Appraisal of Renewable Energy Projects with Cases from Samso

Contents

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Standard Saving Values

Tab. 1. Standard values (selection from Teknologisk Institut 2013)

Advice	Savings [kWh]	Comment
Replace 1 halogen lamp (35 W) by an LED lamp (5.1-7 W)	27	Usage 1000 h / yr
Replace a 3-speed circulation pump by a continuous class A pump	280	
Install a timer on the circulation pump for hot water.	58	
Replace an old hot water tank (with jacket), size 100 litres, by a new standard tank	1206	Losses: 4 W/K
Bi-annual service check of an oil boiler	935	
Bi-annual service check of district heating unit	815 (small), 1358 (large)	
Install a standby switch on IT devices	90	

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Colophon

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ECS Chapter 1

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Background and objective

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Fig. 1. Samso energy academy. The building houses three private organisations.

Samso is a 100% *renewable energy island*. The island became 100% renewable during a 10-year project that lasted from 1997 to 2007. We have in our archives a large collection of information and data from that project, and the objective of this handbook is

- to make the results and data from the project accessible to students and project partners.

The goal is to use it in courses for students, journalists, politicians, municipal officers, and engineers.

The Samso Energy Academy is both a building (Fig. 1) and an organization, which resulted from the project. The Samso Energy Agency and the Samso Energy and Environmental Office are two other organizations under the *Samso Energy Academy*. All organizations are private, non-governmental organizations funded by project finance and fees for our services.

When we say the island is a *100% renewable energy island*, it does not mean the island is self-sufficient, but it refers to the following ratio computed on an *annual* basis:

annual renewable energy production / annual energy consumption = 100%

The island still consumes fossil fuel, especially for transportation. It is important to note that Samso has an electric cable to land with traffic both ways, mostly export.

There are other renewable energy islands. ISLENET is a network of European islands that promote sustainable and efficient energy and environmental management. It is much more difficult to become 100% renewable if the island does not have a cable to an outside electric grid. *El Hierro*, one of the islands of the Canary Islands, will solve that problem by means of a water reservoir with a pumped water storage power plant that collaborates with wind turbines.

External links

1. %ElHierro%

2. %EuropeanREI%
3. %ISLENET%
4. %MapSamso%
5. %SEHome%
6. %WikipediaSamso%

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Samso, a Renewable Energy Island

Appraisal of Renewable Energy Projects with Cases from Samso > ECS Chapter 1 > Samso, a Renewable Energy Island

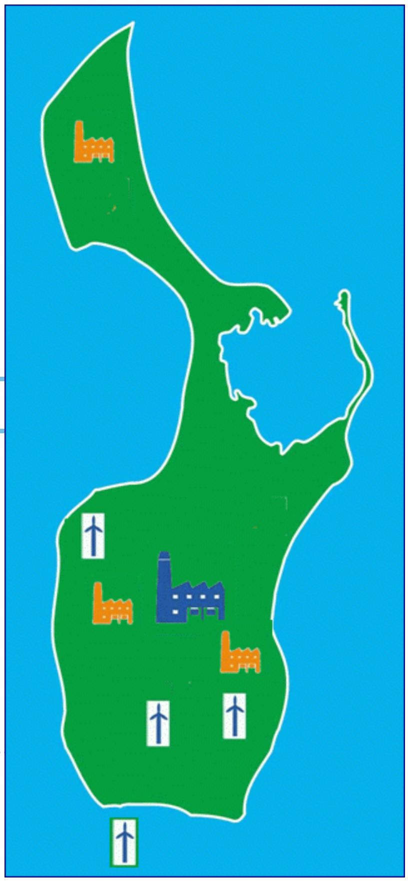

Fig. 1. Samso. The symbols indicate the main energy production sites. The surrounding box is 28-by-12 kilometres.

Samso became a *100% renewable energy island* in ten years. Eleven wind turbines on land cover the electricity consumption. Renewable energy heating by district heating plants and private installations cover more than 70% of the heating demand. Transportation is still mainly based on fossil fuels, but offshore wind turbines compensate for the transport consumption plus the remaining heating based on fossil fuels.

The island has an electric submarine cable to the mainland *Jutland*, with electric traffic both ways. We say the island is *100% renewable*, but it does not mean the island is autonomous. It refers to the following *annual* balance:

annual energy consumption = annual renewable energy production

The island still consumes fossil fuel, especially for transportation. The ferries account for about 50 percent of the total transportation energy, and they run on fuel oil. The island went from 13% to 100% during a 10-year project from 1997 to 2007.

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Project milestones

1997

Energy plan. The Danish government announces a competition in the spring of 1997. The objective is to appoint a renewable energy island. Five islands participate, and each competitor receives an amount of funding to hire consultancy and write their energy plan. Together with the engineering company *Planenergi*, the local business association, the municipality, and the farmers' association Samso submits a proposal in June. A committee of external and governmental evaluators review the proposals according to the criteria: use of well tested technology, energy savings, limited requirements for subsidies, local support and initiative, good traffic connections, and enough tourism for the project to be a *display window* for renewable energy. The minister for the environment and energy, Svend Auken, grants Samso the title *Denmark's Renewable Energy Island* in November.

1997

Samso Energy and Environmental Office. The organization *Samso Energy and Environmental Office* (SEMK) is formed in July in order to have an information office for the public. The *Danish Energy Authority* decides to support SEMK, and in Feb 1998 it is possible to open a professional office with an energy consultant: *Søren Hermansen*. The governmental funding lasts until 2002 after a new government goes into power, and the SEMK funding is thereafter based on projects and consulting.

1999

Electric cars. The Samso municipality leases four Citroen Berlingo electric vehicles for the municipal home care as a supplement to three petrol driven cars. Unfortunately the project is abandoned three years later for various reasons: 1) the batteries needed service on the mainland, and often one car was missing, and 2) the 12 social workers that drove the cars applied less than optimal driving techniques, as they were often in a hurry to attend to emergency calls. The fuel consumption was equivalent to 1.40 DKK/km (0.19 EUR/km). Later in 2006 the Energy Academy receives a Citroen Saxo from the Arhus municipality, and it runs as expected.

2000

Heating campaign. The energy organizations implement two campaigns starting in 1999. The topics are renewable energy and energy savings directed toward 850 houses and 750 summer cottages or temporary residences. Two energy consultants visited 74 families, and about 1/4 establish solar heating after the visit.

2000

Wind turbines. Eleven land based wind turbines start to operate, the size of each is 1 megawatt. Many citizens own two of the wind turbines in a co-operative after forming a *guild*, and nine farmers own one wind turbine each. The total production of the 11 turbines is more or less equivalent to the electricity demand on the island. The government guarantees a minimal selling price at 0.60 DKK/kWh (0.08 EUR/kWh) for the first 12 000 MWh, corresponding to about 5 years of operation, and thereafter 0.43 DKK/kWh (0.057 EUR/kWh) until the end of the tenth year. Thereafter the selling price equals the market price governed by the electricity exchange NordPool.

2002

District Heating Plant, Nordby-Maarup . A very active action group of citizens manage to collect more than 70% of the potential consumers, and the district heating plant goes into operation years ahead of schedule. Due to the relatively large amount of summer residents and the company Br. Kjeldahl's need for process heat to dry onions, an array of solar collectors is built into the plant. The energy supplier NRGi owns the plant.

2003

Onsbjerg district heating plant. A straw fired heating plant starts to supply heating to 75 consumers in Onsbjerg. The company Kremmer Jensen Varmeforsyning Aps owns the plant, controlled by two local brothers. During the intial phases of the project, the initial location was rejected by citizens and the church, but they agree on a better location also in agreement with the local branch of the national environmental organization (the Danish Society for Nature Conservation).

2003

Canola oil. The local wind turbine trust buy and establish together with three organic farmers a rapeseed oil press. The plant oil is for transportation and the remaining cake is fotter for the cows. The first tractor runs on canola oil in 2003. Later on in 2008 three oil presses are in operation.

2003

Offshore wind turbines. Ten wind turbines in the sea south of Samso start operating. Each turbine is 2.3 megawatt and reach 103 metres up from sea level to the upper tip of the wings, and they are a large boost to the renewable energy production (Fig. 2). The cost of each wind turbine is 25 mill DKK (3.3 mill EUR). The Samso municipality borrowed 125 mill DKK (17 mill EUR) and bought five wind turbines. This way each citizen is said to own a piece of a wind turbine at the value of 30 000 DKK (4 000 EUR). A possible municipal profit

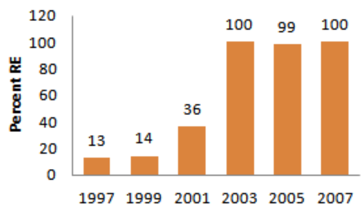

Fig. 2. Renewable energy percentage.

may only be invested in new energy projects; it can not be spent on the ordinary operation of the municipality. One turbine is the Paludans flak wind turbine? co-operatively owned by citizens in a partnership. Two wind turbines are owned by local farmers, and the remaining two are owned by external, professional investors.

When the offshore wind turbines went into operation in 2003, the renewable energy percentage went to 100.

2005

Ballen-Brundby district heating plant . The last straw fired district heating plant starts operation. A shredder takes the straw bales apart and chops it into fine pieces, which are blown into the furnace. The furnace heats up water which is sent to the distribution network and distributed to consumers in two villages. The plant is fully automated, but monitored by a caretaker. The consumers own the plant. The local farmers supply the straw based on a five-year contract.

2005

Samso Energy Agency The EU Save programme, the Danish Enterprise and Construction Authority, and Samso Havvind fund and initiate the Samso Energy Agency. Its objective is to act locally and regionally with respect to renewable energy. Its first tasks are to help establish the Samso Energy Academy, to erect a hydrogen filling station for vehicles, and to promote energy savings by means of home energy checks.

2007

Samso Energy Academy The mayor of Samso inaugurates the new building in May 2007. It houses three energy organizations that promote renewable energy and energy savings. The building is open to the public during the summer period, where visitors get a tour of the exhibition, get a presentation, watch a film, and have discussions with the staff. The Energy Academy organizes workshops, events, and courses for more than 4 000 visitors per year including politicians, public servants, journalists, students, and school children.

General Information about Samso

The population of Samso is around 4 000 people and decreasing (Fig. 3). The area is 114 square kilometres. Samso is an independent municipality in the administrative region Central Denmark Region, which is one out of five national regions. It is one of the smallest municipalities in Denmark, since after the recent municipal reform the nominal size is 30 000 citizens compared to our 4 000.

People live in small villages or in the open land. The nature varies with areas of open landscape, heath, forest, dune, beaches, and hills. The highest hill *Ballebjerg* is 64 metres.

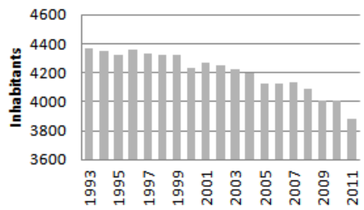

Fig. 3. Population of Samso. Depopulation threatens the island, and it is one of the major concerns of the municipal board.

The largest economical sectors are agriculture and tourism. The social and health care sector is about the same size counted by the number of employees. There was a fishing industry and a wharf, but today only one fishing boat goes to sea on a regular basis. There are 500.000 tourist overnight bookings per year, and the number is increasing. Two ferry connections link the island, one towards east (1 hour 50 min) and another towards west (1 hour).

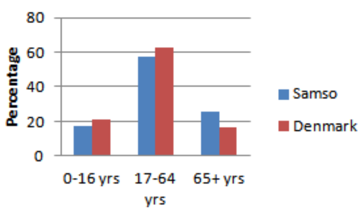

Fig. 4. Age distribution of the population in 2010. There is a relatively large amount of old people.

The island has no secondary school after the tenth form, and teenagers who wish to continue their education leave for the mainland around the age of 16. There are relatively few middle aged citizens on the island, and relatively many pensioners (Fig. 4). The municipality recently built a larger home for the elderly, inaugurated in 2009.

Energy supply and demand

The whole island consumes annually about 600 terajoule (TJ) of energy. That is less than one 1000'th (0.1 percent) of the Danish consumption, and it is thus difficult to scale the results from the Samso renewable energy project to the whole country.

The energy consumption per islander is 3/4 of the average Danish citizen's consumption (0.125 TJ or 35 000 kWh compared to 0.161 TJ, see Wikipedia, List of countries by energy consumption per capita). This puts Samso on the level of Ukraine, Italy, and Greece. As an aside, Iceland consumes four times as much per islander.

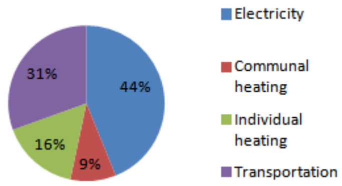

Fig. 5. Energy consumption 2009. The total consumption is 893 TJ, and the electricity net export is 283 TJ.

The island consumes electricity, heat, and fuel for transportation (Fig. 5). Transportation and heating (communal district heating + individual heating) are almost the same magnitude, electricity is relatively small. The electricity comes sometimes from the cable to land, but on an annual basis the net exchange is export; the windturbines thus produce more electricity than the island consumes. The district heating comes from renewable energy, while the individual heating comes from oil, wood and straw. Solar heating contributes very little, and heatpumps are included under electricity. Transportation, which accounts for 40% of the energy consumption, is almost entirely based on fossil fuel (petrol, diesel). The ferries alone consume almost half the energy in the transportation sector. Transportation is therefore a big problem with respect to renewable energy and energy consumption. It remains to be solved.

Over the years the energy consumption has been steady, despite the depopulation and the closing of the pork slaughterhouse in 2000. Figure 6 shows that initially electricity was imported, but after the erection of the offshore windturbines in 2003, the import went negative (= export). There is still a demand for fossil fuel, but this amount is compensated by the electricity export, and the end result is a *100% renewable island*.

Energy balances were made every second year during the project. They contain a large amount of numbers in a spreadsheet for each year. The energy balances keep track of the fossil fuel and renewable energy input to the island, as well as its conversion, losses and end-use. It is a large, valuable piece of work, that documents the transition to renewable energy.

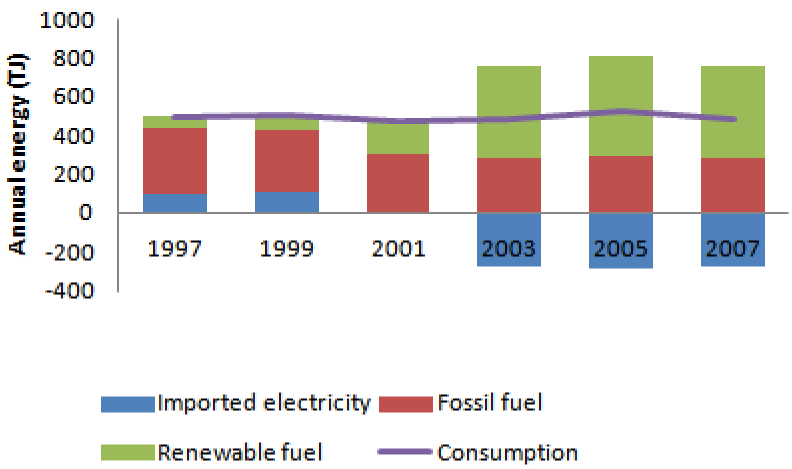

Fig. 6. Energy balance (climate adjusted).

Renewable Energy

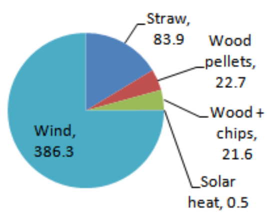

Fig. 7. Renewable energy 2005. The numbers are terajoules.

After 2003 the renewable energy is the same amount as the energy consumption. Figure 7 shows that the renewable energy mainly consists of wind power from the windturbines. Next comes straw, which is fuel for three district heating plants, and wood chips, which is fuel for the fourth district heating plant.

Only 35% of the local biomass resources are exploited, and there is a large biogas potential (145 TJ when supplemented with energy crops). There was a biogas plant, but it was closed due to financial problems. There have been several attempts to establish a biogas plant since. Now an action group has been formed, and they are planning to perform a preliminary investigation.

The final project report, the major reference, describes the whole project in more detail (Jorgensen, Hermansen, Johnsen, Nielsen, Jantzen and Lunden 2007).

External links

1. EDIN Samsø, Denmark, Strives to Become a Carbon-Neutral Island
2. Energinet.dk Energy net now
3. Larson J 2009 Island in Denmark produces more energy than it consumes, Worldfocus, series Green Energy in Denmark, Video 6 mins
4. Map Samso in Europe
5. Planenergi home page
6. Samsø Vindenergi I/S home page
7. State of Green home page
8. Wikipedia Canola
9. Wikipedia Joule
10. Wikipedia Svend Auken
11. Wikipedia List of countries by energy consumption per capita

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Economic Appraisal: Energy Saving Lamp

The EU decided to remove the incandescent lamp gradually from the market, because there are other lamps that are more energy efficient now and therefore cheaper in the long run. In order to check this we make use of a basic principle within engineering economics (Park 2009):

- All that counts is the difference among alternatives.

Graphical plots on this page illustrate a household's risk and surplus when changing an old lamp (Fig. 1) to an energy efficient lamp. It is necessary to draw such plots in order to get a complete overview of the investment. The plots depend on the prices of the old and the new lamp, the annual savings, the hours of usage, and lifetime estimates of the old and the new lamp.

The example on this page is introductory, and it illustrates the type of analysis which is fundamental for the appraisal (valuation) of all the engineering projects on this website.

Fig. 1. Incandescent lamp. After 2012 these are banned, and shops may only sell their remaining stock.(Photo: Wikimedia Commons).

Fig. 2. Compact fluorescent lamp, CFL. (Photo: Wikimedia Commons).

Contents

Introduction

The Danish Energy Agency urges the consumers to change their incandescent lamps (Fig. 1) into something more energy efficient (Fig. 2) arguing that it will be cheaper in the long run. But what does 'cheaper in the long run' actually mean?

An incandescent lamp costs only 12 DKK (1.60 EUR) while an equivalent energy saving compact fluorescent lamp (CFL) of medium durability costs 55 DKK (7.33 EUR). On the other hand, a CFL uses only 1/4 of the energy in comparison.

Since there are some annual savings, it is intuitively clear that the CFL could 'catch up' with the old type of lamp. How long this takes is a measure of *risk*, because the sooner that period is over, the sooner the risk vanishes. Whether there is also a good surplus in the end depends on the lifetime of the lamps and the time horizon of the investment; should the family move to another home in the near future, then the investment could be more or less lost.

Cash Flows

Let us choose a time horizon of ten years. An incandescent lamp burns maybe 1 000 hours, before it breaks, and let us choose an alternative CFL with an estimated lifetime of 10 000 burning hours. The CFL lifetime is clearly much better, and it has the advantage that the lamp must be replaced less frequently. If we assume that the usage of the lamp is 1 000 hours per year -- almost 3 hours per day -- then the incandescent lamp must be replaced once every year while the CFL lasts 10 years. Our appraisal of the investment strongly depends on this good lifetime.

The diagram in Figure 3 is a *cash flow diagram*. When expenditures and receipts are in cash, the net receipts at a single time instant (a column) is termed *cash flow*, and the series of flows over the whole time horizon is a *cash flow stream* (Luenberger 1998). Each cash flow is related to the end of the calendar year. For example, the initial investment is made at the end of year 0; all further investments are assumed to be made at the end of year 1, 2, ..., 10; and all expenditures of electricity are assumed to be calculated on an annual basis at the end of the year.

