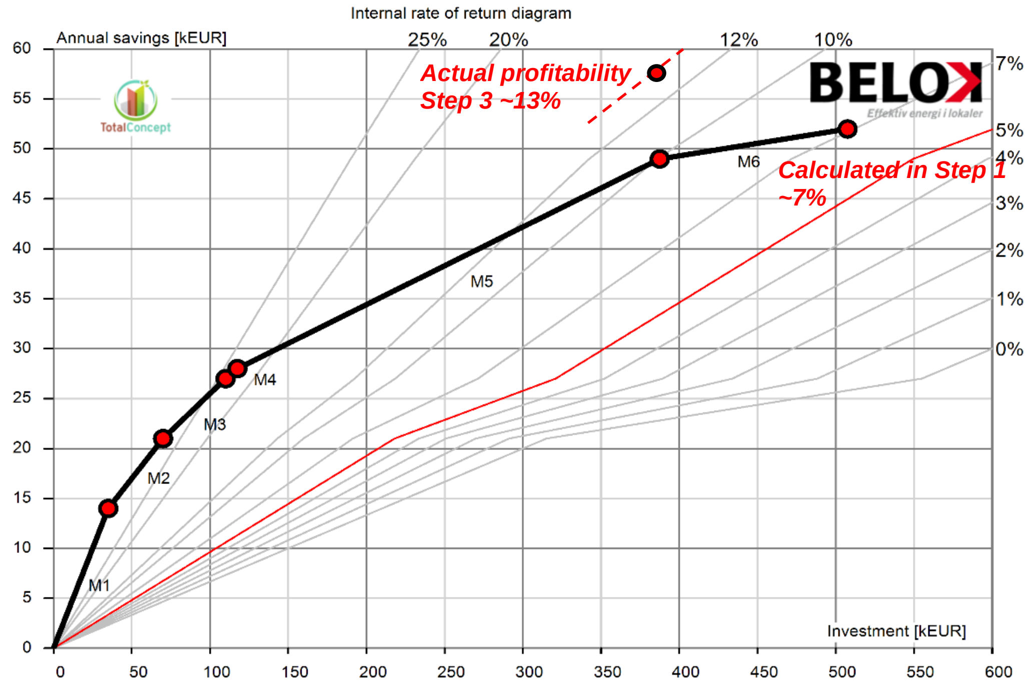
Energy use measurements carried out March 2009 – February 2010.
Following measures were included the action package:

- New common lighting (M1)
- Reduced basic head load (M2)
- Improved roof insulation (M3)
- Introduction of night cooling in the summer time (M4)
- New ventilation system (M5)
- New windows (M6)

The estimated saving potential with the action package was approximately 50 % (incl. tenants' electricity) and the internal rate of return approximately 7 %, based on the calculations in Step 1. In Step 3 the measured energy use of the building was about 126 kWh/m^2, yr (incl. tenants´ electricity). Total energy saving was about 53 % and actual profitability about 13 %. The actual costs were about 25 % lower than calculated. This was partly due to a fall in the market and partly due to the margins allowed for when estimating the costs in the preliminary stages.

Energy use	***Measured 2006 before action package***	***Measured 2009–2010 after action package***
Heat energy [kWh/m^2 A_{temp}]	**105**	**54**
Electricity for the building operation (excl. tenants electricity) [kWh/m^2 A_{temp}]	**72**	**23**
Cooling [kWh/m^2 A_{temp}]	**23**	**9**
Tenants electricity use [kWh/m^2 A_{temp}]	**66**	**40***
Total	**266**	**126**

*) Parts of the office were not rented out during the measurement period. This resulted in decreased energy use from the tenants' side, but increased heat energy use. When the whole building is rented out the tenants´ electricity use will be higher and heat energy use lower.