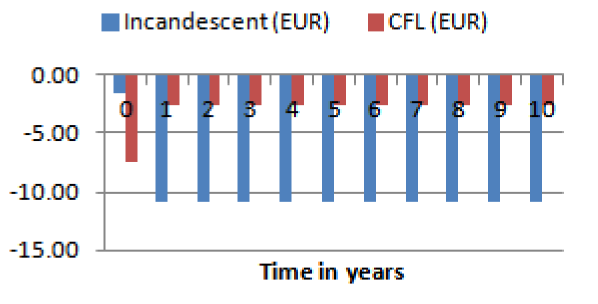

Fig. 3. Two cash flow streams. The incandescent lamp is cheaper to buy, but the CFL is cheaper to operate. All amounts are negative, because they are expenditures.

The diagram gives an overview of the expenditures of the two alternatives, each in a different colour. The diagram depends on estimates of the energy consumed and the energy price, gathered in Table 1 below. This diagram is already more informative than the mere selling prices of the two lamps.

Incremental Cash Flows

Naturally, we view the CFL as an alternative which saves energy in the long run, and we shall apply the above quoted principle: All that counts is the difference among alternatives. We therefore take the incandescent lamp as our reference scenario and compare the CFL with that.

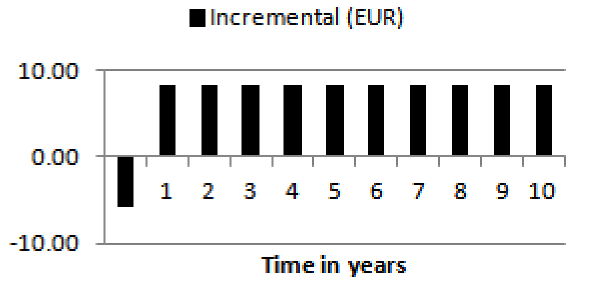

Fig. 4. Incremental cash flow stream. It is the difference

between the two cash flow streams in the previous figure. Now some amounts are positive, because they are savings. The internal rate of return is 146%.

Figure 4 is an *incremental cash flow* diagram. It shows the consequences of moving from the incandescent lamp to the CFL. It is the increment in the cash flow: The CFL cash flow stream minus the incandescent cash flow stream, mathematically speaking.

The plot clearly shows that there are savings over most of the time horizon, and there seems to be more savings (positive cash flows) than expenditures (negative cash flows).

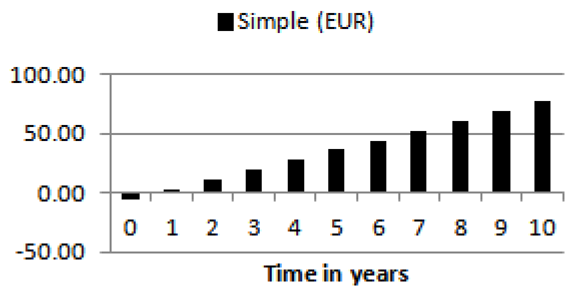

Fig. 5. Cumulative cash flow diagram. This is the successive accumulation of the amounts in the previous figure starting from the left. The initial payment is negative, because the CFL is more expensive, but the cumulative cash flow becomes positive after one year. The surplus after ten years is almost 78 euro.

Internal Rate of Return

The incremental cash flow stream (Fig. 4) can be viewed as an investment with an initial payment at the end of year 0, the *principal*, which returns positive cash flows every year thereafter. It is equivalent to a deposit in a bank account with some unspecified interest rate. We would like to know this interest rate in order to compare the investment with other investments, for example in bonds. That interest rate is the *internal rate of return* (IRR). It is *internal* in contrast to the *external* rate of return, which is the market return rate for an investment under existing market conditions.

The Excel function IRR calculates the internal rate of return, given the incremental cash flow stream as input. In our case the internal rate of return after ten years is 146%; that indicates a very profitable investment.

The internal rate of return is equivalent to the interest rate of a bank account which would just finance the project; the withdrawals would be repaid exactly by the deposits generated by the project plus interest. If we are able to finance the project through an actual bank loan at a lower interest rate than the IRR, then there will be a surplus.

Balance of the Project Account

Inflows and outflows of the cash flow stream are related to an imaginary ideal bank account (Luenberger 1998), the *project account*. It is ideal, because it applies the same rate of interest to both deposits and withdrawals, and it has no service charges or transaction fees. It may apply different interest rates to different kinds of transactions, though. The project account is associated with the outside financial market.

If we sum the cash flows of a whole stream we obtain the *net future value* of the cash flow stream at the end of the time horizon, say, K years from now. This would be the final balance of the project account. It is the *net* future value, because both negative and positive cash flows contribute to the sum.

If we do it successively for each year k on the way ($k = 1, 2, ..., K$), the result is the *cumulative cash flow* diagram in Figure 5. This is a picture of the balance of the project account. Each column in the plot is the successive accumulation of the cash flows (Fig. 4) starting from the left. The plot shows at each time instant k the value of the investment k years from now.

The project balance provides good support for the decision to invest or not. Initially there is a negative cash flow, but the accumulated savings compensate for that, and the balance becomes positive quickly. A positive value means there is a *surplus*, the project gains more than it looses.

Payback Period

There is a distinct point in time, the *breakeven point*, where the cumulative cash flow changes sign from negative to positive. The duration up until this event is the *payback period*, defined as the time it takes before the savings outbalance the expenditures.

In this case breakeven happens after one year. One year is a very short payback period, given that the time horizon is ten years, and we can therefore conclude that the risk is low.

Surplus

The payback period does not tell what happens after the breakeven point, and it is necessary to know the expected *surplus* at the end of the time horizon, in order to valuate the investment. The annual savings, less the initial investment, add up to an amount, which is the expected surplus. This is in fact the same as the final value.

The height of the last column in the project balance (Fig. 5) shows the expected surplus. The exact amount is 77.93 EUR (Table 2 in the Data section). This is very good considering that the initial investment is only 7.33 EUR.

It is convenient that the diagram (Fig. 5) shows both the risk -- in terms of the payback period -- and the surplus in one diagram.

Reinvesting the Savings

The project account accumulates interest, whether it be negative or positive. For example, if energy saving light bulbs save some expenses on the electricity bill, the houseowner withdraws less money from the savings account and thus gains more interest. In case of expenses, the houseowner looses interest.

In general, a bank deposit of a principal P euros at an interest rate i generates interest of the principal plus the accumulated interest that has been added to the account. There is thus an advantage of *compound interest*, which includes interest on interest. The future value F in k years from now of a principal P is

$$F = P(1+i)^k$$

We may apply this to both positive and negative cash flows, and even a whole cash flow stream. In the case of a positive cash flow we gain interest from reinvesting the cash in the project account at an interest rate i, and in the case of a negative cash flow we assume we loose interest from a foregone opportunity to invest at the interest rate i.

Figure 6 shows what happens to the balance of the project account when considering interest. Due to interest on the first negative cash flow the payback period is prolonged somewhat, but this is hardly visible in the diagram. On the other hand all positive cash flows increase by the achieved interest, and the final value with interest at year ten is clearly larger than the simple final value.

The diagram in Figure 6 is the balance of the project account -- with or without interest -- as time progresses. For example, assume that five years have passed, then the bar at year five shows the balance at the end of the year considering all cash flows from the previous years.

The reinvestment interest is the interest we obtain in the project account. The simple version -- without interest -- corresponds to just spending the yearly savings.

The favourable result of increased surplus is specific for this case. Generally it depends on the amount of negative cash flows and their timing relative to the positive cash flows. The result also depends on the magnitude of the interest rate i. In our case i = 0.04 (four percent).

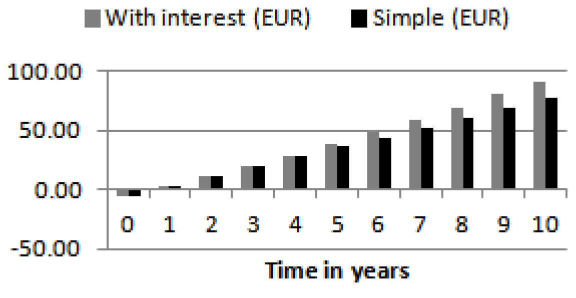

Fig. 6. Cumulative cash flow streams. For comparison the diagram shows the cumulative cash flow from the previous figure (simple), and the same with a 4% interest when reinvesting the savings (with interest).

Conclusions

It is safe to conclude that it pays in the long run to switch from an incandescent lamp (40 W) to a CFL (11 W). The extra cost is paid back already after a year, and from then on surplus builds up during the longer lifetime of the CFL.

There are other decision criteria to consider, for example the colour of the emitted light, the delay when the CFL is switched on, and the content of mercury. Economy is not all.

Our central conclusion is that the cumulative cash flow diagram is very informative, since it shows four pieces of information in a single diagram:

1. The initial investment,
2. the payback period,
3. the lifetime, and
4. the surplus (final value).

For an investor such a diagram is a valuable decision support, because it gives an overview instantly of expenditures and earnings. One could wish it was mandatory to include in all sales material.

For any engineering project a diagram could be made on the basis of the numbers available at the selling time (a pre-calculation), and as time passes another one could show how it actually went (a post-calculation). As a result of the Samso project, we have several cases of such before-and-after data and cumulative cash flow diagrams.

The current analysis concerns actual euros only. It can be made more realistic by including inflation and the preference to receive money earlier than later. The next chapter considers their effect.

Data

Table 1. Assumptions regarding lamp types (Go Energi).

Feature	Incandescent	CFL
Lifetime (h)	1 000	10 000
Price (EUR)	1.60	7.33
Price (DKK)	12.00	55.00
Usage (h/year)	1 000	1 000
Wattage (W)	40	11
Marginal electricity price (EUR/kWh)	0.23	0.23
Marginal electricity price (DKK/kWh)	1.75	1.75

Table 2: Cash flow streams.

Year	0	1	2	3	4	5	6	7	8	9	10
Incandescent (EUR) (A)	-1.60	-10.93	-10.93	-10.93	-10.93	-10.93	-10.93	-10.93	-10.93	-10.93	-10.93
CFL (EUR) (B)	-7.33	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57	-2.57
Incremental cash flows (EUR) (B-A)	-5.73	8.37	8.37	8.37	8.37	8.37	8.37	8.37	8.37	8.37	8.37
Incremental cash flows with 4% interest (EUR)	-5.73	2.40	10.87	19.67	28.82	38.34	48.24	58.54	69.25	80.38	91.96
Simple cumulative cash flows (EUR)	-5.73	2.63	11.00	19.37	27.73	36.10	44.47	52.83	61.20	69.57	77.93

External Links

1. Wikipedia Cash flow
2. Wikipedia Compact fluorescent lamp
3. Wikipedia Incandescent light bulb
4. Wikipedia Internal rate of return
5. Wikipedia Payback period

Created by jj. Last Modification: Tuesday 25 March 2014 19:32:54 CET by jj.

Present Worth

Created by jj. Last Modification: Saturday 26 March 2011 00:20:13 CET by jj.

Inflation

Inflation erodes the purchasing power of money; a euro today does not buy as much bread and butter as a euro did ten years ago. We may wish to account for inflation in order to make investment models more accurate.

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Inflation Rate

Inflation is due to the general increase in prices with time. It is desribed by an *inflation rate f*. Prices one year from now will on average be today's prices multipied by a factor $(1 + f)$. Inflation compounds the same way as interest does, and after k years of inflation at rate f, prices will be $(1 + f)^k$ times their value today.

In other words, the value of money decreases. If the inflation rate is f, then the value of one euro next year is only $1/(1 + f)$, and after k years it is $1/(1 + f)^k$, assuming the inflation rate is constant.

In Denmark the national bureau of statistics (Statistics Denmark) is responsible for measuring the price index and calculating the inflation rate (Fig. 1). They participate in a European collaboration to create socalled Harmonised Indices of Consumer Prices (HICP), which are published on the Eurostat homepage. In November 2011 the overall HICP inflation rate for the EU is 3.4% (Denmark 2.5%).

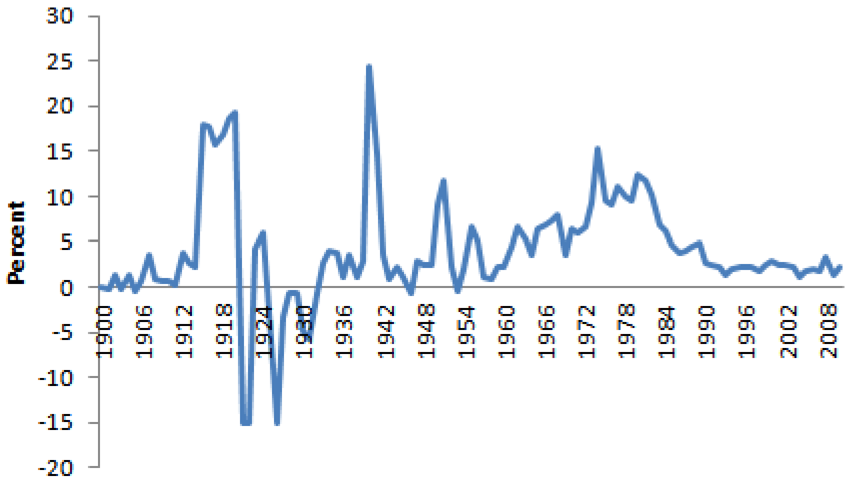

Fig. 1. Inflation in Denmark from the year 1900 to 2010 (Danmarks Statistik, Statistikbanken).

Real Euros

Each cash flow at year *k* in a cash flow stream must be multiplied by $1/(1 + f)^k$ in order to account for inflation. After multiplication, the amounts we look at are no longer the actual euros we really use in transactions, but they are 'equivalent euros' according to purchasing power. If the starting point for the inflation series is today, the amounts are in *real euros*. That is, they are in *today's euros* corresponding to today's general price level, as opposed to *actual euros* (current prices).

This point is a turning point. As long as cash flows concern actual inflows and actual outflows, including interest, then the monetary unit is actual euros. But as soon as we include inflation -- and other concepts related to value -- then the monetary unit becomes hypothetical. It is no longer its face value, but its *present worth* to the owner.

Real Interest Rate

The *real interest rate* is then the nominal interest rate *i* adjusted by the inflation rate *f*. Money in the bank increases nominally by the factor $(1 + i)$, but its purchasing power is deflated by $1/(1 + f)$. Therefore, due to the inflation rate *f*, the real interest rate i_0 is determined by

(1) $$1 + i_0 = (1 + i)/(1 + f),$$

or

(2) $$i_0 = (1 + i)/(1 + f) - 1$$

For small inflation rates *f* the real interest rate i_0 is approximately equal to $(i - f)$ (Luenberger 1998).

In other words, if we wish to account for inflation, we choose the real interest rate instead of the nominal interest rate *i*. That is, we use i_0 as a substitute for *i*.

Usually the interest rate in a bank is higher than the inflation rate, so that there is an incentive to make a deposit. In other words, the real interest rate is usually positive ($i_0 > 0$).

External Links

1. Eurostat: Inflation dashboard
2. Wikipedia Inflation

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Time Value of Money

Because we can earn interest on money received, there is a *time value of money* associated with cash flows. As a basic principle (Park 2009):

- A nearby euro is worth more than a distant euro.

The value of a cash flow stream not only depends on the magnitude of the inflows and outflows, but also on the timing of the cash flows relative to each other.

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Future Value

A deposit of P euros in a bank account at an interest rate i generates interest of the principal as well as the accumulated interest that has been added to the account as follows.

- At the end of the first year the balance is $P + iP = P(1+i)$.
- At the end of the second year the balance is $P(1+i)+iP(1+i) = P(1+i)(1+i)$.
- ...
- At the end of the tenth year the balance is $P(1+i)...(1+i)$ (ten times).

Therefore, due to *compound interest*, the future value F of a principal P is

(1) $F = P(1+i)^k$

If we wish to find the value after ten years, we insert $k = 10$. The equation applies to an ideal bank account, that accrues interest year by year at no administration costs.

Each cash flow in a cash flow stream thus has a future value. Assume we take each cash flow and deposit it in an ideal bank as it arrives (every year). If the cash flow is negative we cover it by taking out a loan. The final balance in the account is a combination of the individual cash flows.

Consider the cash flow stream (x_0, x_1, ..., x_K). After the Kth year the initial cash flow x_0 will have grown to $x_0(1+i)^K$. The next cash flow, x_1, received after the first year, will at the end of the final year have been in the account for only K - 1 years, and hence it will have a value of $x_1(1+i)^{K-1}$. And so on. The final cash flow x_K will not collect any interest.

In summary, the future value of the cash flow stream is (Luenberger 1998)

(2) $F = x_0(1+i)^K + x_1(1+i)^{K-1} + ... + x_{K-1}(1+i) + x_K$

All cash flows are included, both positive and negative, which explains why it is called the *net future value* (NFV) of the cash flow stream.

Example (net future value) Consider the cash flow stream (-10, 9, 1, 1) when the interest rate is 5%. If you just add the values, the final value is 1 (= -10 + 9 + 1 + 1). If you include the interest rate, the net future value is

$NFV = -10 * (1.05)^3 + 9 * (1.05)^2 + 1 * (1.05) + 1 = 0.396$

Present Value

Cash flows are worth less and less the longer we look toward the time horizon, because we can earn interest in the meantime.

Example (present value) Imagine you have to choose between two alternatives:

1. You will receive 104 EUR in one year, or
2. you receive 100 EUR now and deposit it in the bank for one year at 4% interest rate.

Clearly the result is the same after one year; you will receive 104 EUR. Therefore, receiving 104 EUR in one year has the same value as receiving 100 EUR now when the interest rate is 4%. We say that the 104 EUR to be received in one year from now has a present value of 100 EUR.

The present value of a future cash flow is less than the face value of the cash flow. The previous formulas can be reversed in time in order to calculate the present value of a future cash flow.

The *present value* of a future amount F, when the interest rate is i, is given by Equation (1) also, but we have to invert it to find P:

(3) $P = F/(1+i)^k$

The *present value of a cash flow stream* is a combination of the cash flows. Given a cash flow stream (x_0, x_1, ..., x_K) and interest rate i per period, the present value of the stream is (Luenberger 1998)

(4) $P = x_0 + x_1/(1+i) + x_2/(1+i)^2 + ... + x_K/(1+i)^K$

All cash flows are included, both positive and negative, and therefore it is called the *net present value* (NPV) of the cash flow stream. Net present value is the present value of the benefits minus the present value of the costs. It is a single number, and it must be positive for an investment to be considered worthy; the more positive the better.

Example (net present value) Take the same cash flow stream (-10, 9, 1, 1) as in the previous example. The net present value is

$$NPV = -10 + 9/(1.05) + 1/(1.05)^2 + 1/(1.05)^3 = 0.342$$

However, if we take the cash flow stream (-10, 1, 9, 1), where the second and the third element have swapped places, then

$$NPV = -10 + 1/(1.05) + 9/(1.05)^2 + 1/(1.05)^3 = -0.021$$

Although the direct sums of the two cash flow streams (their simple future values) are equal, the net present values are unequal. Furthermore, the latter NPV is even negative, which indicates a loss.

The example shows that the timing of the cash flows plays a role. We would prefer that the large inflows arrive as early in the stream, if at all possible.

Two cash flow streams are equivalent if their net present values are equal -- for a given interest rate. And vice versa: If two cash flows have the same net present value, they are equivalent -- for a given interest rate. The net present value is a single number, which is both necessary and sufficient to characterise a cash flow stream. Therefore the cash flow stream may be transformed, by a bank for instance, in a variety of ways as long as the net present value remains the same. A customer can thus use the bank to tailor the stream to another, more desirable shape.

Relationship Between NPV and NFV

Equation (2) above defines the future value F of a cash flow stream. Likewise Equation (4) defines the present value P of a cash flow stream. Now take for instance the equation for F (Equation 2) and divide both sides by $(1+i)^k$. The resulting right hand side is the same as the right hand side defining P. If we substitute NPV for P and NFV for F, just to emphasise there are both negative and positive cash flows, we can find one from the other by the following relationships,

(5) $$NFV = NPV(1+i)^k$$

and

(6) $$NPV = NFV/(1+i)^k$$

That is, we are assured that the previous Equations (1) and (3) also apply to whole cash flow streams. We thus interpret the NPV (NFV) as an equivalent cash flow stream consisting of just one cash flow.

External Links

1. Wikipedia Time value of money

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Internal Rate of Return

The internal rate of return of a cash flow is the interest rate implied by a cash flow stream. It is the yield of the investment when considering both positive and negative cash flows.

If the investment is to be financed through a bank loan, then the bank loan's rate of interest must be less than the internal rate of return in order for the investment to be acceptable.

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IRR

The *internal rate of return* (IRR) of a cash flow is equivalent to the interest rate of a bank account with an overdraft facility (cash credit). Assume that cash inflows are deposited and cash outflows withdrawn from the bank account. Then the internal rate of return is the interest rate that would just pay the cost of having the account.

Example (bank loan) Take the cash flow stream (-10, 1, 1, 11) related to a bank account. It corresponds to taking out a loan of a principal of 10 euros, followed by payments of 10% interest for three years of 1 euro. The principal is paid back after the end of the third year (1 + 10 = 11).

The balance of the account at the end of the period, the net future value, is formally

$NFV = -10 * (1 + i)^3 + 1 * (1 + i)^2 + 1 * (1 + i) + 11$

$= -10 * (1 + 0.1)^3 + 1 * (1 + 0.1)^2 + 1 * (1 + 0.1) + 11$

$= 0$

The interest rate i = 0.1 results in NFV = 0, because the loan is exactly repaid at the end of the period, and the account is empty.

The IRR of a cash flow stream is that interest rate of a bank account, which would result in a final balance (net future value) of zero. Equivalently, it results in a net present value of zero, since it is proportional to the net future value.

Stated more precisely: Given the cash flow stream (x_0, x_1, ..., x_K), then the internal rate of return is a number i = IRR that satisfies the equation NPV = 0, that is

$$0 = x_0 + x_1/(1+i) + x_2/(1+i)^2 + ... + x_K/(1+i)^K$$

The consequence of this definition is that we have to solve a Kth order polynomial equation in order to find IRR. It is in general difficult to find the solution, but it is possible with a computer program (for instance the Excel function IRR). Another problem is that the equation may have more than one solution. Many cash flows have, however, an initial negative outflow followed by positive inflows. In that case the IRR is well-defined.

Notice that the IRR is determined entirely by the cash flows of the stream. There is no reference to the external market rates, which is why it is called *internal* rate of return.

The higher IRR, the more acceptable the investment. If the IRR is higher than the prevailing market rate of interest, the investment is considered better than what is available externally in the financial market.

If a project is to be financed by a loan, then the loan's interest rate must be lower than the IRR in order for the project to be economically acceptable.

The lower bound for the IRR is the minimum rate of return that will be attractive to the investor, known as the *minimum attractive rate of return* (MARR). In some situations the MARR is the available interest rate in the external market, for instance the rate that can be achieved by investing in secure bonds.

External Links

1. Wikipedia Internal rate of return

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Discounting

Appraisal of Renewable Energy Projects with Cases from Samso > Present Worth > Discounting

It is somewhat easier to understand and valuate an investement's cash flow, if all amounts are in today's euros. The present worth of a future cash flow is its value in today's euros. For a cash flow stream all cash flows must be transformed into present worth using some interest rate, the discount rate.

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Discount Rate

Discounting is the process of evaluating future cash flows as an equivalent present worth. The present worth of a future cash flow is usually less than the face value.

The factor by which the future cash flow must be discounted is the *discount factor*. The one-year discount factor is $d_1 = 1/(1 + r)$, where r is the one-year *discount rate*. If an amount A is to be received in one year, its present worth is the discounted amount d_1A ($d_1 < 1$).

For public projects, the UK government recommends a specific real discount rate of 3.5% (Treasury 2003), while the Danish Energy Agency requires a real discount rate of 5% in project analyses.

Obviously, the discount rate is not just a market interest rate, but it must accomodate inflation and risk. The lower bound for the discount rate is the minimum rate of return that will be attractive to the investor, known as the *minimum attractive rate of return* (MARR). This is for instance the rate that can be achieved by investing in secure bonds. The discount rate is therefore

r = MARR + risk premium

The Danish discount rate for public projects is based on a 4% real MARR plus a 1% risk premium (Energistyrelsen 2011).

Discounted Cash Flow

For a cash flow stream we define a discount factor d_k for each time point k. The future cash flows must be multiplied by these factors to obtain the present worth.

For a given cash flow stream (x_0, x_1, ..., x_K) and discount rate r per period, the discount factor is $d_k = 1/(1 + r)^k$. The discounted cash flow stream (DCF) is (Luenberger 1998)

$$\text{DCF} = (x_0, d_1x_1, d_2x_2, ..., d_Kx_K)$$

Each discount factor d_k is a weight that transforms its cash flow x_k into its present worth. It is a separate concept from inflation, and it is based on the principle that a nearby euro is worth more than a distant euro, *time preference*.

Example (discount factors) Consider a discount rate of 1% corresponding to $r = 0.01$. The corresponding discount factor for year 1 is

$$d_1 = 1/(1 + r) = 1/(1 + 0.01) = 0.99$$

To compare, the ten times larger discount rate of $r = 0.1$ results in

$$d_1 = 1/(1 + r) = 1/(1 + 0.1) = 0.91$$

The difference is noticeable. Continuing for ten years, the results are gathered in the table below and also plotted in Figure 1.

	Year 0	1	2	3	4	5	6	7	8	9	10
$r = 0.01$	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.93	0.92	0.91	0.91
$r = 0.10$	1.00	0.91	0.83	0.75	0.68	0.62	0.56	0.51	0.47	0.42	0.39

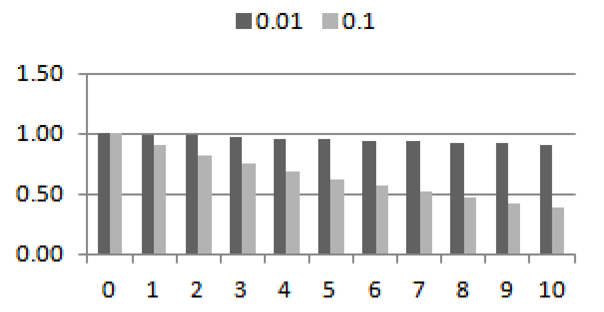

Fig. 1. Discount factors. Factors using the high rate (0.10) drop off much faster than those using the low rate (0.01).

The magnitude of the discount factors d_k over a period of time ($k = 1, 2, ..., K$) decreases exponentially. The discount rate controls the decay of the exponential curve. A large discount rate suppresses distant cash flows more than a small discount rate.

We can therefore adjust the curve to suit our personal time preference.

The 72 rule

The 72 rule is a method to calculate, mentally, the halving (doubling) time of an exponential function. In order to quickly estimate the number of periods $k_{0.5}$ required to halve the initial amount, divide the number 72 by the discounting rate in percent. That is,

$$k_{0.5} = 72/(r * 100)$$

For $r = 0.10$, $k_{0.5} = 72/10 = 7.2$. Comparing with Figure 1 ($r = 0.10$), it does seem that at year 7 the discount factor is close to half; it is actually 0.51 according to the table. The event happens after the end of year 7, and due to the discrete nature of the cash flows, it appears at the end of year 8.

We can invert the calculation in order to guess at a discount rate. Let us say that our desired halving time is $k_{0.5}$ = 5 years, then

$$r = 72/(k_{0.5} * 100) = 72/500 = 0.144$$

That is, a discount rate of approximately 14.4% will model our time preference.

A discount rate of 3.5%, as in the UK (Treasury 2003), corresponds to a halving time of 21 years. A discount rate of 5%, as in Denmark (ref), corresponds to a halving time of 14 years.

External Links

1. Wikipedia Discounted cash flow
2. Wikipedia Minimum acceptable rate of return
3. Wikipedia Rule of 72

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Example: LED lamp

Appraisal of Renewable Energy Projects with Cases from Samso > Present Worth > Example: LED lamp

The light emitting diode (LED) lamps are better now, and for households the LED lamp is an alternative to the compact fluorescent lamp (CFL). They are both energy class A lamps.

LED lamps are more expensive, but they last longer, and they consume less electricity. A cash flow analysis shows it is economically worthwhile to replace a CFL by an LED lamp. The payback period is 15 years under certain assumptions. A simple analysis, that disregards interest and inflation, indicates a saving of 6.33 EUR after 25 years. A more elaborate analysis includes interest rate, inflation rate, and discount rate, resulting in higher savings.

Fig. 1. Light emitting diode (LED) lamp (Philips MyVision 9W, equivalent to 40 watts, picture by Philips).

Contents

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Introduction

The compact fluorescent lamp (CFL) is an energy saving lamp of energy class A. So is the light emitting diode (LED) lamp, but it has some advantages over the CFL: It switches on immediately, and it does not contain mercury. Furthermore, it lasts longer, and it is a little cheaper to use. Some models also have some disadvantages, however: The colour of the light can be rather blue and unpleasant, and sometimes the light flickers.

The following looks at the economy of replacing one CFL with one LED lamp. Or more specifically, the difference between the cash flows of an LED lamp and a CFL. The goal is to obtain a diagram of the investment account, a project balance, in order to appraise such an investment.

We choose an LED lamp equivalent to a 40 watt incandescent lamp. It is the same size as the lamps in the previous example concerning the incandescent lamp and the CFL (Introductory Example: Energy Saving Lamp).

The LED lamp consumes 9 watts (Fig. 1), where the CFL consumes 11 watts. That is not much difference in absolute numbers, but if electricity is expensive, then maybe there is money to be saved after all. The LED lamp is more expensive than the CFL, but it lasts longer than the CFL. Table 1 below contains the specific data, and also below there is a link to a datasheet for the LED lamp.

Time Horizon

We assume the CFL lasts 10 years, before it breaks, but the LED lasts 25 years, so we choose a time horizon of 25 years. We assume also that the CFL is five years old at the beginning of the project period. Therefore it must be replaced after year 5 and again after year 15. After year 25 both lamps are scrapped with a scrap value of zero.

A time horizon of 25 years is rather long, especially for a household, and we must consider discounting.

Internal Rate of Return

We view the LED as an alternative, which hopefully saves money in the long run, and we shall apply the earlier quoted principle that only differences count. We therefore take the CFL as our reference and the LED as our investment scenario.

Consequently we form the two cash flow streams and subtract the reference stream from the CFL cash low stream. The resulting cash flow stream is the incremental stream (for assumptions and data see %SEAFigLEDpdf%). The resulting incremental cash flow stream shows that the internal rate of return (IRR) for the 25 year project period is 2.6%.

Earning a 2.6% interest (tax free) over 25 years is comparable to investing in secure bonds (after 50% tax).

Payback Period and Surplus

Based on the incremental cash flow stream (not shown), Figure 2 shows the simple project balance (cumulative cash flows diagram). It is *simple* because it omits interest and inflation. The diagram shows that the payback period is 15 years.

The balance of the account steadily increases after the payback period. Finally, after 25 years, the surplus is 6.33 EUR (the initial investment was 20 EUR).

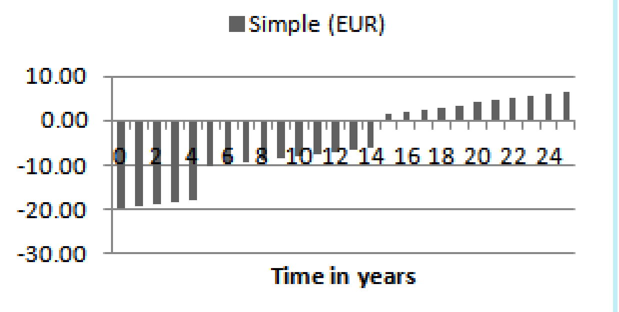

Fig. 2. Simple project balance. The abrupt changes after year 5 and year 15 are due to the shorter lifetime of the CFL.

Project Balance with Interest

The previous analysis is a first approximation to the evolution of the project account. A more advanced — and possibly more accurate — model includes interest, inflation and time preference. For this we need:

- An estimate of the interest rate related to the project account,
- an estimate of the inflation rate, and
- an estimate of the discount rate affecting the present worth of the 25 years of cash flows.

These estimates are more or less subjective, and therefore the result will be uncertain corresponding to the uncertainty in the estimates. The result will be closer to reality, however. Using for instance real interest instead of actual interest will account for a loss of purchasing power in the future.

- *Interest rate*. Since we are looking at household lighting with LED lamps, we assume a household economy, that is, payments and receipts are related to a bank account. At the moment a typical rate is 0.13% per year for a standard savings account in the bank (in Denmark).
- *Inflation rate*. The current inflation rate is 2.5% (in Denmark), and it has been around that level for the last 15 years (Inflation), so we assume it stays on that level.
- *Discount rate*. In public projects the Danish government requires a fixed discount rate at 5% per year. But this is a private project, so we have freedom to choose it equal to the real interest rate, or higher.

As a result, the investment balance undergoes some changes, and Figure 3 is the result. The initial value is the same as previously, but the remainder is clearly affected. The payback period is still 15 years, but the surplus is now 14.69 EUR (was 6.33 EUR).

With a 2.5% inflation rate, and an interest rate of 0.13%, the real interest rate is actually negative (-2.31%). The surplus is thus higher than it was in the simple model, despite discounting. With a negative discount rate, a nearby euro is worth *less* than a distant euro.

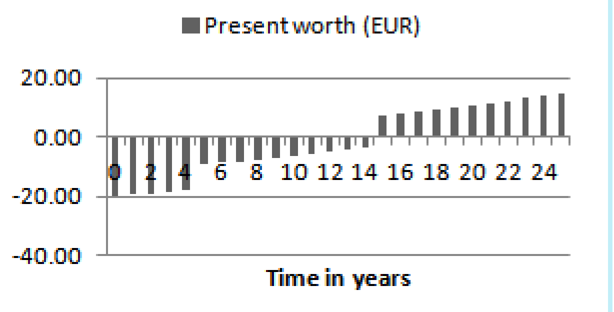

Fig. 3. Project balance with interest. This is the previous balance transformed into present worth. The discount rate is chosen equal to the real interest rate.

Sensitivity

In order to test the vulnerability of the result we change the discount rate.

With a discount rate of 5%, used in Danish public projects, the distant values become more suppressed and the surplus smaller, see Figure 4. The situation corresponds to a risk premium of 7.31% which again corresponds to a halving time of almost 10 years (the 72 rule under Discounting); the interpretation is that 1 euro today has the same preference as 2 euros in almost ten years time. This could be realistic for a house owner, because Danish families that live in a detached house move every 9 years on average, while people in row-houses, apartments and student dorms move more often (Danmarks Statistik 2003). The investment may be lost altogether if the family moves to another home, but of course, the time preference is individual.

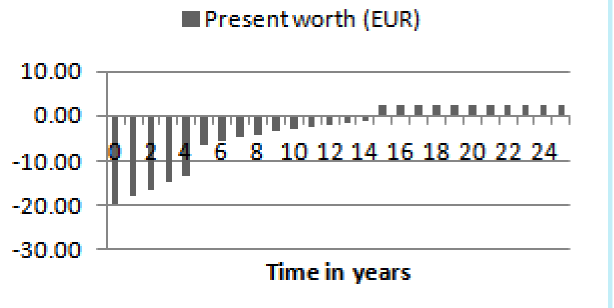

Fig. 4. Sensitivity. Project balance with heavy discounting (discount rate 5%).

If the discount rate were equal to the internal rate of return, then the surplus would be zero. This corresponds to a market interest rate of 5.17% (keeping the inflation rate fixed). That means the market rate has a margin from 0.13% to 5.17% where the net present worth of the project stays positive. The 5.17% is a socalled *switching value* beyond which the net present worth change from a surplus to a deficit.

Data

Table 1: Assumptions regarding lamp types (Go Energi, Philips).

	CFL	LED
Lifetime (h)	10 000	25 000
Price (EUR)	7.33	20.00
Price (DKK)	55.00	150.00
Usage (h/year)	1 000	1 000
Wattage (W)	11	9

Marginal electricity price (EUR/kWh)	0.23	0.23
Marginal electricity price (DKK/kWh)	1.75	1.75

External Links

1. %GoEnergiApaere%
2. %PhilipsMyVisionLED9W%
3. %SEAFigLEDpdf%
4. %WikipediaCompactFluorescent%
5. %WikipediaLEDlamp%

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Cases

Appraisal of Renewable Energy Projects with Cases from Samso > Cases

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District Heating Plant, Ballen-Brundby

The district heating plant between the villages Ballen and Brundby runs on shredded straw. It supplies heating to the two villages by means of hot water running through seven kilometers of highly insulated pipes. The consumers own the plant through a cooperative. It is the only heating plant on the island owned entirely by the consumers.

Straw bales on the conveyor belt that feeds the shredder.

History

1998

The original plan was to build a district heating system for four villages: Ballen, Brundby, Ørby and Permelille. At a meeting with the citizens of this area in Brundby, a work group of local people was defined. The meeting particularly aimed to define this group of people representing the four villages.

1999-2002

The group asked the energy company NRGi to establish a district heating plant for the four villages. Calculations soon showed that the economy was not sound. The villages Ørby and Permelille were too far away, causing large heat losses in the distribution system. Furthermore, the number of potential district heat consumers was relatively small in these two villages. The group accepted this verdict, and the group was reduced to citizens from Ballen and Brundby. NRGi proposed several plans for the area of Brundby and Ballen, but the potential heat consumers rejected all. In October 2002 NRGi gave up looking for an acceptable economic model for the project, and they withdrew from the planning.

2003

Visualization used during the project stages before official approval.

The remaining members of the group and the Samsø Energy Company decided to try one more time. First all potential district heat consumers were asked to say whether or not they were interested in joining the district heating system. The consumers were promised heat prices similar to those in Onsbjerg, the cheapest on the island. The group then decided to work for a cooperative model, whith the consumers owning a straw fired plant. The workgroup held 11 meetings and 2 public metings. They distributed a folder to the villages. Finally they conducted a general assembly meeting which elected six board members from the villages. The six were later supplemented by a seventh board member from the municipality, and the municipality must approve the energy price asked from the consumers.

2004
: Plant construction and commissioning.

2005
: In operation.