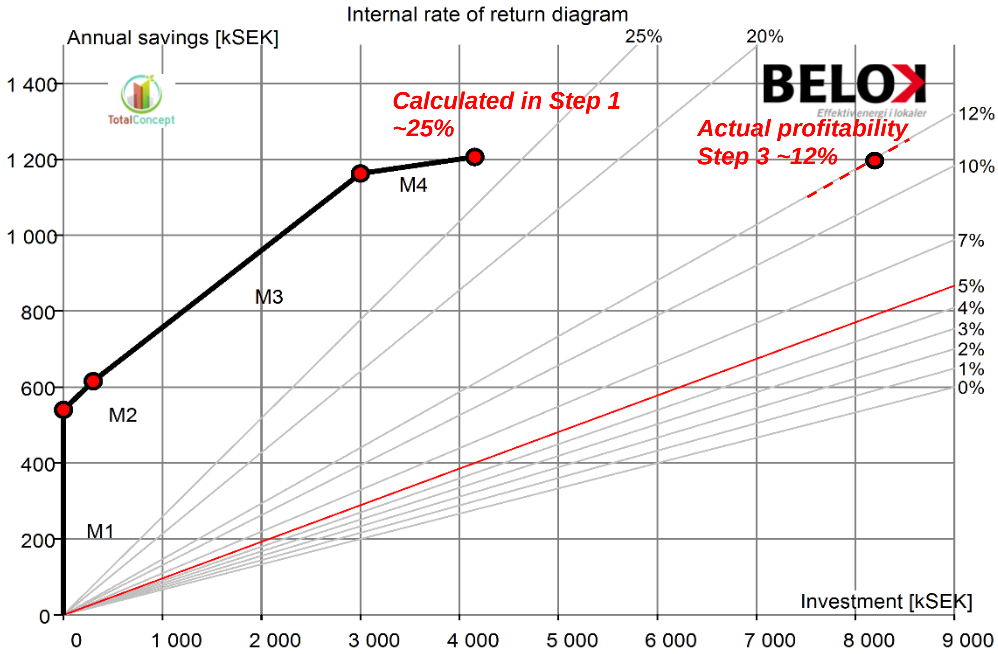
3) Hägern mindre 7, Drottninggatan, Stockholm
Buit in 1970, refurbished 2001
Offices and shops. A_{temp} 17 200 m^2 (heated area)
Total Concept method started 2010

Energy use measurements have been carried out so far during January– August 2012. Following measures were included the action package:

- Optimizing the ventilation systems' performance (M1)
- Installation of free cooling to the cooling system (M2)
- New ventilation units (M3)
- Installation of demand controlled ventilation in shops (M4)

The estimated saving potential with the action package was approximately 53 % (excl. tenants´ electricity) and the internal rate of return approximately 25 %, based on the calculations in Step 1. In Step 3 the measured energy use of the building was about 99 kWh/m^2, yr (excl. tenants´ electricity). Total energy saving was about 50 % and actual profitability about 12 %. Some of the measures became more expensive since it was difficult to close the shops during the renovations. The figures below are for an assumed whole year period.

Energy use	***Measured 2006 before action package***	***Measured 2012 after action package***
Heat energy [kWh/m^2 A_{temp}]	**131**	**56**
Electricity for the building operation (excl. tenants) [kWh/m^2 A_{temp}]	**50**	**25**
Cooling [kWh/m^2 A_{temp}]	**16**	**18**
Total	**197**	**99**