Specifications

Energy	
Power rating	1.6 MW
Heat generator	1.6 MW straw boiler (LIN-KA)
Auxiliary generator for reserve and peak load	2.0 MW oil burner
Fuel	Straw: 1 500 tons/year, one big-bale weighs 600 kg. Oil: 4 700 liters/year
Storage coverage	Straw: 750 tons. Oil: 1.5 days at peak load
Potential heat demand	5 500 MWH/year
Current heat demand (2009)	4 900 MWH/year
Design capacity	80% of the potential heat demand
Current consumer load (2009)	89% of the potential heat demand
Initial consumer load (2005)	57% of the potential heat demand
Environment	
Heat transmission net	7 km of twin pipes (STAR PIPE)
Buildings	one for straw storage + one for the boiler room
CO2 savings (2009)	1 600 tons/year (expected 1 100 tons/year)
Economy	
Start-up year	2005
Ownership	The consumers, through a cooperative with limited liability (amba)
Consumers connected initially (2005)	187
Consumers connected (2009)	258 (161 houses + 82 summer houses + 7 large consumers + 8 properties without buildings)
Consumer's annual subscription fee (2010)	4 050 DKK/year (540 EUR/year), VAT (25% tax) included
Consumer's heat price (2010)	735 DKK/MWH (98 EUR/MWH), VAT (25% tax) included
Price of straw to farmer (2013)	0.69 DKK/kg (0.092 EUR/kg) +/- 10% depending on humidity
Plot and buildings	1.8 million DKK (240 thousand EUR)
Boiler system	2.69 million DKK (359 thousand EUR)
Distribution net + house installations	11.2 million DKK (1 490 thousand EUR)
Consultants + other costs	0.485 million DKK (65 thousand EUR)
Total construction costs (2005)	16.2 mill DKK (2.2 mill EUR)
Subsidies (2005)	2.5 mill DKK (0.33 mill EUR)
Consumer's price of a new connection (2009)	45 000 DKK (6 000 EUR)

External Links

- Location on a satellite map
- Ballen-Brundby Fjernvarme amba, http://bbf-veo.dk/
- The energy company NRGi, http://www.nrgi.dk
- Pre-insulated pipe systems by STAR PIPE now acquired by Logstor home page

Combustion of biomass by LIN-KA ENERGY, http://www.linka.dk/content/us

- The Danish Energy Regulatory Authority (Energitilsynet), pricing statistics
- Groth T 2009 Socioeconomic Evaluation Of The Ballen-Brundby District Heating Plant. MSc thesis, Aarhus University, School Of Business. PDF 1 MB

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District Heating Plant, Nordby-Maarup

The Nordby-Maarup plant supplies district heating to the villages of Nordby and Maarup. The plant burns wood chips, and it has an array of solar panels as a supplementary source of heat. In fact, during the summer-period the solar array supplies all energy in extended periods of time. The energy company NRGi owns and operates the plant. According to the original master plan, this plant was to be the last to be built. But a local group of citizens managed to accelerate the project and finish it five years before the final deadline.

The Nordby-Maarup plant. Solar array in the foreground. Accumulation tank (round) and boiler house (with chimney) in the background.

History

1998

After a citizens meeting, a local work group asks the energy company NRGi to design a district heating plant. Meanwhile the work group walks from door to door to talk to the potential consumers, and the group is highly active in all respects.

1999

NRGi submits the first project proposal end of November 1999.

2000

After negotiations — with the national authority (the Danish Energy Agency, da: Energistyrelsen), the municipality, and the Samso Energy Company — the energy company NRGi submits its second revised proposal in October 2000.

2001

The municipality pre-approves the proposal, then the Danish Energy Agency approves. The municipality gives its final approvement on the following conditions: that all municipal buildings connect to the distribution net, that at least 70% of all houses with own central heating agree to connect, that all new buildings are obliged to connect, and that the owner tries to utilize local energy crops such as elephant grass. Start-up of wood chip boiler in November.

2002

Start-up of solar array in April.

Specifications

Energy	
Power rating	1.4 MW
Heat generators	0.9 MW wood chip boiler with flue gas heat exchanger (Weiss) + 2.2 MW solar collector array (ARCON)
Auxiliary generator for reserve and peak load	1.4 MW oil burner, delivers about 4% of the energy
Hot water accumulation tank	800 cubic meters
Fuel	3 200 MWH/year wood chip + 96 MWH/year oil at design capacity.
Storage	Wood chip: 7 days of peak load. Oil: 14 days of peak load.
Design capacity	90% of the potential heat consumption
Potential heat consumption	3.7 MWH/year
Initial consumer connections	72% of the potential heat consumption
Production by solar array	1 090 MWH/year or 430 KWH/sq m,
Solar array coverage	21% of the energy (May 2002 - Apr 2003)
Environment	
Buildings	- One boiler room with 130 cubic meters of chip storage, - one accumulation tank, diameter 8.5 m and 300 mm insulation, - 2 500 square meters of solar panels, and - a 25 000 liter oil tank underground
Solar array	20 rows of 10 panels at 12.5 sq meters, bearing 167 degrees, inclination 40 degrees. Max power rating: 2 200 kW.
Fuel savings	1 000 MWH/year compared to individual oil boilers
Fuel source	Primarily from the woods of Brattingsborg at Samso
Economy	
Owner	NRGi
Construction costs	20.4 mill DKK (2.7 mill EUR)
Subsidies	9 mill DKK (1.2 mill EUR) from the Danish Energy Agency
Construction cost of solar array	4.7 mill DKK (0.63 mill EUR)
Calculated consumer price of solar energy	0.29 DKK/KWH or 0.15 DKK/KWH with subsidies
Consumers connected	180 households corresponding to 80%
Consumer's annual fee (2010)	2817 DKK/year (376 EUR/year), VAT tax (25%) included
Consumer's heat price (2010)	755 DKK/MWH (101 EUR/MWH), VAT tax (25%) included
Consumer's connection fee	25 000 DKK + 1 200 DKK/m piping (3 330 EUR + 160 EUR/m)

External Links

- See the Nordby-Maarup plant on a map
- Nordby-Maarup District Heating Plant, http://www.nordby-maarup.dk
- Automation and high voltage switchboards by NB Automatic, http://www.nb-automatic.dk
- TRNSYS, a program used for the design, http://sel.me.wisc.edu/trnsys
- Weiss combustion systems, http://www.weiss-as.dk/side5399.html
- The Danish Energy Agency, http://www.ens.dk/en-us
- The energy company NRGi, http://www.nrgi.dk
- Jensen SØ and Tambjerg LH 2004 *Nordby Mårup Varmeværk — Evaluering af målinger* (Nordby Maarup Heating Plant —

Assessment of Measurements). Teknologisk Institut (Solenergicentret) and Planenergi, http://www.buildvision.dk/pdf/nordby_maarup_varmevaerk.pdf

- The Danish Energy Regulatory Authority (Energitilsynet), pricing statistics

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Biogas Plant, Samso South (proposal)

Samso has a relatively large amount of biomass. Biogas is CO2 neutral and therefore renewable energy. There was a biogas plant (*Samsofarmen*), but it is no longer in operation. In 2002 a consulting company performed a feasibility study (Planenergi 2001). It proposed several communal plants, wikth the largest covering the southern part of the island. The report named the proposed plant *Samso South*. It has not been built, but there is now renewed interest on the island, and the government has announced a scheme for subsidies for the period 2010 - 2012 (*Green Growth*).

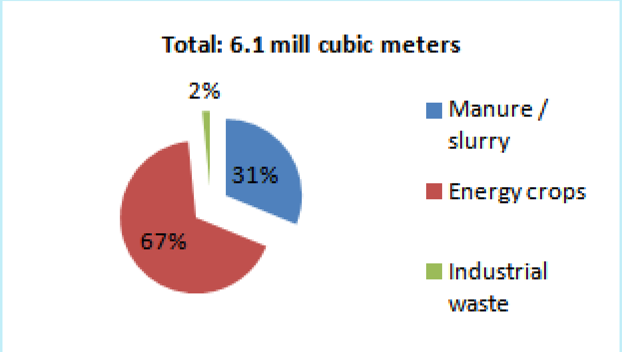

Fig. 1. Biogas potential (Planenergi 2002).

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Biogas Potential

A *communal* (central) biogas plant converts animal manure from several farms and other organic material, including municipal organic waste, into energy. Denmark has about 20 communal biogas plants.

Samso has only a small amount of organic industrial waste (Fig. 1). On the other hand the island has a relatively large potential from energy crops in fallow fields and potato tops. Grass, among others, is well suited for a biogas plant.

The largest possible biogas production corresponds to 30% of the energy demand of the entire island (500 TJ per year). The calculation assumes that a central biogas plant produces 35% electric energy, and 50% heat energy; the remainder is for the plant's own consumption and losses.

With the 2008 energy agreement in parliament, the selling price of electricity is now 0.10 EUR (0.745 DKK) per KWH. It is an improvement from the previous 0.08 EUR (0.60 DKK) or lower, and thus a new incentive has arrived. As a consequence of that, the national biogas production is expected to triple by the year 2020. In the period 2010 - 2012 the government intends to subsidise the construction of new biogas plants (Biogasbranchen).

The Samso municipality has already included biogas in its municipal waste plan. It is a facility that extracts gas from the municipal landfill.

Benefits

A biogas plant offers advantages for waste management, and the biogas plant produces liquid fertilizer and fibre for compost. It has a number of benefits:

- Lower emissions of greenhouse gases,
- milder odour than slurry when fertilizing the fields,
- cost savings in slurry transportation and fertilizer purchase,
- better use of the fertilizer in a mix of cow and pig manure,
- fewer nutrients are washed out,
- weeds and pathogens are killed,
- waste is recycled in accordance with the national waste plan,
- there is a tax on waste if incinerated but not if recycled,
- organic waste in landfill is avoided,
- heat can be fed into the district heating network, and
- it contributes to the renewable energy island status.

Even though biogas is renewable energy, it does not necessarily reduce CO2. If for example the biogas is used for heating in the Ballen-Brundby area, the existing district heating plant is already renewable (straw fired), and there will be no CO2 replacement. But the electric production from the biogas plant feeds into the grid and substitutes coal in a coal fired power plant on the mainland; that will contribute to the island's CO2 reduction.

If an animal farmer delivers to a central biogas plant, he might save a slurry tank on his own farm; the biogas company offers the storage and maintenance. A study in Lintrup showed overall cost savings for the farmer at 0.67 EUR (5 DKK) per delivered cubic meter of slurry (Hjort-Gregersen 1999).

The *Samso Energy and Environmental Office* participated in an EU project Biores with five other islands. The objective was to overcome non-technical barriers that hinder investments in energy production from biogas derived from waste (Biores).

Base Model, M0

A study of centralised biogas plants in Denmark established several economic models of biogas plants (Nielsen, Hjort-Gregersen, Thygesen and Christensen 2002). The authors set up three standard sizes of plant. The smallest has a daily treatment capacity of 300 cubicmetres of biomass. We use that as a reference (M0) since it is closest to the proposed plant size.

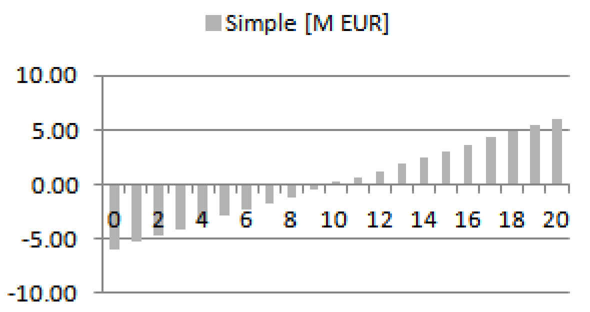

Fig. 2. Basemodel M0. Synthetic plant with a daily treatment capacity of 300 cbm biomass per day (Nielsen et al 2002).

External Links

- Brancheforeningen for biogas (home page)
- Lemvig Biogasanlæg amba (home page)
- Samso Energy and Environmental Office (home page)
- The Biores project, Reinforcing Investments in Biogas Technologies for Small-Scale RES Applications in Islands (home page)

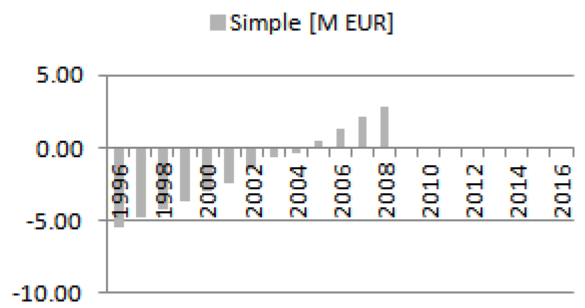

Fig. 3. Model M1. Actual numbers from Lemvig biogas plant (Hjort-Gregersen 2008).

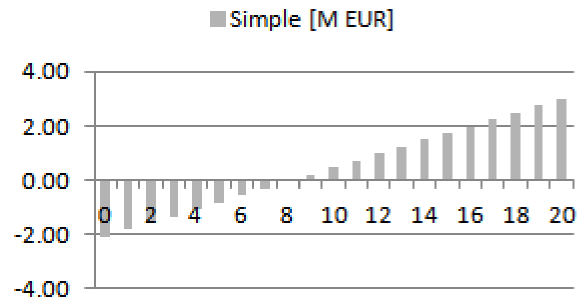

Fig. 4. Model M2. *Samso South* proposal (Planenergi 2002).

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Offshore Wind Turbine T1, Paludans Flak I/S

Appraisal of Renewable Energy Projects with Cases from Samso > Cases > Offshore Wind Turbine T1, Paludans Flak I/S

Fig. 1. The partnership *Paludans Flak I/S* owns wind turbine T1 (framed, Bonus/Siemens 2.3 MW). Picture by Sweco, who did the environmental assessment.

The first of ten offshore wind turbines south of Samso, counting from land, is entirely owned by Samso citizens. One share corresponds to 1/7765 of the cost of the whole wind turbine, but a partner can own several shares. The price of one share was 3 150 DKK (420 EUR) in 2002. The expected lifetime of the turbine is 20 years. According to the numbers in the sales material a small investor can earn up to 8.2% interest after tax.

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Introduction

The partnership *Paludans Flak I/S* owns the first wind turbine (*T1*) from land in the wind park south of Samsø. The distance from land is 3.5 kilometres and the depth of the sea is 10 - 13 metres. When a wing tip is in the top position, it is 102 metres above sea level.

The tower of the wind turbine is mounted on a foundation, which is a monopile hammered into the sea bed. The monopile is a tube, 45 metres long, with 30 metres below the sea bed. A transition piece connects tower and foundation. The transition piece provides a landing for vessels as well as ice reinforcement, and it is constructed to make the tower absolutely vertical should the foundation be leaning a little bit.

The turbine starts to rotate at wind speed 3 metres per second. At 15 metres per second it reaches its rated electrical power, which is 2.3 megawatt. At higher wind speeds the power is the same, and at 25 metres per second the wind turbine stops rotating. This is the *cut-out wind speed*, where the security system will pitch the blades, turning them into the wind.

The nominal energy production of the wind turbine is 7 765 megawatt-hours per year. The actual production can vary up or down depending on wind and failures, mechanical or electrical.

Ownership

The company *Samso Havvind A/S* (Samso Sea Wind Ltd) signed a contract with a turn-key development company to construct and commission the wind park. Samso Havvind A/S takes care of the operation and maintenance.

A *wind turbine guild* legally organized as a *general partnership* (da: *interessentskab*) owns wind turbine *T1*. All partners are fully liable for losses, an ownership model used in almost all wind turbine partnerships in Denmark (apart from partnerships, many turbines are owned by a single owner or by an electricity company). Consequently, every partner is liable with all personal savings, and creditors can decide which partner(s) they prefer to pursue. The guild is not allowed to have debts, and the wind turbine is insured.

A single share corresponds to an energy production of 1 megawatt-hour. There are thus 7 765 shares in total.

The partnership distributes the income from selling electricity, after deduction of expenses, untaxed to the partners. Each partner pays tax on the surplus using personal tax rates.

Operation and Maintenance

Samso Havvind is responsible for the operation and maintenance of the whole wind park, but the cost is split between the turbines, so the guild pays its equal share. For example, if one turbine stops and a repair team has to go out with a boat to repair it, then the cost will be shared between all wind turbines according to an agreement.

The authorities require that the guild allocates savings to a reserve fund for decommissioning and scrapping of the construction at the end of its lifetime.

The total cost for the guild of operation, maintenance, and savings is a little over 600 000 DKK (80 000 EUR) per year. There are additional annual costs for the management and administration of the business.

Pre-Calculation Based on Sales Material

According to the sales material (Paludans Flak 2002) the total investment for the whole turbine is almost 25 million DKK (3.3 million EUR). The annual income depends on the selling price of the electricity. The first ten years the government guarantees a *feed-in tariff* at 0.43 DKK/kWh (0.057 EUR/kWh).

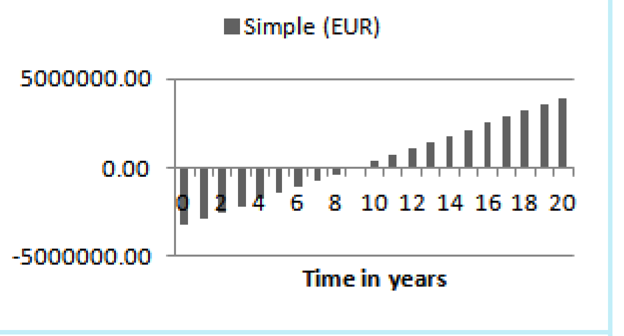

Fig. 2. Simple (without interest) balance. It is based on the sales material (Paludans Flak 2002). It is an

Figure 2 shows the pre-tax project balance over the estimated lifetime of 20 years. All numbers are in year 0 prices. The balance shows there is a simple (not counting interest) payback period of 10 years.

The diagram is based on an optimistic estimate of the selling price after year 10 at 0.43 DKK/kWh (0.057 EUR/kWh).

Calculations show that the internal rate of return (IRR) is 9.1%. This means that in principle there will be a profit if the investment can be financed by a loan at an interest rate lower than the IRR.

The surplus at the end of the investment period is nearly 30 million DKK (4 million EUR).

It is an uncertain investment in the sense that the selling price of the electricity is not known at the time of investment. Also, if some of the equipment breaks the repair costs are higher for an offshore turbine than for an onshore turbine. Furthermore, the lifetime could be shorter than the estimated 20 years, because there are not yet enough experiences with offshore turbine lifetimes.

The electricity selling price is guaranteed by the government, but only for the first ten years (0.43 DKK/kWh or 0.057 EUR/kWh). Thereafter the electricity price is the spotprice on the Nordpool electricity exchange plus a governmental *add-on*.

The sales material presents a pessimistic scenario based on a low selling price (0.28 DKK/kWh or 0.037 EUR/kWh after the 10th year). Figure 3 shows the effect on the project balance. After year 10 the growth is clearly less, and the final surplus in that case drops to a little under 18 million DKK (2.4 million EUR). The internal rate of return drops to 7% (was 9.1%).

optimistic scenario with an electricity selling price at 0.43 DKK/kWh (0.057 EUR/kWh) every year until the end.

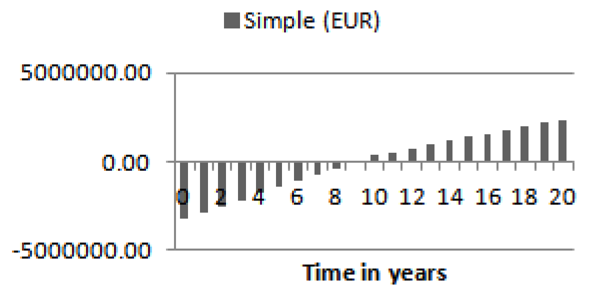

Fig. 3. Pessimistic scenario. The electricity selling price is now 0.28 DKK/kWh (0.037 EUR/kWh) after year 10 (all other equal).

The Shareholder's Economy

The economy is a little different seen from the shareholder's viewpoint, since it is affected by tax. On the other hand there are also governmental incentives and subsidies, for example the previously mentioned fixed selling price of the electricity for the first ten years, which is usually higher than the market price (but not always).

The cost of one share is fixed and well known, because it is an equal share of the total initial investment. Uncertainty enters with regard to the revenues and expenses. Since the selling price after year ten is unknown, the sales material makes three scenarios (low, medium, high selling price). The expenses are more or less known the first five years of operation, but thereafter the price of the service contract will likely increase as well the insurance premium. The sales material, however, assumes fixed annual expenses of 83 DKK/share (11.1 EUR/share), see the specifications below.

Figure 4 shows the result of buying a single share under the same conditions as previously (optimistic scenario). Buying a single share is below the tax allowance, and the picture is similar to the balance for the whole turbine (Fig. 2), only scaled, because all expenses and income are shared equally between all shares.

The tax is determined by the so-called *schematic rule* (da: *skematisk regel*) after which deductible expenses are assumed to be a fixed amount of 40% of the turnover. The tax is paid on the remainder.

More shares than seven will release a tax payment every year, which will diminish the internal rate of return. Figure 5 shows the result of buying 30 shares, which is a scenario in the sales material. In this case the tax will deteriorate the investment, and the after-tax internal rate of return drops to 3.8% and the payback period is prolonged to 14 years.

The worst case scenario in Figure 6 assumes further that the selling price of electricity is low (0.28 DKK/kWh or 0.035 EUR/kWh). In that case the payback period is 17 years and the internal rate of return 1.5%.

Finally, with a medium selling price (0.36 DKK/kWh or 0.048 EUR/kWh) and up to 7 shares, the simple payback period is 10 years and the internal rate of return 8.2% (after tax).

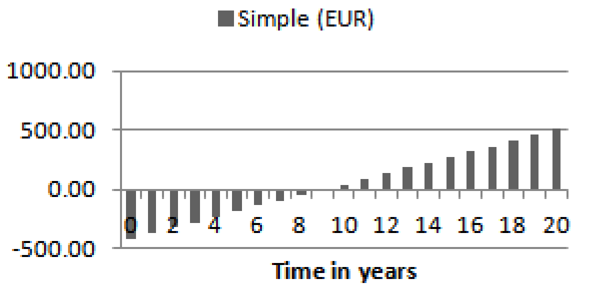

Fig. 4. Buying 1 share. There is a standard tax allowance, therefore no tax, and the IRR is 9.1% (assumptions: electricity selling price 0.43 DKK/kWh or 0.057 EUR/kWh after year 10).

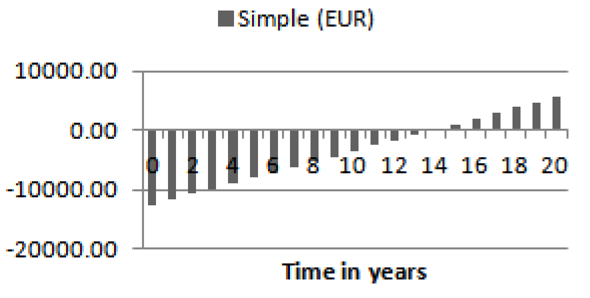

Fig. 5. Buying 30 shares. The standard tax allowance has less impact, and the IRR is now 3.8%.

Specifications

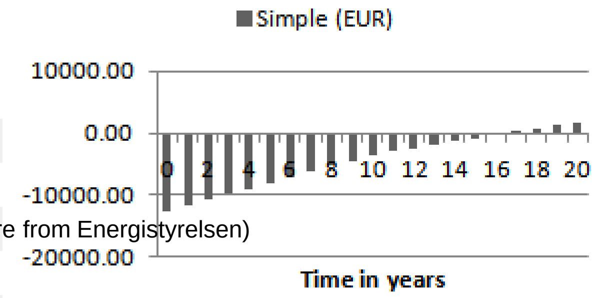

Fig. 6. Worst case scenario. Buying 30 shares, and selling price 0.26 DKK/kWh (0.035 EUR/kWh). The IRR is 1.5%.

Energy	
Power rating	2.3 MW
Nominal energy production	7 765 MWh/year (= index 100)
Nominal capacity factor	39% of full capacity
Production to date (31 Dec 2010)	61 500 MWh (all production data are from Energistyrelsen)
Average production (until 31 Dec 2010)	7 692 MWh/year (index 99)
Production 2003	6 070 MWh (index 85)
Production 2004	8 210 MWh (index 106)
Production 2005	7 580 MWh (index 98)
Production 2006	7 370 MWh (index 95)
Production 2007	8 340 MWh (index 107)
Production 2008	7 930 MWh (index 102)
Production 2009	8 180 MWh (index 105)
Production 2010	7 860 MWh (index 101)
Production 2011	8 926 MWh (index 115)
Environment	
Producer	Bonus Energy (now Siemens)
Dimensions	Hub height 61.2 m, rotor diameter 84.6 m, height from sea level to wing tip 103.5 m.
Foundation	Monopile, steel, diameter 4.5 m, length 45 m, 300 tonnes, hammered into the sea bed.
Savings	SO_2 22.6 tons, NO_x 22.3 tons, CO_2 6 630 tons, particles 429 tons.
Economy (2002 prices)	
Owner	citizens through the *Paludans Flak I/S* general partnership
Start-up date	8 Feb 2003
Nominal lifetime	20 years
Number of shares	7 765 shares
Turn-key construction costs	22 135 200 DKK (2 951 413 EUR)
Project development	1 180 500 DKK (157 400 EUR)
Project office	193 300 DKK (25 773 EUR)
Reserve for unforeseen expenses	950 750 DKK (126 767 EUR)
Total construction costs	24 459 750 DKK (3 261 300 EUR)
Price per share	construction costs / shares = 3 150 DKK (420 EUR)
Original feed-in tariff	0.43 DKK/kWh (0.05733 EUR/kWh)
Selling price for electricity per share	430 DKK (57.33 EUR)
Operation and maintenance per share	83 DKK (11.07 EUR)
Net income per share before tax	347 DKK (46.27 EUR)
Insurance	1 000 000 DKK/year (133 333 EUR/year)
Administration	400 000 DKK/year (53 333 EUR/year)
Power operations manager	150 000 DKK/year (20 000 EUR/year)
Management	75 000 DKK/year (10 000 EUR/year)
Audit	50 000 DKK/year (6 667 EUR/year)
External consulting	100 000 DKK/year (13 333 EUR/year)
Miscellaneous including purchase of IT	100 000 DKK/year (13 333 EUR/year)
Operations cost less servicing	1 875 000 DKK/year (250 000 EUR/year)
Share allocated to this turbine is 10%	187 500 DKK/year (25 000 EUR/year)
Turn-key Contractor	Deme

Foundation	Bladt

External Links

1. %Bladt%
2. %DanishWindTurbine%
3. %Deme%
4. %EnerginetDKTheDanishWindcase%
5. %EnergistyrelsenStamdata% T1 has turbine ID 570715000000062926
6. %LORCKnowledge%
7. %PaludansFlakOnAMap%
8. %PaludansFlakProduction%
9. %SamsoHavvind%
10. %SiemensWind%
11. %Sweco%
12. %Vindinfo%
13. %WindEnergyTheFacts%

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Offshore Wind Turbine T7, I/S Difko Samso 1

Fig. 1. The partnership *I/S Difko Samso 1* owns wind turbine T7 (framed, Bonus/Siemens 2.3 MW). Picture by Sweco, who did the environmental assessment.

Shareholders own offshore wind turbine number 7, south of Samso. The shareholders do not necessarily live on Samso. They are organised in the socalled *I/S Difko Samsø 1* partnership, which is nationwide. One share corresponds to 1/7800 of the whole wind turbine, but a partner can own several shares. The price of one share was 3 400 DKK (453 EUR) in 2002. The expected lifetime of the turbine is 25 years. A small investor could earn up to 7.1% interest after tax according to the sales material.

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Introduction

The partnership *I/S Difko Samsø 1* owns the seventh wind turbine counted from land south of Samso. The company *Difko* is a professional investment foundation that specialises in raising funds for projects (solar, wind, real estate, ships).

A Difko subsidiary bought the wind turbine from *Samsø Havvind A/S* (Samso Sea Wind Ltd), designed the project, and sold it to *I/S Difko Samsø 1*. The latter is a partnership of shareholders, some of which may live on Samso, but most shareholders probably live somewhere else. This is an exceptional case of external ownership.

The initial idea was to offer all ten offshore wind turbines to the citizens of Samso, but it was impossible to raise enough funds. The outside investor Difko then bought turbine 7. To finance the project, Difko published sales material offering shares at 3 400 DKK (453 EUR) per share (Difko 2002). The sales material included a form with a contract, on which the investor could write the number of shares he wished to buy.

A subsidiary of Difko manages the project. Naturally the management effort is an expense on the project account, but on the other hand professional management may reduce some of the risk.

Ownership

There are 7 800 shares in total, owned by the members of a *wind turbine guild*. The guild is legally a *general partnership*. The partnership owns the wind turbine, while Samso Havvind is the daily operations manager. The general partnership is exempt from tax, instead each partner pays tax on the income.

The project has a 25-year concession granted by the government. An investor ends his ownership either automatically when the concession period ends or by selling his shares in the meantime. Investors may sell and buy shares through a Difko trade company. At the end of the concession, the wind turbine must be decommissioned. Every year during the period of operation funds are saved to pay for the decommissioning.

Operation and Maintenance

The budget assumes that the company *Samso Havvind A/S* operates and maintains all the wind turbines in the wind park. The cost is split equally, so the Difko budget is 1/10 of the expenses for the whole wind park. Samso Havvind pays all expenses before they distribute the income from the electricity sales to the turbine owners.

The budget also assumes a service contract with the contractor, the cost of which is shared equally between all ten wind turbines. The service contract, at a fixed price, guarantees a minimum production of electricity during its duration.

The partnership has an agreement with a Difko subsidiary (Difko Administration) to take care of all administration. That includes, for example: accounting, monitoring of the financial operations, making payments, and organizing the annual general assembly. The price for these services was fixed at the beginning but adjusted automatically every year according to the net price index.

Pre-Calculation Based on Sales Material

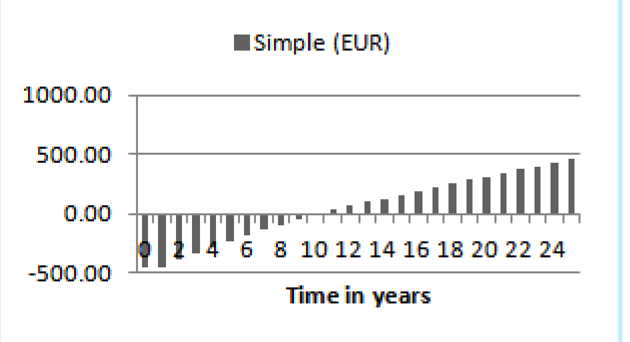

Figure 2 shows the balance when buying a single share. The diagram assumes the electricity selling price is 0.36 DKK/kWh (0.048 EUR/kWh) after year 10. Buying a single share is below the tax allowance, thus there is no tax on the electricity income. The figure shows that the investment is paid back after 11 years. A calculation shows that the internal rate of return (IRR) is 7.1%.

The tax is determined by the so-called schematic rule (da: skematisk regel) according to which deductible expenses are assumed to be a fixed amount of

40% of the income. The tax is then paid on the remainder.

Fig. 2. Simple project balance for a single share. It is based on the sales material (Difko 2002). The internal rate of return is 7.1%.

Risk Assessment

Although the government guarantees a fixed feed-in tariff for the first ten years, and the partnership has taken out an insurance, there is still some uncertainty present. For example, the selling price of electricity after year ten is unknown, and it depends on an unpredictable electricity market (Nordpool). The assessment of the risk factors below is largely based on the sales material (Difko 2002).

Energy Production

Consultants estimated the wind energy, and actual wind data from a nearby wind park (Tunø Knob) supported the calculations. They arrived at a nominal production of 7 765 megawatt-hours per year, but naturally it can change from year to year due to changing weather. The available energy depends not only on wind speed, but also on humidity. This source of uncertainty should be taken into account when assessing the risk.

It has turned out, in fact, that the average yearly production over the first eight years is 98% of the calculated, nominal production (see Specifications). It is not quite 100%, but the first year of operation was not a full calendar year, and it took one month to commission the turbine causing more stoppage time than normal. It is thus likely that the final end-of-lifetime production will be as estimated.

Repair Costs

The contractor gave a two year warranty on the foundations and a five year warranty on the wind turbines — as well as a fixed price on servicing. There is also a guaranteed minimum production, which is set lower than the nominal production, however.

The budget for repair costs is conservative, but actual repair costs might still deviate in a positive or negative direction. Gear boxes are vulnerable since they have moving parts, and it is expensive to change the gear box at sea. Actually, the gear box had to be changed in 2009.

The cement used in the foundation may crack or crumble, particularly the grouting in the transition piece from foundation to tower, and that is also expensive to repair.

Electricity Selling Price

The government guaranteed a fixed feed-in tariff for the first ten years (0.43 DKK/kWh or 0.057 EUR/kWh). Furthermore, wind turbine electricity is prioritised which obliges the electricity company to buy it. The base feed-in tariff is 0.33 DKK/kWh, but then the government gives an add-on (0.10 DKK/kWh) as a compensation for an absent market for renewable energy certificates.

Scrap certificates contribute further to the selling price (+ 0.17 DKK/kWh) for the first 3.5 years. When a wind turbine owner scraps a wind turbine he will receive scrap certificates from the national electricity system operator. A certificate has a value, and it can be sold. The buyer of the certificate is then granted the extra premium (0.17 DKK/kWh) on a new wind turbine. The duration of the scrap certificates corresponds to 12 000 hours at full load (2.3 MW), equivalent to the first 27 600 megawatt-hours of production.

After the first ten years, the selling price is the market price as it is dictated by the Nordpool electricity exchange. The government will give a fixed subsidy, however, as long as the total price is below a certain limit (0.36 DKK/kWh). The market price may rise above the limit, and in that case the wind turbine guild is allowed to sell at the market price (without receiving subsidies).

Difko chose 0.36 DKK/kWh as the likely selling price after year ten in the budget. But since the price is based on the market price, the estimate is uncertain.

Technical Lifetime

Difko assumes the wind turbine lasts 25 years (others assume 20 years), but there is still little experience with offshore wind turbines, and it is uncertain how long turbines can resist tear and wear at sea. In case the wind turbine must be scrapped earlier, it will have a considerable impact on the surplus of the investment. If on the other hand, the wind turbine is in a good condition after 25 years, the concession with the government could perhaps be extended.

Insurance

It is possible to take out an insurance against loss of production and breakage of equipment. The insurance will cover unforeseen loss, but it will not cover events that can be planned and foreseen within some reasonable time horizon.

The sea cable — it connects the wind park with a land cable and farther on a transformer — is at risk, because it could be damaged physically by for instance a ship anchor. The cables are buried, however, 1.5 metres below the sea bed, and trawling is forbidden within 200 metres. The risk of damage is small, but the consequences are serious, and it is therefore necessary to consider the price of insurance against the potential loss as well as its probability.

Liability

The I/S Difko Samsø 1 is a general partnership in which each partner is personally and directly liable for the whole. That means 1) any partner is liable with all his personal savings, and 2) a creditor can decide himself which partner(s) to pursue.

The written regulations of I/S Difko Samsø 1 state that the partnership cannot have debt, except for the initial cash credit that paid for the scrap certificates. That loan is against security in the wind turbine.

The risk is thus minimised. But, although risk is minimised, bankruptcy could have dire consequences for a partner.

Sensitivity Analysis

In order to get a better idea of the consequences of some of this uncertainty, we change the value of some of the variables in the financial model and observe the effect. Thus, we observe what happens to the internal rate of interest (IRR) as we change the production (Wind), the selling price (Price), and the cost of operation plus maintenance plus administration (O&M).

Figure 3 shows how IRR changes by changing each of the three variables one-by-one by an amount up to +/- 20%. First of all we see that if Wind (electric production) increases, then we get a better IRR. The same with Price. Oppositely, if operation and maintenance costs increase, we get a worse IRR.

From the curvature of the Wind and Price curves we see that they tend to become horizontal as we move toward the right. It is thus more difficult to gain a better IRR than to loose it; there is a certain amount of 'friction' against earning a higher interest, one could say.

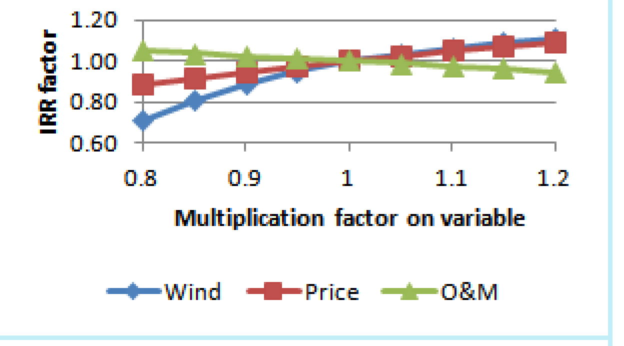

Fig. 3. Sensitivity of IRR to changes. Wind refers to annual energy production, Price to the selling price after year 10, and O&M to operation, maintenance and administration cost after year 5.

We also see a higher sensitivity to changes in Wind than to Price. Notice also that if Wind is multiplied by 0.8 (80% of the base value), the IRR drops to about 0.7 times its base value (70%), which is a larger drop. It accelerates as we decrease Wind. We can conclude it is most important not to loose any of the production.

Example (sensitivity). The procedure is to multiply, say, the base value of the electric production by a factor K_1, which will result in a new IRR, which is K_2 times the original IRR.

Multiply for example the production every year by K_1 = 1.05, which means we increase the values by 5%. The new IRR is K_2=1.03 times the base value of IRR, that is, it increased by 3%.

Regarding Price we have only changed the selling price after year ten, because it is fixed until then thanks to the government. Likewise we have only changed O&M after year five, because the costs are fixed for the first five years due to contracts.

Specifications

Energy	
Power rating	2.3 MW
Nominal energy production	7 765 MWh/year (= index 100)
Nominal capacity factor	39% of full capacity
Average production (until 31 Dec 2010)	7 642 MWh/year (index 98)
Production 2003	6 007 MWh (index 77)
Production 2004	8 237 MWh (index 106)
Production 2005	8 159 MWh (index 105)
Production 2006	6 657 MWh (index 86)
Production 2007	8 230 MWh (index 106)
Production 2008	7 927 MWh (index 102)
Production 2009	8 211 MWh (index 106)
Production 2010	7 639 MWh (index 98)
Production 2011	8 742 MWh (index 113)
Environment	
Producer	Bonus Energy (now Siemens)
Dimensions	Hub height 61.2 m, rotor diameter 84.6 m, height from sea level to wing tip 103.5 m.
Foundation	Monopile, steel, diameter 4.5 m, length 45 m, 300 tonnes, hammered into the sea bed.
Savings	SO_2 22.6 tons, NO_x 22.3 tons, CO_2 6 630 tons, particles 429 tons.
Turn-key Contractor	Deme
Foundation	Bladt Industries
Economy (2002 prices)	
Owner	Shareholders through the *I/S Difko Samsø 1* general partnership
Start-up date	8 Feb 2003
Nominal lifetime	25 years
Number of shares	7 800 shares
Feed-in tariff first ten years	0.43 DKK/kWh (0.05733 EUR/kWh)
Capital expenditures (budget)	
Buying price from Samso Havvind	24 500 000 DKK (3 266 667 EUR)
Acquisition and implementation of scrap certificates	2 246 000 DKK (299 467 EUR)
Bank guarantee and interest expenses	500 000 DKK (66 667 EUR)
Legal services, creation of partnership, etc.	130 000 DKK (17 333 EUR)
Project fee to Difko	790 000 DKK (105 333 EUR)
Acquisition of rights in Difko Investeringsfond	300 000 DKK (40 000 EUR)
Total project cost	28 766 000 DKK (3 835 467 EUR)
Financed by cash credit	-2 246 000 DKK (-299 467 EUR)

Total investment	-26 520 000 DKK (3 536 000 EUR)
Price per share	3 400 DKK (453 EUR)
Operating expenses (budget)	
1/10 of Samso Havvind expenses	187 500 DKK (25 000 EUR)
Difko Administration	150 000 DKK (20 000 EUR) + 2% every year
Service contract year 1	251 000 DKK (33 467 EUR)
Service contract year 2	251 000 DKK (33 467 EUR)
Service contract year 3	432 000 DKK (57 600 EUR)
Service contract year 4	432 000 DKK (57 600 EUR)
Service contract year 5	432 000 DKK (57 600 EUR)
Service contract year 6	600 000 DKK (80 000 EUR)
Service contract onward	same + 2% per year

Budget operating expenses for Samso Havvind (2002 prices)		
	DKK	EUR
Insurance	1 000 000	133 333
Administration of the wind park	400 000	53 333
Manager of technical operations	150 000	20 000
Board meetings and management	75 000	10 000
Audit	50 000	6 667
External consulting	100 000	13 333
Miscellany including IT	100 000	13 333
Total	1 875 000	250 000

External Links

1. %Bladt%
2. %DanishWindTurbine%
3. %Deme%
4. %DifkoInternational%
5. %DifkoSamso%
6. %DifkoTurbineProd%
7. %EnerginetDKTheDanishWindcase%
8. %EnergistyrelsenStamdata% T7 has turbine ID 570715000000062988
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Offshore Wind Turbines T2-T6, municipal

Appraisal of Renewable Energy Projects with Cases from Samso > Cases > Offshore Wind Turbines T2-T6, municipal

In 2002 the Samso municipality bought five offshore wind turbines. The municipality created a municipal energy company *Samsø Vedvarende Energi Aps* (Samso Renewable Energy) which takes care of the investment. The surplus from the company is re-invested in energy activities.