Appendix 2. Help tables for economical calculations

Table 1. Net present value factors for individual yields *i(i,n)*

$$i(i,n) = \frac{1}{(1+i/100)^n}$$

where
i = *interest rate, %*
n = *economic calculation period, yrs*

Year	4%	6%	8%	10%	12%	15%	20%	25%
1	0.9615	0.9434	0.9259	0.9091	0.8929	0.8696	0.8333	0.8000
2	0.9246	0.8900	0.8573	0.8264	0.7972	0.7561	0.6944	0.6400
3	0.8890	0.8396	0.7938	0.7513	0.7118	0.6575	0.5787	0.5120
4	0.8548	0.7921	0.7350	0.6830	0.6355	0.5718	0.4823	0.4096
5	0.8219	0.7473	0.6806	0.6209	0.5674	0.4972	0.4019	0.3277
6	0.7903	0.7050	0.6302	0.5645	0.5066	0.4323	0.3349	0.2621
7	0.7599	0.6651	0.5835	0.5132	0.4523	0.3759	0.2791	0.2097
8	0.7307	0.6274	0.5403	0.4665	0.4039	0.3269	0.2326	0.1678
9	0.7026	0.5919	0.5002	0.4241	0.3606	0.2843	0.1938	0.1342
10	0.6756	0.5584	0.4632	0.3855	0.3220	0.2472	0.1615	0.1074
11	0.6496	0.5268	0.4289	0.3505	0.2875	0.2149	0.1346	0.0859
12	0.6246	0.4970	0.3971	0.3186	0.2567	0.1869	0.1122	0.0687
13	0.6006	0.4688	0.3677	0.2897	0.2292	0.1625	0.0935	0.0550
14	0.5775	0.4423	0.3405	0.2633	0.2046	0.1413	0.0779	0.0440
15	0.5553	0.4173	0.3152	0.2394	0.1827	0.1229	0.0649	0.0352
16	0.5339	0.3936	0.2919	0.2176	0.1631	0.1069	0.0541	0.0281
17	0.5134	0.3714	0.2703	0.1978	0.1456	0.0929	0.0451	0.0225
18	0.4936	0.3503	0.2502	0.1799	0.1300	0.0808	0.0376	0.0180
19	0.4746	0.3305	0.2317	0.1635	0.1161	0.0703	0.0313	0.0144
20	0.4564	0.3118	0.2145	0.1486	0.1037	0.0611	0.0261	0.0115
25	0.3751	0.2330	0.1460	0.0923	0.0588	0.0304	0.0105	0.0038
30	0.3083	0.1741	0.0994	0.0573	0.0334	0.0151	0.0042	0.0012
35	0.2534	0.1301	0.0676	0.0356	0.0189	0.0075	0.0017	0.0004
40	0.2083	0.0972	0.0460	0.0221	0.0107	0.0037	0.0007	0.0001
45	0.1712	0.0727	0.0313	0.0137	0.0061	0.0019	0.0003	0.0000
50	0.1407	0.0543	0.0213	0.0085	0.0035	0.0009	0.0001	0.0000

Table 2. Net present value factor *I(i,n)*

$$I(i,n) = \frac{1-(1+i/100)^{-n}}{i/100}$$

where
i = interest rate, %
n = economic calculation period, yrs

Year	4%	6%	8%	10%	12%	15%	20%	25%
1	0.9615	0.9434	0.9259	0.9091	0.8929	0.8696	0.8333	0.8000
2	1.8861	1.8334	1.7833.	1.7355	1.6901	1.6257	1.5278	1.4400
3	2.7751	2.6730	2.5771	2.4869	2.4018	2.2832	2.1065	1.9520
4	3.6299	3.4651	3.3121	3.1699	3.0373	2.8550	2.5887	2.3616
5	4.4518	4.2124	3.9927	3.7908	3.6048	3.3522	2.9906	2.6893
6	5.2421	4.9173	4.6229	4.3553	4.1114	3.7845	3.3255	2.9514
7	6.0021	5.5824	5.2064	4.8684	4.5638	4.1604	3.6046	3.1611
8	6.7327	6.2098	5.7466	5.3349	4.9676	4.4873	3.8372	3.3289
9	7.4353	6.8017	6.2469	5.7590	5.3282	4.7716	4.0310	3.4631
10	8.1109	7.3601	6.7101	6.1446	5.6502	5.0188	4.1925	3.5705
11	8.7605	7.8869	7.1390	6.4951	5.9377	5.2337	4.3271	3.6564
12	9.3851	8.3838	7.5361	6.8137	6.1944	5.4206	4.4392	3.7251
13	9.9856	8.8527	7.9038	7.1034	6.4235	5.5831	4.5327	3.7801
14	10.5631	9.2950	8.2442	7.3667	6.6282	5.7245	4.6106	3.8241
15	11.1184	9.7122	8.5595	7.6061	6.8109	5.8474	4.6755	3.8593
16	11.6523	10.1059	8.8514	7.8237	6.9740	5.9542	4.7296	3.8874
17	12.1657	10.4773	9.1216	8.0216	7.1196	6.0472	4.7746	3.9099
18	12.6593	10.8276	9.3719	8.2014	7.2497	6.1280	4.8122	3.9279
19	13.1339	11.1581	9.6036	8.3649	7.3658	6.1982	4.8435	3.9424
20	13.5903	11.4699	9.8181	8.5136	7.4694	6.2593	4.8696	3.9539
25	15.6221	12.7834	10.6748	9.0770	7.8431	6.4641	4.9476	3.9849
30	17.2920	13.7648	11.2578	9.4269	8.0552	6.5660	4.9789	3.9950
35	18.6646	14.4982	11.6546	9.6442	8.1755	6.6166	4.9915	3.9984
40	19.7928	15.0463	11.9346	9.7791	8.2438	6.6418	4.9966	3.9995
45	20.7200	15.4558	12.1084	9.8628	8.2825	6.6543	4.9986	3.9998
50	21.4822	15.7619	12.2335	9.9148	8.3045	6.6605	4.9995	3.9999