Fig. 1. The municipality owns wind turbines T2-T6 (framed, Bonus/Siemens 2.3 MW). Picture by Sweco, who did the environmental assessment.

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Introduction

The Samso municipality participated from the very beginning in the renewable energy island project (Samso a Renewable Energy Island). The municipality participated in the steering group for the erection of the offshore wind park.

Ownership

The municipal board decided to borrow funds and buy five offshore wind turbines. The board had difficulties making the decision, because it was a risky investment to be made on behalf of the tax payers.

Eventually the decision was approved by the authority that supervises the operation of all the municipalities (da: tilsynsstyrelsen), on the condition that the purpose of the company is *not* business, but to support sustainability or renewable energy projects within the municipality.

According to law the municipal ownership must be via a company with limited liability. The energy company that was established, *Samsø Vedvarende Energi Aps*, is thus a limited shareholder company with a single shareholder, and the shares cannot be sold publically. The equity capital is 125 million DKK (17 million EUR). The profit cannot be used to cover the daily operation of the municipality, but only for energy related purposes.

Pre-Calculation Based on Sales Material

The price of each wind turbine is the same as the other wind turbines in the park, and the five municipal wind turbines are also operated by the company Samso Havvind. Therefore the simple project balance is similar (see Offshore Wind Turbine T1).

The price of one turbine is almost 25 million DKK (3.3 million EUR) which explains why the equity of the limited company is five times larger. The annual income depends on the selling price of the electricity. The first ten years the price is guaranteed by the government (feed-in tariff) at 0.43 DKK/kWh (0.057 EUR/kWh).

With an optimistic selling price the internal rate of return (IRR) is 9.1% and a payback period of 10 years.

But the municipality borrowed the investment capital in *Kommunekredit* which is the funding agency for local governments (municipalities). The interest rate of such a loan is perhaps 3-4%. There are therefore some financial costs that prolong the payback period and diminish the internal rate of return (IRR). Furthermore, the limited company must pay tax on the surplus.

It is an uncertain investment in the sense that the selling price of the electricity was not known at the time of investment. Also, if some of the equipment breaks the repair costs are higher for an offshore turbine than for an onshore turbine.

The electricity selling price is guaranteed by the government, but only for the first ten years (0.43 DKK/kWh or 0.057 EUR/kWh). Thereafter the electricity price is the spotprice on the Nordpool electricity exchange plus a governmental add-on.

Post-Calculation of Actual Project

Data are not readily available, but we have some of the annual financial statements. It is quite difficult to see how the project balance evolves, because there are many accounting lines that disturb the picture. But, concentrating on the long-term debt, Figure 2 plots the debt.

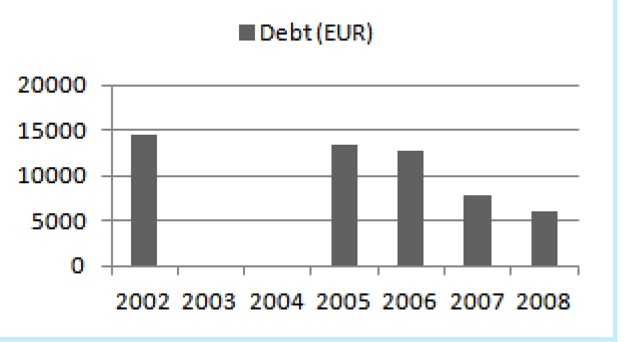

Fig. 2. Long-term debt in the project company.

Apparently the debt decreases reassuringly. After six years of operation, the debt is reduced to almost one third (the initial investment was in 2002, and the wind turbines were commissioned in 2003). In 2006 almost 2 million DKK (267 000 EUR) of the surplus was passed on to finance an energy project instead of reducing the debt.

By extrapolation the debt should be paid back at the end of year 2013, after 11 years.

Turning to the technical side, where the data material is better, the five turbines run as expected. Figure 3 shows the annual production of energy relative to the nominal production. The first year is low, because the turbines were only just installed and did not run a full calendar year. Otherwise they produce a little more than nominal, except for the year 2006, which was a poor wind year nationally. In fact 2006 was the worst year in 27 years of recording.

Specifications

Fig. 3. Annual production index. The nominal production is index 100. The average over the whole period is 99.

Energy	
Power rating	5 turbines at 2.3 MW = 11.5 MW
Nominal energy production	5 x 7 765 MWh/year = 38 825 MWh/yr (= index 100)
Nominal capacity factor	39% of full capacity
Production to date (31 Dec 2010)	61 500 MWh (all production data are from Energistyrelsen)
Average production per turbine (until 31 Dec 2010)	7 663 MWh/year per turbine (index 99)
Production 2003	29 633 MWh (index 76)
Production 2004	40 227 MWh (index 104)
Production 2005	39 643 MWh (index 102)
Production 2006	35 842 MWh (index 92)
Production 2007	41 682 MWh (index 107)
Production 2008	39 990 MWh (index 103)
Production 2009	40 324 MWh (index 104)
Production 2010	39 164 MWh (index 101)
Production 2011	43 823 MWh (index 113)
Environment	
Producer	Bonus Energy (now Siemens)
Dimensions	Hub height 61.2 m, rotor diameter 84.6 m, height from sea level to wing tip 103.5 m.
Foundation	Monopile, steel, diameter 4.5 m, length 45 m, 300 tonnes, hammered into the sea bed.
Savings	SO_2 113 tons, NO_x 112 tons, CO_2 34 000 tons, particles 2 100 tons
Economy (2002 prices)	
Owner	Samso municipality through the *Samsø Vedvarende Energi Aps* limited company.
Start-up date	8 Feb 2003
Nominal lifetime	20 years
Total construction costs	5 times 24 459 750 DKK = 122 mill DKK (16.3 mill EUR)
Original feed-in tariff	0.43 DKK/kWh (0.05733 EUR/kWh)
Turn-key Contractor	Deme
Foundation	Bladt

External Links

1. %Bladt%
2. %DanishWindTurbine%
3. %Deme%
4. %EnerginetDKTheDanishWindcase%
5. %EnergistyrelsenStamdata%, T2 has turbine ID 570715000000062933
6. %LORCKnowledge%
7. %PaludansFlakOnAMap%
8. %PaludansFlakProduction%
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Household Wind Turbine

A household wind turbine which is smaller than or equal to 6 kilowatts can use net metering in Denmark. The selling price of electricity is thus very good, and the administration is minimal. It is relatively expensive to buy, but its production is high.

Fig. 1. Household wind turbine (Proven 6 kW). Photo by AB Albrechtsen.

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Household Wind Turbines

A household wind turbine is a smaller wind turbine (max 25 kilowatt) erected in relation to a detached household, where its primary objective is to deliver energy to the household (Danmarks Vindmølleforening 2011). The total height should be less than 25 metres from the foundation to the wing tip.

The wind turbine is connected to the grid through the electric installation of the household.

The house owner must obtain a permit in order to erect a wind turbine, and the wind turbine must be on the governmental white list. It must be placed near the owner's main buildings, and such that the noise level is less than 45 decibel on the neighbour's property.

Since 2010 all renewable energy installations below 6 kilowatt are allowed to use net metering.

Net Metering

On windy days, when the turbine produces more than the home consumption, the surplus electricity is fed into the public grid. Using *net metering* the electricity meter 'runs backwards'. When the production is less than the domestic consumption, then the public grid will deliver the remaining power. When the production is larger than the domestic consumption, the public grid will accept the surplus production.

It is more windy during winter time, so the production will be high. The meter is able to measure inflow and outflow, and it will calculate an annual balance. If there is a net outflow to the grid the electricity price will be lower than the buying price. Normally the annual production is less than the consumption, and the production reduces the electricity bill. Thus the price for a kilowatt-hour is the same as the buying price.

Pre-Calculation from Sales Material

Figure 1 shows a 6 kilowatt wind turbine. The tower is 15 metres high. The rotor diameter is not very big and it spins rather fast.

The sales material specifies a nominal production of 11 000 kilowatt-hours (Ecowind) at an average annual wind speed of 5.2 metres per second. The initial investment is 300 000 DKK (40 000 EUR) turn-key.

Figure 2 shows the pre-tax simple project balance based on the data form the sales material. The payback period is 10 years and the internal rate of return (IRR) is 10.7%. Notice that the income is tax free as as a consequence of net metering.

The actual production depends on the exact location, the landscape, and the weather. A location on the west coast of Samso is maybe 30% better than inland.

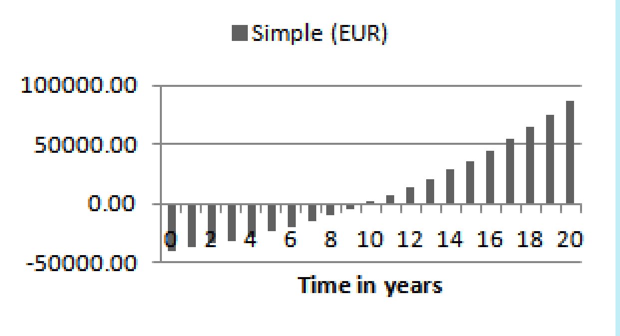

Fig. 2. Simple project balance. Data from sales material.

Sensitivity Analysis

The previous calculation assumed that the electricity selling price grows at 7% per year. If we instead assume that it grows with the inflation rate only, then the price is fixed at year 0 level. All prices are year 0 prices in fact.

Furthermore we change the electricity price to 1.81 DKK/kWh (was 2.00 DKK/kWh), which is closer to the current marginal electricity price (disregarding subscription fees) on Samso.

Then we obtain Figure 3. Now the payback period is 17 years (up from 10 years), and the internal rate of return is 2.3% (down from 10.7%).

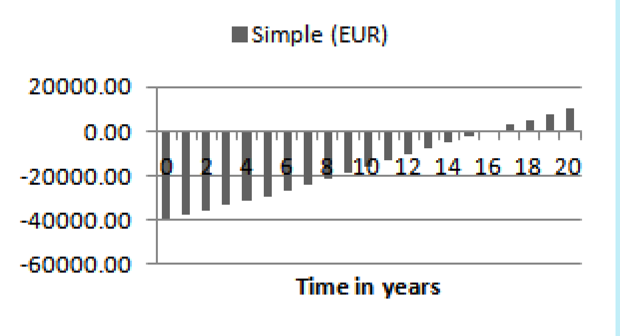

Fig. 3. Simple project balance with less optimistic electricity prices.

Clearly the picture depends on the future electricity prices. Even though spot market prices may have increased 7% per year, the consumer price has only increased more or less by the inflation rate the last ten years. Future prices may increase as a result of the new government in 2011, who has announced more tax on energy in order to pay for the future national transition to a renewable energy supply.

External Links

1. %EcoWind%
2. %EcoWindProven6kW%
3. %EcoWindCalculation2010%
4. %Vindinfo%
5. %WikipediaNetMetering%

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Ground Heat, Private Residence

Appraisal of Renewable Energy Projects with Cases from Samso > Cases > Ground Heat, Private Residence

Fig. 1. Heat pump (Klimasol). The smaller box is the heat pump and the tall box contains a hot water storage tank.

In this case study a *ground source heat pump* uses electricity and heat stored in the shallow ground to heat a private house. The ground heat comes from the sun, it is therefore renewable energy (the electricity part is not). It is supplemented with 6 square metres of solar panels.

The central piece of equipment is similar to a refrigerator with the cool side underground and the warm side indoor. It generates 2.5 times more heat than the electricity it uses; in other words 60% of the energy comes from the ground. Operation and maintenance is more or less limited to an annual check by an expert.

The operational costs are low, but the installation is expensive. It has been running since 2001, and it looks as if the payback period over an oil furnace will be less than 11 years. The expected lifetime is 15 years.

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Ground source energy

Figure 2 shows the ground heat system consisting of a heat pump, ground pipes, and a storage tank. The pipes contain water with an alcohol as antifreeze (not glycol) to minimize pollution in case of a leak. The amount of liquid, and the length of the pipe, is designed to keep the house warm in most cases. A supplementary electric water heater kicks in if the weather is very cold, it covers the *peak load*.

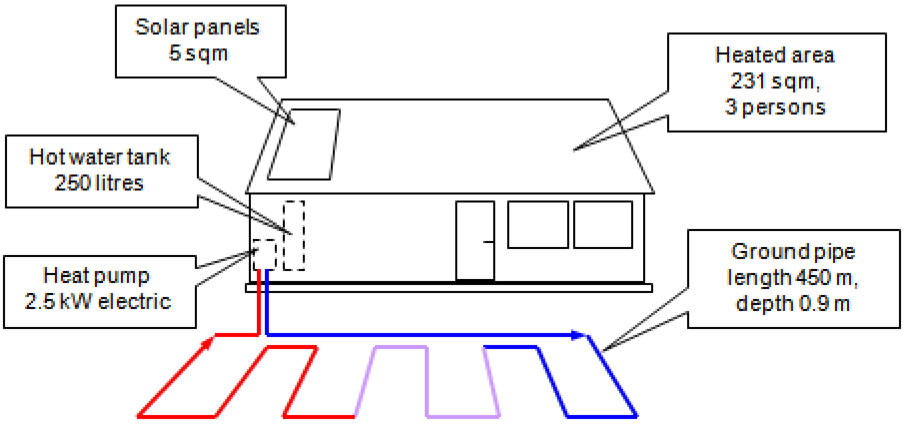

Fig. 2. Ground source heat pump. The earth heats the liquid in the ground pipe by 2-4 degrees. The heat pump transforms it into, say, 40 degrees celsius in the indoor radiators. The solar panels supply additional heat Spring, Summer, and Autumn.

The heat pump heats water, which is pumped through radiators and underfloor pipes to heat the house. It also provides hot water for showering and washing. The solar panels provide supplementary energy, which is stored in the tank.

The heat pump runs on electricity, so it is a form of electric heating, but it spends less electricity than direct electric heating; up to 2/3 of the energy may come from the ground.

The ground heat system replaced an old oil furnace with a poor efficiency.

Coefficient of performance, COP

A heat pump takes renewable heat from the ground, and uses it to heat the building. It comes *at a price*, which is the electricity spent in order to operate the heat pump. The ratio between the heat produced Q_{out} and the power spent Q_{in} is larger than 1, because the heat pump adds heat from the ground to its performance.

This ratio is the *coefficient of performance* which is abbreviated COP.

~hs~ ~hs~ ~hs~ COP = Q_{out} / Q

Typical values for a ground source heat pump are in the range 2 - 5. It is the *gain factor* that we multiply on the input power to find the output power.

Example (COP). Assume a heat pump has COP = 3. Consequently it transforms 1 kilowatt of electricity (input) into 3 kW of heating (output). Out of the 3 kW output, 1 kW came from electricity, therefore 3 - 1 = 2 kW came from the ground source.

As a result, we can say that 2/3 of the produced heat comes from the ground.

Pre-Calculation Based on Sales Material

The contractor had a calculation example in the sales material, where the heat pump replaces an oil furnace in a house of 160 square metres. The investment after subsidies is 102~hs~000 DKK (13~hs~600 EUR), and the annual savings over an oil furnace are 8~hs~952 DKK (1~hs~194 EUR).

Figure 3 shows how the value of the investment evolves over the estimated lifetime of 15 years. The figure shows the future value relative to the time of investment at the end of year 0. The simple project balance shows a payback period of 12 years and a final surplus of 17~hs~500 DKK (2~hs~300 EUR).

The internal rate of return is 3.7%. In principle there will be a surplus if the project can be financed at an interest rate lower than that.

The breakeven point, where the investment is paid back, is fairly late in the project, which indicates that the surplus could be upset by small unforeseen expenses.

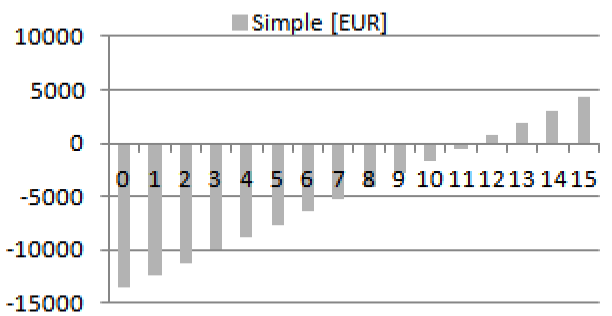

Fig. 3. Simple project balance. Based on the sales material in 1999 prices (Arke 1999).

All in all a fairly risky investment for a household. A time horizon of 15 years is long for a private household, and equipment could break before the expected lifetime. On the other hand a houseowner may not expect to earn any surplus on the heating installation; in that case there is a margin of 2~hs~300 EUR for unforeseen expenses.

Post-Calculation Based on Actual Numbers

The total construction cost was 131~hs~760 DKK (17~hs~568 EUR) in year 2000 prices. Figure 4 shows how the investment has evolved from the time of investment at the end of year 2000 up until present time.

Year 2009 is the year of breakeven of the undiscounted cash flow, that is, the actual undiscounted payback period turned out to be 9 years. The discounted payback period is one year longer.

The heat pump is still running, and if it lasts all the projected lifetime, there will be a good surplus.

Oil prices

The actual undiscounted payback period is three years earlier than estimated in the contractor's example. The reason is not that the contractor used pessimistic estimates, but rather due to increasing oil prices (Fig. 5). In fact, while the electricity price increased 17% in nine years, the price of oil increased 33%, thereby improving the savings on fuel.

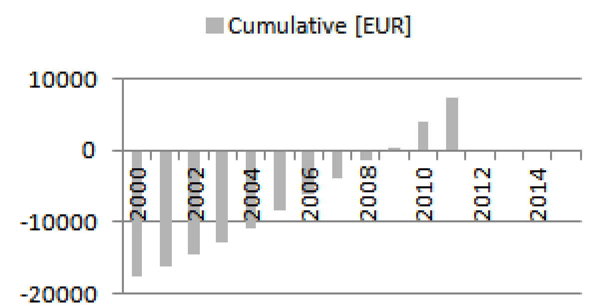

Fig. 4. Simple project balance based on actual prices. The investment was at the end of 2000.

History

Spring 2000

Initial contact to the Samso Energy and Environmental Office. They provide information material, a sales brochure with calculation examples (Arke 1999), and contact to the energy company (ARKE). The energy company is the main contractor, but they use local installers to perform the installation.