Table 3. Annuity factor *P(i,n)*

$$P(i,n) = \frac{i/100}{1-(1+\mathrm{i}/100)^{-n}}$$

Where,
i = interest rate, %
n = economic calculation period, yrs

Year	4%	6%	8%	10%	12%	15%	20%	25%
1	1.0400	1.0600	1.0800	1.1000	1.1200	1.1500	1.2000	1.2500
2	0.5302	0.5454	0.5608	0.5762	0.5917	0.6151	0.6545	0.6944
3	0.3603	0.3741	0.3880	0.4021	0.4163	0.4380	0.4747	0.5123
4	0.2755	0.2886	0.3019	0.3155	0.3292	0.3503	0.3863	0.4234
5	0.2246	0.2374	0.2505	0.2638	0.2774	0.2983	0.3344	0.3718
6	0.1908	0.2034	0.2163	0.2296	0.2432	0.2642	0.3007	0.3388
7	0.1666	0.1791	0.1921	0.2054	0.2191	0.2404	0.2774	0.3163
8	0.1485	0.1610	0.1740	0.1874	0.2013	0.2229	0.2606	0.3004
9	0.1345	0.1470	0.1601	0.1736	0.1877	0.2096	0.2481	0.2888
10	0.1233	0.1359	0.1490	0.1627	0.1770	0.1993	0.2385	0.2801
11	0.1141	0.1268	0.1401	0.1540	0.1684	0.1911	0.2311	0.2735
12	0.1066	0.1193	0.1327	0.1468	0.1614	0.1845	0.2253	0.2684
13	0.1001	0.1130	0.1265	0.1408	0.1557	0.1791	0.2206	0.2645
14	0.0947	0.1076	0.1213	0.1357	0.1509	0.1747	0.2169	0.2615
15	0.0899	0.1030	0.1168	0.1315	0.1468	0.1710	0.2139	0.2591
16	0.0858	0.0990	0.1130	0.1278	0.1434	0.1679	0.2114	0.2572
17	0.0822	0.0954	0.1096	0.1247	0.1405	0.1654	0.2094	0.2558
18	0.0790	0.0924	0.1067	0.1219	0.1379	0.1632	0.2078	0.2546
19	0.0761	0.0896	0.1041	0.1195	0.1358	0.1613	0.2065	0.2537
20	0.0736	0.0872	0.1019	0.1175	0.1339	0.1598	0.2054	0.2529
25	0.0640	0.0782	0.0937	0.1102	0.1275	0.1547	0.2021	0.2509
30	0.0578	0.0726	0.0888	0.1061	0.1241	0.1523	0.2008	0.2503
35	0.0536	0.0690	0.0858	0.1037	0.1223	0.1511	0.2003	0.2501
40	0.0505	0.0665	0.0839	0.1023	0.1213	0.1506	0.2001	0.2500
45	0.0483	0.0647	0.0826	0.1014	0.1207	0.1503	0.2001	0.2500
50	0.0466	0.0634	0.0817	0.1009	0.1204	0.1501	0.2000	0.2500

Appendix 3. Examples of recommended economic lifetimes for different measures

Table A1 Recommended economic lifetimes for energy saving measures according to different sources (Reference projects in Sweden, EU standards and documents)

Measure	Economic lifetime [years]		
	Reference projects (Sweden)	CEN 15459	2006/32/EC
Facade insulation	40	-	25 – 30
Roof insulation	40	-	25
Foundations insulation	40	-	25
AHU with heat exchanger	20	15 – 20	17 – 20
Energy-efficient windows	30	-	30
Demand controlled ventilation	15	15	15
Individual domestic hot water metering	15	10[8]	-
Solar collectors	20	15 – 25	20
Solar cells	20	-	23
Tighter building envelope	40	-	5
Extract air heat pump	15	15 – 20	15
Better control of heating system	15	15 – 25	10
Replacement of domestic hot water fittings	15	-	15
Energy-efficient lighting	15	-	10 – 15
Property measures (lighting and SFP)	15	-	-

[8] Applies to meters

Appendix 4. Check list for questions to be put to the maintenance staff, property manager and tenant´s representative

Check list for questions to be put to the maintenance staff and the property manager

- Describe the general function of the building. How is the building used, are the tenant's requirements fulfilled?
- What is the history of the building?
- Describe the different technical systems, i.e. HVAC, lighting machines; how the systems function at present?
- What indoor climate requirements apply for the building(s)? Are these requirements fulfilled? What problems occur (if any)?
- Have there been any complaints from the tenants; why, what measures were taken?
- Which structural changes and changes to the technical systems have been carried out over the past 10 years?
- Are there any planned structural changes or renovation works?
- Do the maintenance staff or the property manager have any own suggestions about what should be done in order to save energy?

Check list for questions to be put to the tenant´s representative

- How are the premises used?
- How many people use the building, how many rooms are used at the same time, when are they used, are they used during holiday periods, etc?
- What do the tenants/users think about the indoor climate?
- Are there any problems connected to the building or the operation of the building?
- What is their opinion about the condition of the building, are there any suggestions regarding measures that could be taken?
- What types of machines and pieces of equipment are used by the tenant (number, type, operating hours, etc)?

Appendix 5. Checklists for frequently adopted improvement measures in the building envelope and technical systems

The following checklists are used when investigating whether or not there is potential for improving building envelope and technical systems in a building. The lists contain both check questions and suggestions for possible measures to be taken. It is not complete and only a selection of common issues and possible measures that can be used in non-residential buildings is shown. The opportunities for carrying out improvements to the building envelope are quite limited in non-residential buildings, especially those which have large internal heat loads. However, additional insulation and the use of energy-efficient windows could prove worthwhile, especially if the façade needs to be replaced and the windows need to be replaced for maintenance reasons.

Note: No matter which measure is carried out, one must always regard the building in its entirety. Always remember that measures can have considerable effects on each other and on the different technical systems in the building.

The building envelope

- What types of doors are installed? Are there doors that cannot be completely closed?
  - Install automatic door closers.
  - Seal points of leakage.
  - Consider replacing them with more energy efficient doors.
  - Consider replacing frequently used doors with an air sluice to reduce the inflow of outdoor air.
- What is the situation with the insulation in the loft space (roof)?
  - Consider extra insulation.
- How are the cellar walls and façade insulated?
  - Consider extra insulation
- What types of windows are installed? How are they insulated?
  - Consider sealing the windows.
  - Install extra panes of insulating glass in existing window frames (seldom advisable from an energy point of view, but could be used to improve the indoor climate. The climate benefits are not to be included in the energy savings costs).
  - Consider installing energy-efficient windows (seldom advisable from an energy point of view only, but could be used to improve the indoor climate. The climate benefits are not to be included in the energy savings costs).

Heating systems

Heat demands

- Is it possible to reduce heat demands?
  - Adjust the room temperature during the heating season.
  - Adjust the supply air temperature.
  - Avoid heating and cooling at the same time in the same space.

- Improve the efficiency of the building envelope: seal leakages, improve U-values.
- Improve the efficiency of the ventilation system: improve heat recovery.
- Improve the domestic hot water system.