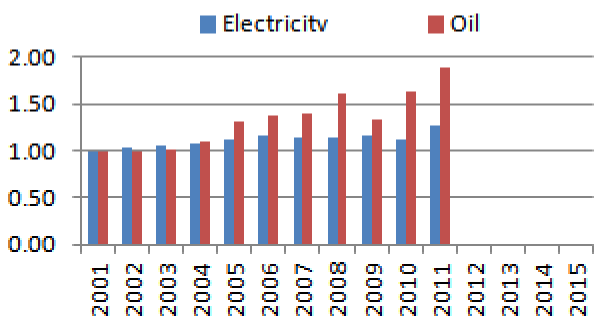

Fig. 5. Oil prices versus electricity prices. During the lifetime of the heatpump, oil prices have increased more than electricity. Year 2001 prices correspond to index 1.

13 May 2000

Calculation of the energy demand of the house by the contractor (ARKE). Calculation of the size of the heat pump.

17 Jul 2000

Offer from the contractor. In the meantime sub-constractors have provided their prices.

17 Jul 2000

The contractor sends an application for an installation permit to the municipality. It contains engineering dimensions, a proposal for the layout of the underground piping, and a map. The municipality forwards it to the county's environmental department (off the island).

20 Jul 2000
: The contractor sends an application for government subsidies to the Danish Energy Agency (Energistyrelsen) under the ministry for the environment and energy.

31 Jul 2000
: The county sends a letter that there will be a one month delay in the processing of the application due to summer holidays.

4 Aug 2000
: The Danish Energy Agency grants the subsidies.

15 Sep 2000
: The environmental department of the county forwards a draft of their permit. It contains specifications of technology, distance requirements, test for leakages, municipal supervision duties, and a special requirement about the location of the pipes in order to maximize the distance to a water well downstream. They ask for comments.

19 Sep 2000
: The environmental department of the county issues the permit, on the condition that no protests appear before 18 Oct 2010.

23 Oct 2000
: Letter from the county that there were no protests within the stipulated protest period.

Nov - Dec 2000
: Subcontractors dig the trenches, deliver the heat pump, deliver the solar collector and tank, mount the solar collector on the roof, and they make the plumbing and electric connections.

1 Jan 2001
: The heat pump is installed and starts operating.

27 Feb 2001
: The Danish Energy Agency sends a letter that the subsidy will be paid within three weeks and accounts closed.

28 Nov 2001
: The house is registed as an electrically heated house to the electricity company NRGi and the national register for buildings and dwellings. There is consequently a discount on the electricity price from NRGi.

7 Dec 2002
: Service.

7 Dec 2003
: Service: 1125 DKK.

2004
: Expansion tank renewed: approx 1000 DKK.

6 Dec 2005
: Service.

2007
: Expansion tank renewed + anode renewed: approx 3000 DKK

12 Jun 2007
: Service.

2008
: Bought manual pump and liquid for solar panel: approx 1500 DKK

29 Oct 2009
: Refill of IPA alcohol + service: 2880 DKK.

30 Nov 2009
: Replacement of pressure valve at the top of the panels, replacement of liquid: 635 DKK.

10 Apr 2010
: Solar panels unmounted and scrapped. Photovoltaic panels mounted, 26 panels at 1.5 square metres each, 39 square metres total.

4 Aug 2010
: Photovoltaic panels connected to the grid, but only 9 of 26. Waiting for the correct size inverter.

16 Jan 2011
: Correct inverter (SMA Sunny Boy) installed. Full capacity of the plant is 5 kW peak.

Specifications

Energy	
Heat pump power rating	2.5 kW electric and 7.0 kW heat
Max boiler temperature	55 C
Nominal energy consumption of the house	30~hs~000 kWh / year
Hot water storage tank	250 litres with 3 spiral heat exchangers
Environment	
Refrigerant	R 407C, 1.25 kg
Heat pump	height 92 cm, depth 60 cm, width 59 cm, weight 174 kg
Ground pipe dimensions	2 x 200 m Ø 40, 2*25 m Ø 50, polyethylene.
Ground pipe liquid	water and alcohol (IPA: 90% ethanol, 10% isopropanol)
Liquid volume	391 litres including 98 litres IPA
Ground pipe depth	0.9 metres
Ground pipe lifetime	more than 50 years
Economy (2000 prices)	
Start-up year	2001
Expected lifetime	15 years
Heat pump and pipes	52~hs~088 DKK (6~hs~945 EUR)
Excavation of pipes	18~hs~800 DKK (2~hs~507 EUR)
Solar panel and tank	28~hs~520 DKK (3~hs~803 EUR)
Mounting panel and tank	5~hs~500 DKK (733 EUR)
Plumber	8~hs~000 DKK (1~hs~067 EUR)
Electrician	8~hs~500 DKK (1~hs~133 EUR)
Subtotal	121~hs~408 DKK (16~hs~188 EUR)
Value added tax 25%	30~hs~352 DKK (4~hs~047 EUR)
Subtotal	151~hs~760 DKK (20~hs~235 EUR)
Government subsidy for heat pump	-12~hs~000 DKK (-1~hs~600 EUR)
Government subsidy for solar panel	-8~hs~000 DKK (-1~hs~067 EUR)
Total construction costs	131~hs~760 DKK (17~hs~568 EUR)
Ground heat split, including tax	107~hs~360 DKK (14~hs~315 EUR)
Subsidy ground heat	12~hs~000 DKK (1~hs~600 EUR)
Total ground heat cost	95~hs~360 DKK (12~hs~715 EUR)
Solar panel split, including tax	44~hs~400 DKK (5~hs~920 EUR)
Subsidy solar panel	8~hs~000 DKK (1~hs~067 EUR)
Total solar panel cost	36~hs~400 DKK (4~hs~853 EUR)

External Links

- Turn-key contractor: NRGi (formerly ARKE)
- Heat pump (Vølund DSC 4): Vølund Varmeteknik
- PVGIS: Solar irradiation data
- Solar heat system (ARCON Klimasol S-250): Arcon solvarme
- Wikipedia: Geothermal heat pump
- Wikipedia: Solar water heating

Created by system. Last Modification: Wednesday 04 January 2012 22:16:17 CET by jj.

Solar Thermal Heat, Private Residence

Created by system. Last Modification: Tuesday 10 January 2012 00:37:34 CET by system.

Photovoltaic Panels on Grid, Private Residence

A household photovoltaic installation, which is smaller than or equal to 6 kilowatts, can use net metering in Denmark. The selling price of electricity is thus very good, it is tax free, and the administration is minimal. The simple payback period in this case study is 18 years or less and the internal rate of return is estimated at 3.6% (tax free).

Fig. 1. Photovoltaic panels for a household (Scheuten 5.07 kW, 39 square metres).

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Introduction

A photovoltaic (PV) cell converts sunlight directly into electricity. A manufacturer wires multiple cells together and assembles them into a panel. The installation in Figure 1 consists of 26 panels, and the capacity is just over 5 kilowatts. It could drive 4 vacuum cleaners, just to give an idea of its power.

On sunny days the panels provide energy to the household. If there is more energy available, it is exported to the national electric grid (Samso has an electric cable to the mainland). It is a relatively simple installation, modular, and it is reliable since it is without moving parts.

The panels produce direct current (DC) electricity, but the electric grid is an alternating current (AC) system. An electronic *inverter* between the panels and the grid converts from DC to AC, and it is relatively expensive. It develops heat, therefore it must be cooled, either passively by a self-circulating flow of the surrounding air, or actively by a built-in electric fan (low noise, but audible). Running the fan costs a little bit of energy, therefore the inverter should be placed in a shady, cool location if possible. The whole inverter switches off at about 65 degrees C to prevent damage.

The panels are mounted on rails of aluminium profiles that are bolted onto the beams that carry the roof. Electric wires interconnect the panels in groups of fairly equal size. On Figure 1 there are three groups of 9, 8, and 9 panels each. If there is a fault in one group, the two other groups will still produce energy. The wires are kept as short as possible in order to minimise electric losses.

Losses directly affect the economy. The panels actually loose 87% of the energy coming from the sun, or in other words the utilisation of the available solar energy is only 13%. The inverter looses at least 3% of its incoming energy to heat, and there are additional heat losses in the wiring in the system. Furthermore, the panels perform poorer the warmer the weather is.

The overall efficiency of the whole system may be as low as 11-12%. On the other hand the lifetime is long — generally estimated at 30 years — so it may be an economically viable investment after all.

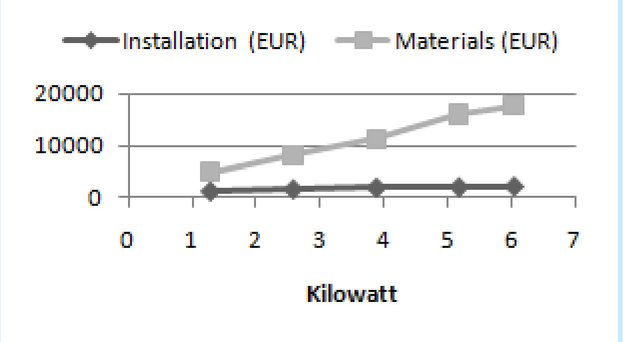

Fig. 2. Cost according to size. The installation cost is stacked on top of the materials cost. The total cost is almost linealy increasing with size in kilowatt (prices from Brdr. Stjerne Feb 2012).

The installer *Brdr. Stjerne* offers five different packages of different capacities below the 6 kilowatt limit for net metering. The installer split the price of a package into materials and installation, see Figure 2. This is because the installation could become more expensive in case it is a complicated installation.

In each package the inverter determines the capacity, so the installer has fit the number of panels to the capacity of the inverter. It is important that the house owner selects the correct size of the system, because adding more panels later, would cost him a new inverter.

The figure shows that the total cost increases more or less linearly with the size of the system. The installation becomes a relatively smaller proportion of the total cost when the system is large. For a large system we could say that the materials cost dominates the installation cost, and since the panels generate the income, a larger system has to cover relatively less overhead. There is, after all, a benefit from economies of scale; that is, the larger the system the better the economy.

The electricity production depends on the number of sunny hours per year and the intensity of the sun. A combination of these affect the energy production. It also depends on orientation and slope; on Samso the optimal slope is 40 degrees, and the optimal orientation is 2 degrees east of South (PVGIS). If the panels face due West, the production will be 75% of due South.

Example (solar radiation potential) Assume the geographical location is good — relative to the average solar activity in the country — such that the number of sunny hours is 1.1 times the average (10% above average) and the intensity also 1.1 times the average (10% above average).

Then the available energy is 1.1 * 1.1 = 1.21 times the average, or 21% higher than average.

In the example two increases of 10% resulted in a bonus of 21% more energy. Islands and peninsulas in Denmark often have more sunny hours and more solar intensity as well; islanders may thus benefit from their remote location. The variation of the solar energy potential within Denmark is approximately +/- 5% (PVGIS).

Net Metering

On a sunny day, when the PV panels produce more than the home consumption, the surplus electricity is fed into the public grid. Due to the *net metering* arrangement the electricity meter is allowed to 'run backwards'. When the production is less than the home consumption, the public grid will deliver the deficit. When the production is larger than the domestic consumption, the public grid will accept the surplus production.

It is more sunny during summer time, so the production will be high. The meter is able to measure inflow and outflow, and it will accumulate the annual balance. If there is a net annual outflow to the grid the electricity price will be lower than the buying price. Normally the annual production is less than the home consumption, however, and the production thus helps to pay the household's electricity bill. The selling price for a kilowatt-hour is thus the same as the buying price, and it is tax free.

Since 2010 all renewable energy installations below 6 kilowatt are allowed to use net metering in Denmark.

Pre-Calculation from Sales Material

The installer uses for Samso the key figure 1 049 kilowatt-hours per installed kilowatt in order to estimate the annual energy production for a given size of installation. A maximum size installation of 6 kilowatt should then produce about 6 300 kilowatt-hours in a year. For comparison, a household wind turbine at 6 kilowatt produces nominally 11 000 kilowatt-hours in a year, but it is also more expensive to buy (Household Wind Turbine).

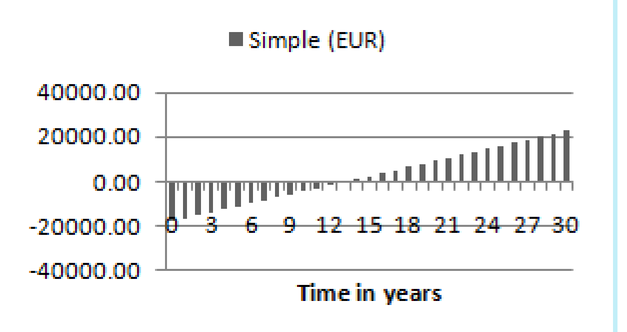

Fig. 3. Simple project balance. The size of the installation is 5.16 kilowatts (data from Brdr. Stjerne Feb 2012).

If we take the second largest package (5.16 kilowatt) from the installer the total investment is 18 100 EUR. The installer estimates that the annual production will be 5 460 kilowatt-hours. With an estimated electricity selling price at 1.87 DKK/kWh (0.25 EUR/kWh), Figure 3 shows the simple (without interest) project balance.

With the installer's assumptions, the simple payback period is 14 years and the internal rate of return (IRR) is 6.3%. At the end of the lifetime, after 30 years, the surplus is more than 22 000 EUR. It looks like a good investment, especially since the payback period is less than half of the lifetime; there is room for uncertainty and risk, for instance regarding the electricity price or the political regulations around net metering.

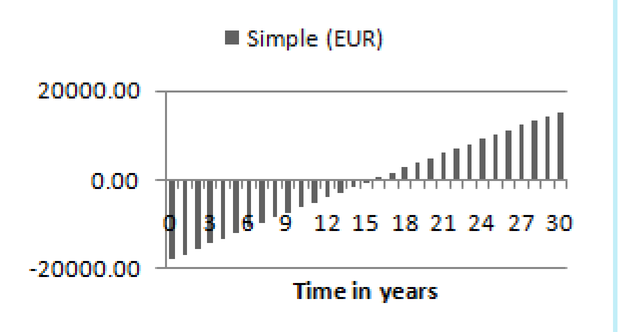

Fig. 4. Same as previous figure, but with marginal electricity price 1.67 DKK/kWh (0.223 EUR/kWh) and degradation due to ageing.

Even though it looks like a sound investment, the payback period is rather long for a private household. If the owner should wish to move to another home before the investment is paid back, he can hope for a better price for the home due to the PV panels, but there is no guarantee. Also the technical development may be such that panels with a better efficiency at a cheaper price may appear on the market in a few years. In that case the owner must again calculate whether it pays to switch to the new technology.

With a lower electricity price the picture changes somewhat. For a house with a large demand for electricity, for instance a house with an electric heat pump, there is a discount above 4 000 kilowatt-hours. The kilowatt-hours from the PV system reduce the electricity bill from the top end. If for instance the consumption before the PV system was 10 000 kWh, and after the PV system it is 5 000 kWh, then we have to use the price of the topmost 5 000 kWh, that is, the *marginal price* of a saved kilowatt-hour. In 2011 that price was 1.67 DKK/kWh (0.223 EUR/kWh), which is lower than what the installer assumed.

Furthermore, the PV panels degrade over the years due to ageing. Ultraviolet radiation, heat, frost, and corrosion erode the performance gradually over the years. The manufacturer guarantees at least 97.5% output for the first two years, then less than 0.63% linear performance reduction each year.

Figure 4 includes the lower electricity price and degradation. The simple payback period is now 16 years (up from 14) and the internal rate of return (IRR) is 4.7% (down from 6.3%).

Post-Calculation of Actual System

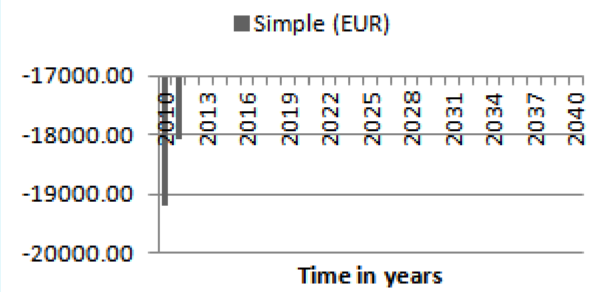

Fig. 5. Actual project balance in current prices.

The actual system (Fig. 1) is a little bigger than the previously treated installer package. It was also more expensive, because there were some complications and a price drop soon after the installation.

Figure 5 shows the actual project balance. The system was installed in 2010 and set into operation in the beginning of 2011. Therefore the time series is still very short.

The actual marginal price is the same as in Figure 4, but the production was higher than expected in the sales material. The electricity production in 2011 was 1075 kilowatt-hours per installed kilowatt. This is higher than expected, and it is due to a good location.

At the moment (end of 2011) the outlook is that the payback period will be 18 years and the internal rate of return (IRR) 3.6%.

Monthly Production

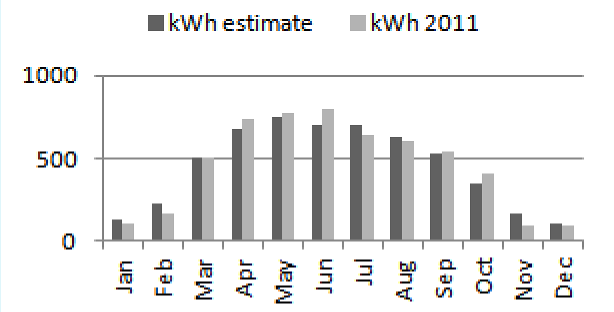

Fig. 6. Actual monthly kilowatt-hour production (kWh 2011) and estimate (kWh estimate).

The first year of operation gives a good indication of the future production, naturally. Production numbers were collected every month to give an idea of the seasonal variation, see Figure 6. The figure shows that the maximal production was in May, which is perhaps a surprise since the Summer Solstice is not until late June. The reason is most likely that May is cooler, and the panels perform better in cool weather. Actually, a temperature drop of 10 degrees improves the performance by 4.8% according to the datasheet.

It is also possible to estimate the monthly production by means of the web-based Photovoltaic Geographical Information System (PVGIS). For a given geographical location, that the user picks on a map, PVGIS returns an estimate of the monthly production. PVGIS must know the system losses after the panels (3% in our case), the panel surface slope (45 degrees in our case), and the compass bearing (7.5 degrees westerly from south in our case).

The estimates are plotted in Figure 6, and the actual 2011 production fits well. The estimates are consistently higher during the winter period; this may be due to shade from nearby trees when the sun is low on the horizon. The actual annual production is only 0.2% off the estimated production.

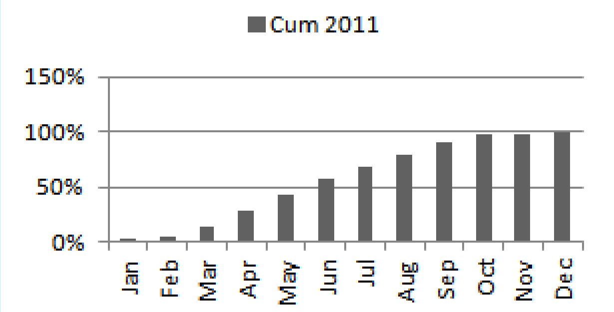

Fig. 7. Energy counter. Cumulative actual production (2011) in percentages of the full year production.

Figure 7 shows how the kilowatt-hour counter grows month-by-month (2011). The numbers are normalised, and the diagram shows the production in percent of the full year production. The diagram shows that at the end of May, the panels had produced almost half of the production (42%), and by the end of August almost 80%.

By the end of August in future years, it should thus be possible to make a rather good guess at the final annual production.