Heat distribution

- Do the room units/radiators work properly? Are there thermostats on the radiators? Do the thermostats work?
  - Install/replace thermostats.
  - Improve the function of the room units/radiators.
- When was the hydronic balancing of the heating system carried out last? Are there any problems regarding uneven temperature distributions in the building? Any problems with warm/cold rooms in winter?
  - Balance the heating system. *Note: Hydronic balancing of the heating system will be required even if the other measures that affect the heat demand are carried out!*
  - Adjust the temperature control curve.
- How are the pumps controlled? Are the pumps dimensioned to meet the demands?
  - Replace old, small pumps, often with very poor efficiencies with new, energy-efficient pumps with higher efficiencies.
  - Install frequency controlled pumps, provided that this will improve the efficiency of the heating system.
  - Adjust the control settings of the pumps (operating times).
- What are the flow temperatures in the different shunt groups? *In non-residential buildings, checks regarding the function of the heating system will normally be carried out outside working hours. During working hours, many spaces normally have a heat surplus, which means that the thermostats in the radiators are closed.*
  - Adjust the temperature control curve.
  - Adjust the water flows in the system if these are significantly wrong. If the thermostats are working properly, then they will normally accommodate reasonable balancing errors.
- Are the heating pipes insulated? In what condition is the insulation material?
  - Improve the insulation on piping.
- Is there ground heating in front of the building? How is it regulated? Is ground heating needed, are there any icing problems in winter?
  - Adjust/change the control of the ground heating

Heat production

- What is the status and condition of the heat production unit? How large are the heat losses in the system?

- Change to a more efficient unit.
- Convert to a more environmentally-friendly energy source if an old boiler has to be replaced anyway.

Domestic hot water system

- In what condition are the present taps and fittings?
  - Install water-saving mixer taps or modern tap fittings. Modern fittings have much better seals and use considerably less water, which can offer savings both regarding water use and heat.
- Are the pipes insulated? In what condition is the insulation?
  - Improve the insulation of the pipes of the hot water supply.
- Check that the circulation pump is working properly.
  - Change to more energy-effective circulation pumps in the circulation system.

Comfort cooling systems

Cooling demand

- Is it possible to reduce the need for comfort cooling?
  - Reduce internal heat generation, for example, by replacing the lighting system with a more energy-efficient one.
  - Increase room temperatures during the cooling period.
  - Install external solar shading.
  - Install solar shading films on windows.
  - Make use of night cooling and ‘free’ cooling
  - Eliminate heating and cooling in the same space at the same time, make sure that radiators and other heat sources are switched off when cooling is needed.
  - Adjust the supply air temperature. For more information, see Ventilation Systems below.

Comfort cooling distribution (flow, pumps, balancing, pipe insulation)

- How are the pumps controlled? Do the pump sizes correspond to the demands?
  - Adjust, or change the sizes of the pumps. Old, small pumps with low efficiencies and long use should always be changed.
  - Install frequency-controlled pumps if this will improve the functioning of the system.
- When was the hydronic balancing of the cooling system last carried out?
  - Balance the cooling system.
- Are the cooling media pipes insulated enough? What is the condition of the insulation?
  - Improve the pipe insulation.

Comfort cooling production

- What is the status and condition of the cooling unit?
    - Replace with a more efficient unit.
    - Adapt the operating temperature and operating times of the production unit to the demands.
    - Check the status of the heat transmitting surfaces and clean them if necessary.
- Make use of the condenser heat to preheat hot water.
- Make use of ‘free’ cooling. This can be done in water based cooling systems with cooling beams and similar solutions. *This might require extensive extra installations if the cooling system has not been prepared for this.*

Ventilation systems

Ventilation demands

- What ventilation flows are introduced at room level? Do they meet today’s requirements? What are the operating times?
    - Adapt the operating times.
    - Adapt/adjust the air flow rates according to demand.
    - Night and weekend reductions/operating schemes
    - Install demand control. In practice, this will mean converting CAV systems to DCV systems[9]
- What is the supply air temperature? How is the supply air temperature controlled? Has the supply air a cooling function or a heating function? Is this needed?

[9] Converting from CAV to (Demand Controlled Ventilation) DCV is quite a major measure but it could be profitable. If it is carried out correctly, the need for heating air can almost be eliminated and the electricity need for the fans halved. This means having a correctly designed and built system.

1. Existing terminal devices must be replaced by VAV devices.
2. If flows are governed by room temperatures, then they should be able to manage low supply air temperatures of about +15ºC without causing problems with draught.
3. *All* the devices in the system must be able to manage these conditions. If only one single device in the system requires a higher supply air temperature, then this will be the governing device for the supply air temperature in the whole system, the cooling effect of the air will be reduced and all the other devices will increase their air flows to provide the required room temperatures. Displacement devices in practice require a supply air temperature of around +19 ºC if problems with draught are to be avoided. If there is one displacement device in a DCV system, this will determine the supply air temperature. The cooling effect of the air will be small and all the devices in used spaces will open fully. The system in practice will function as a CAV system and all the gains of the conversion will be lost.
4. VAV devices must be able to manage quite large pressure drops, normally up to 120 Pa, without causing a disturbing noise. At low flow rates, the pressure drops in the system will be small and the pressure just before the device high. This is important to avoid having to install additional dampers in the system.
5. Frequency control of fans must be installed but this is a comparatively small cost.

  - Adjust the supply air temperature.

Ventilation distribution

- What are the ventilation demands in the different parts of the building? Are individual demands met?
  - Balance the ventilation flows.
  - Sectionalise the distribution of the ventilation flows and when needed install more units to meet individual demands.
  - Install after-treatment units with heating/cooling//filtering (humidification).
- What does the ducting system look like? Are there large pressure drops in the ducting system? Is it possible to reduce the pressure drops in the ducting system?
- Does the ducting need insulating?
  - Insulate the ducts

Ventilation production

- What are the operating times for the ventilation system during weekdays and at weekends? Do the operating times match the working hours? Are there different operating levels?
  - Adjust the operating times.
- What is the estimated SFP for the fan system?
  - Reduce pressure levels.
  - Install frequency control system for the fans.
  - Change to more energy efficient fans.
- Is there any heat recovery? Is the correct type of heat recovery used? What is the temperature efficiency of the system? What are the system temperatures during different seasons? Does the control system work properly?
  - Replace with a better heat recovery system.
  - Install a heat recovery system if there none in place.
  - Improve system control.
  - Clean the heat recovery system.
- How are the heating and cooling batteries controlled? How do they interact with each other? Check pumps and leakage from valves.
  - Balance the flows.
  - Add a deadband in the control system between the cooling and heating valve opening.
  - Clean the system.
  - Stop leakages from valves and pumps.
- Have the right classes of filters been used? Check pressure drops through filters.
  - Replace filters.
  - Change the filter-change times and maintenance routines.

Lighting

- Are the operating times set to match working hours?
    - Adjust the operating times according to the use of the building.
- How is the lighting in stairways and corridors controlled?
    - Adjust or change the control system and operating times.
- Is outdoor lighting switched on in daytime?
    - Adjust or change the control system and operating times.
- What sort of lighting is used and in what condition is it? What sort of fittings are used and in what condition are they?
- What is the installed power in W/m^2?
    - Change to more efficient devices (HF devices, more efficient sources and fittings).
- Is lighting automatically controlled? How does it function?
    - Adjust the function of the control system for lighting
    - Sectionalise the lighting and adapt the time channels accordingly.
    - Install occupancy control, occupancy sensors.
    - Install daylight control to the lighting, adjust the daylight control units (lux requirements). *Note: be aware of stand-by effects*.

Machinery/equipment

- What are the operating times during the week and at weekends?
    - Adjust the operating times.
- Temperatures in computer rooms, TV rooms, control rooms? What are the demands on the set points?
    - Adjust the temperature set points.
- Is there a compressed air system? Are there any compressed air leakages?

Systems for control and monitoring

- Install separate metering systems for heat, electricity and cooling if there are none in place.
- Install separate metering systems in different buildings if there are none in place.
- Check alarm functions: what?, how?, displays?, logs?
- How often are reports generated: weekly, monthly, yearly?
- How are the systems visualized: circuit diagrams and plots?

Stand-by effects

- Stand-by functions for different apparatuses perhaps only require a few watts each but there are often a lot of them and they are often switched on all year round.

    - Form an overall picture and see what can be done to reduce them.
    - Replace old stand-by units.
- Some energy saving measures, such as advanced lighting control, can include stand-by functions which require more energy than would be saved by installing the new lighting control system. Check this before carrying out this measure.