Specifications

Energy	
Power rating	5.07 kWp
Production 2011	5 450 kWh (index 103)
Production per kWp 2011	1 075 kWh/kWp
Panels	Scheuten Solar Multisol P6-54 UL series 195 watt
Inverter	SMA Solar Technology, Sunny Boy 5000TL

Turn-key contractor	energiTech, Samso
Dimensions	1 panel is 1-by-1.5 metres, 26 panels, 39 square metres
Environment	
CO_2 (greenhouse gas) 473 g/kWh	2 490 kg
CH_4 (greenhouse gas) 0.24 g/kWh	1.260 kg
N_2O (greenhouse gas) 0.006 g/kWh	0.032 kg
Greenhouse gases (CO_2 equivalents) 480 g/kWh	2 530 kg
SO_2 0.07 g/kWh	0.369 kg
NO_x 0.34 g/kWh	1.790 kg
CO 0.15 g/kWh	0.791 kg
NMVOC (unburnt hydrocarbons) 0.05 g/kWh	0.264 kg
Particles 0.01 g/kWh	0.053 kg
Reference: NRGi Net 2010	
Economy	
Owner	Private
Start-up date	1 Jan 2011
Nominal lifetime	30 years
Marginal electricity price 2011	1.67 DKK/kWh (0.223 EUR/kWh)
Investment (2010 prices)	
Equipment and installation with tax	144 049 DKK (19 207 EUR)
Price per kWp	28 400 DKK/kWp (3 790 EUR)

External Links

1. %BrdrStjerne%
2. %NRGInetEldklaration%
3. %PVGIS%
4. %ScheutenSolar%
5. %WikipediaNetMetering%
6. %WikipediaPVsystem%
7. %WikipediaSolarInverter%

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Energy Efficiency, Private Residence

Fig. 1. Private house on Samso. Built in 1906 as a small farm. The heated floor space is 273 square metres (the two larger buildings).

In one of our case studies (Ground Heat, Private Residence), a model estimates the energy consumption of a private house depending on outdoor temperatures. Given a record of the actual number of degree days summed over a week, the model provides an estimate to be compared with the actual energy consumption for that week.

This is useful for at least two purposes: 1) a large deviation is a sign of an irregularity, and 2) if the actual consumption is lower than the estimate, the inhabitants of the house have saved energy.

It is a way to motivate energy efficient behaviour, because the deviation from the model acts as an *econOmeter* that shows every week if the actual consumption is above or below the expected values.

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Annual consumption

The private home in question is a family dwelling consisting of a main building (Figure 1, right), a smaller annex (Figure 1, left), and an unheated garage (Figure 1, front). The main heat source is a ground source heat pump (Vølund) providing heating for both houses. A solar collector (Batec) on the roof of the annex provides supplementary hot water during spring, summer, and autumn. Hot water flows through radiators in the two buildings to heat the rooms, and each radiator has a valve (Danfoss) with a thermostat that keeps the room temperature steady. The ground heat installation operates on electricity; therefore the house is electrically heated, and it is relatively easy to record the energy consumption.

Figure 2 shows the annual electricitry consumption over a range of eight years. The electricity supplier uses those numbers to estimate the quarterly installments of the bill. At the end of the heating season the supplier asks for the reading of the electricity meter, and then he adjusts the electricity bill to reflect the exact consumption. The annual energy consumption depends on the weather, however, specifically the number of *heating degree days* for that year, so it can be difficult to predict; therefore the final payment may deviate somewhat from the pre-paid installments.

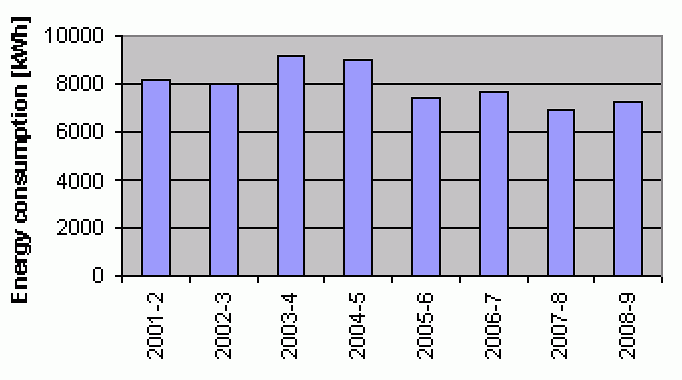

Fig. 2. Annual energy consumption. There was an increase in 2003, and two years were more expensive. Then the energy consumption dropped.

In order to compare the energy consumption year-by-year, we calculate the key figure *average energy per degree day*,

average energy per degree day = annual consumption [kWh] / annual heating degree days [HDD]

Figure 3 is a plot of the energy per degree day for the same period of years. The energy per degree day is relatively steady, it stays within roughly +/- 15 percent of the mean value, except for the last year which was exceptional. Most years lie in the interval 3.0 - 3.5 kWh/HDD. Apparently this home requires that amount of energy — given its state of insulation, leaks, and the number of windows — to keep it warm enough to be comfortable. That is the *observed energy demand* of the house depending on degree days. But the energy demand also depends on the inhabitants' behaviour. To be energy efficient, a *target demand* is chosen in the lower end of the interval,

target demand per HDD = 3 kWh

We wish to be below this figure at the end of the year. The value is low, but it seems possible to achieve by energy efficient behaviour according to Figure 3. In any case it acts as a reference for further analysis. All other things equal, the demand per HDD is in principle a characteristic constant that reflects the energy losses through the envelope of the house as well as the behaviour of the inhabitants. The actual losses also depend on wind and solar irradiation, however, and these have been neglected.

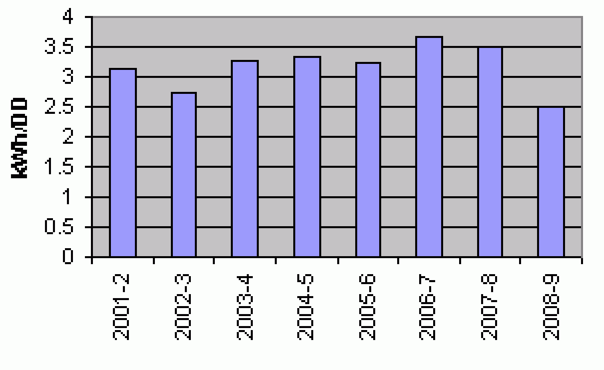

Fig. 3. Energy per degree day. The two periods from 2006 to 2008 were the least efficient. The period 2008 -

2009 was good, but that is because the house was empty for six weeks, and the heat pump was off.

Energy characteristic

A dedicated electricity meter measures the electricity consumption due to the heat pump and auxiliary equipment (pumps, electronics). The meter is read off manually every week, if possible.

Figure 4 is a plot of the historical measurements of energy consumption against heating degree days, HDD, that are derived from outdoor temperature measurements. The set of data points in Figure 4 corresponds to more than seven years of operation.

It shows that the energy consumption increases with the number of degree days, but it is not quite a linear dependency. On top of the data points is a line depicting the target demand per HDD.

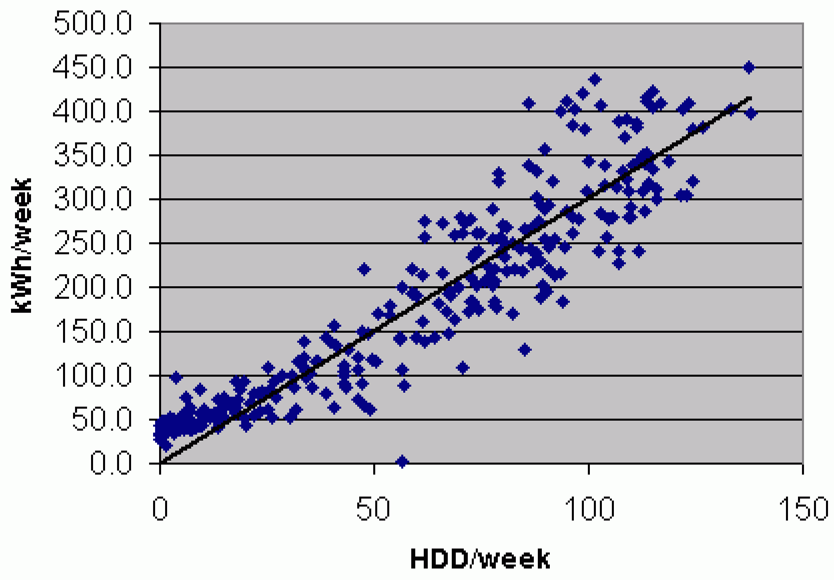

Fig. 4. Target efficiency. The data points are simultaneous measurements of energy and degree days. There is variation, especially in the high end. The straight line represents the target demand 3 kWh/HDD. Data points falling below the line are from weeks with a good efficiency.

The data points are distributed around an imaginary characteristic function that determines the energy demand as a function of the outdoor temperature (degree days).

The data points vary considerably due to unmeasured effects, such as wind and sun, and also changes of behaviour (visitors, adjustments to radiator valves, open windows). There is also a solar panel in the installation that affects the energy measurement.

Apparently there is an electricity consumption even when the degree days are zero. That is because the heat pump must produce hot water for the bathroom and kitchen even when it does not produce space heating. This is the *degree day independent consumption*, and it is present all year round. It can be read off the vertical axis at zero degree days.

In general the data points tend to curve upward. In fact, a second order model *M2* of the form

$$y = ax^2 + bx + c$$

provides a more accurate fit to the measured data points. Here *x* is the HDD value, and *y* is the model's estimate of the kWh value. The constants {a, b, c} must be adjusted so that the curve fits the data best. This can be done conveniently in a spreadsheet program, see

Figure 5. The upward curvature shows that increasingly more energy is needed in colder weather. One reason is that the ground pipes collect less heat from the ground when it is cold. A second reason is the low solar irradiation on the house during the three winter months while at the same time winds are stronger than usual. A third reason is the diminishing contribution from solar panel as we move toward the winter season.

The model cuts through the observed data points (Figure 5), such that the sum of the squared vertical distances from all points to the line is minimal.

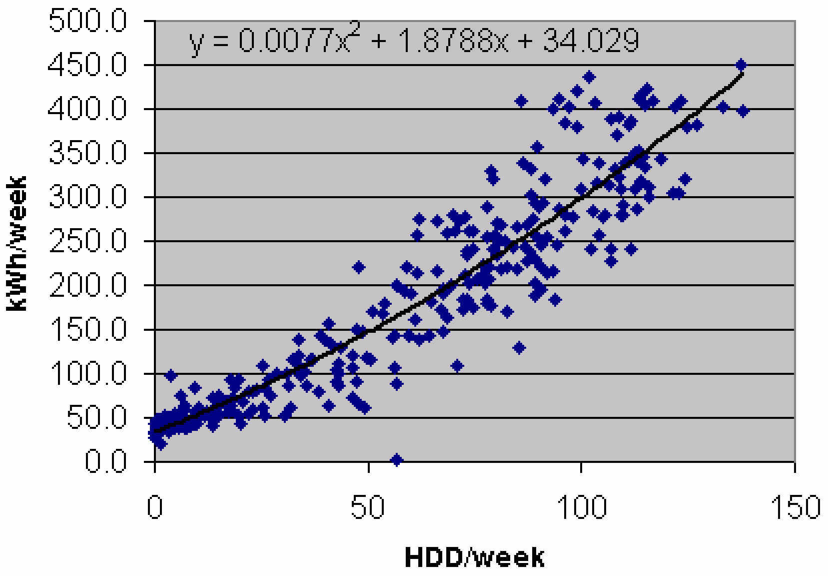

Fig. 5. Energy characteristic (solid line). The line is the model *M2* of the heat production. Assuming the model has the form of a second degree polynomial, the line is the best fit to the data points.

Simulation

The model can estimate the energy consumption given a degree day value. Figure 6 shows the model estimate together with the actual energy consumption. By observation, there is good agreement in the last 2/3 of the period, while the actual consumption in the leading 1/3 is somewhat higher than the model. The deviation is most likely due to an occupant, who required a higher setting of the radiator thermostats than usual.

The model only considers degree days. A windy, cold week will generate a measurement higher than the estimate. By the same reasoning, high solar irradiation will result in an energy measurement lower than the model estimate. These unmodelled effects are especially pronounced in the winter time, where they make more difference.

It is also possible to detect irregularities or failures. If the actual consumption is much larger than the estimate, for no known reason, it could be a sign of a technical failure somewhere in the heating installation.

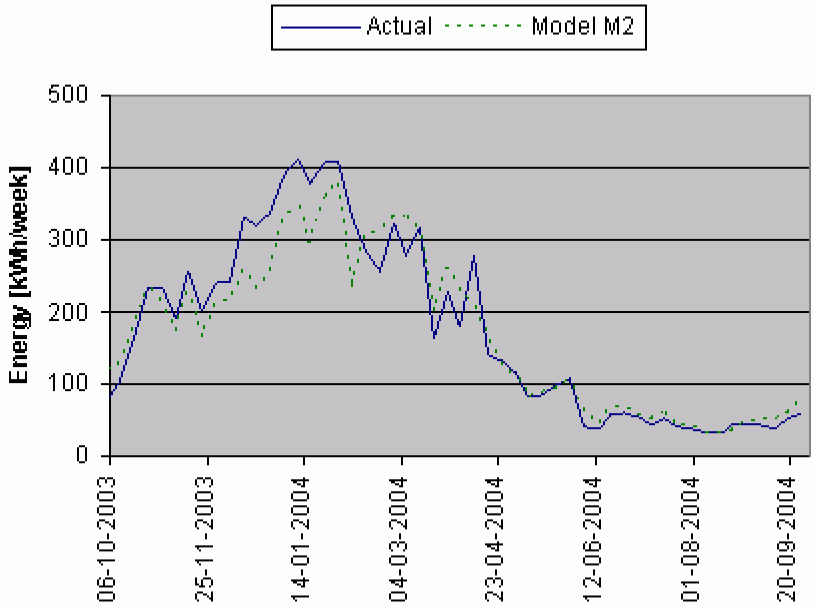

Fig. 6. Actual energy measurements and model. Given the actual degree days, the model estimates the energy consumption. Disagreements are due to unmodelled influences, such as wind, sun, visitors, or change of settings on the heat installation.

EconOmeter

By changing behaviour, or by simply turning the heat down, the inhabitants can influence the energy consumption. Thus, if the houseowner manages to stay below the black line in Figure 5, energy will be saved.

From the viewpoint of Figure 6, the goal is to stay below the model estimate, the dotted line in the plot. Figure 7 shows the distance between the model and the actual energy consumption. The diagram is renewed every week. It acts as an *econOmeter* in the sense that an actual consumption higher than the model estimate, alerts the owner to take action to compensate for the loss. For example, the owner could decide to save energy the following week, either by turning the radiators down or by making adjustments to the settings of the installation.

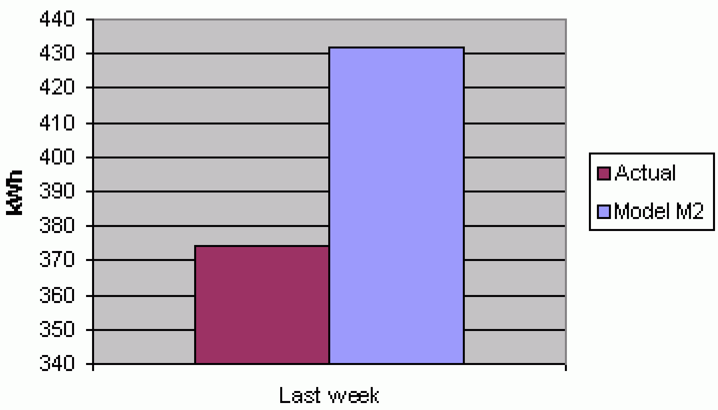

Fig. 7. EconOmeter. The actual consumption was less than the model, and energy was saved.

External links

Degree Days.net: HDD and CDD for locations worldwide

- Wikipedia: Heating degree day

Created by system. Last Modification: Saturday 23 November 2013 11:28:43 CET by jj.

Cost Benefit Analysis of the Ballen-Brundby Plant

Created by jj. Last Modification: Saturday 26 March 2011 00:42:53 CET by jj.

Introduction to Cost Benefit Analysis

Cost Benefit Analysis

Cost Benefit Analysis (CBA) is the flow of costs of a project over its entire lifetime versus the flow of benefits of a project over its entire lifetime. By costs, we mean ALL the costs associated with the project; the financial costs measured in currency, the environmental costs measured in noise disturbances, impact on wildlife, emissions cost of transport and construction, impact on future generations etc. Likewise, by benefits we mean ALL the benefits from a specific project, financial, environmental, social etc.

Furthermore, the analysis must be compared to the most likely alternate scenario, usually a continuation of the current scenario. For the example in this section, the proposal is for a straw-based district heating plant in an area where heating is predominantly supplied by individual oil-based furnaces. Therefore all the costs and benefits of a corresponding investment in oil-based furnaces have to be calculated as a flow over the lifetime of the project.

Ideally, all costs and benefits can be monetized such that the conclusion can be summed as one number; a negative value if the proposal worsens the socioeconomic balance relative to the closest alternative, and a positive value if the proposal improves the socioeconomic balance. A positive value indicates a net improvement of welfare - i.e. the total benefits of the project outweigh the total costs, *and* the project is a better use of resources than the closest alternative.

In addition, the stream of monetized costs and benefits is discounted over time, resulting in a net present value (Net present value). The rate of discount used is generally set by a regulatory authority for national guidelines on cost benefit analyses, in order to secure comparability across projects.

For Denmark the guideline for socioeconomic analyses in the energy sector is released by the Danish Energy Authority and can be found on the following page:

Guideline for Socioeconomic Analysis

Additionally, the Danish Energy Authority has calculated a series of standard values to be used for energy calculations, which can be found here:

Overview of key assumptions for socioeconomic calculations

Unfortunately, both sites are only available in Danish.

The table below shows some of the given emission coefficients for heat producing boilers based on some fuel sources. Source: Table 7 of the key assumptions for socioeconomic calculations from DEA database.

Table 1. Overview of emission coefficients

Fuel	Boiler type	CO2	CH4	N20	SO2	NOx
-	-	Kg/GJ	g/GJ	g/GJ	g/GJ	g/GJ
Electricity	Central power plant	N/A	16.3	26.0	636	1318
Biogas	District heating plant	0	4.0	2.0	25.0	28.0
Hay	District heating plant	0	32.0	4.0	130.0	90.0
Heating oil	Private boiler	74.0	1.5	2.0	23.0	52.0
Wood pellets	Private boiler	0	200.0	4.0	25.0	120.0
Natural gas	Private boiler	56.8	6.0	1.0	0.3	30.0

The corresponding guideline for socioeconomic analyses in the UK can be found here:

Economic Assessment of Spending and Investment

EU related links

;Evalsed : Evalsed is an online resource providing guidance on the evaluation of socio-economic development

;CBA : Guidance on the Methodology for Carrying Out Cost-Benefit Analysis

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Overview of the Economic Feasibility

Appraisal of Renewable Energy Projects with Cases from Samso > Cost Benefit Analysis of the Ballen-Brundby Plant > Overview of the Economic Feasibility

Introduction

Please refer to ((District Heating Plant, Ballen-Brundby)) for background information on the plant.

Fig. 1 Ballen-Brundby District Heating Plant

This section presents an overview of the economic feasibility of the plant. The plant was constructed in 2004 and began operations in 2005. The numbers in this section are primarily based on a MSc thesis released in September 2009. The full report can be found here: seacourse.dk/download/Groth09.pdf

The table below presents the project scenario for the plant and the reference scenario for the continued use of oil and electrical heating. All values are held constant in 2007-prices (i.e. no inflation effect). The breakdown of the numbers can be found in Costs in the project scenario and Costs in the reference scenario, respectively.

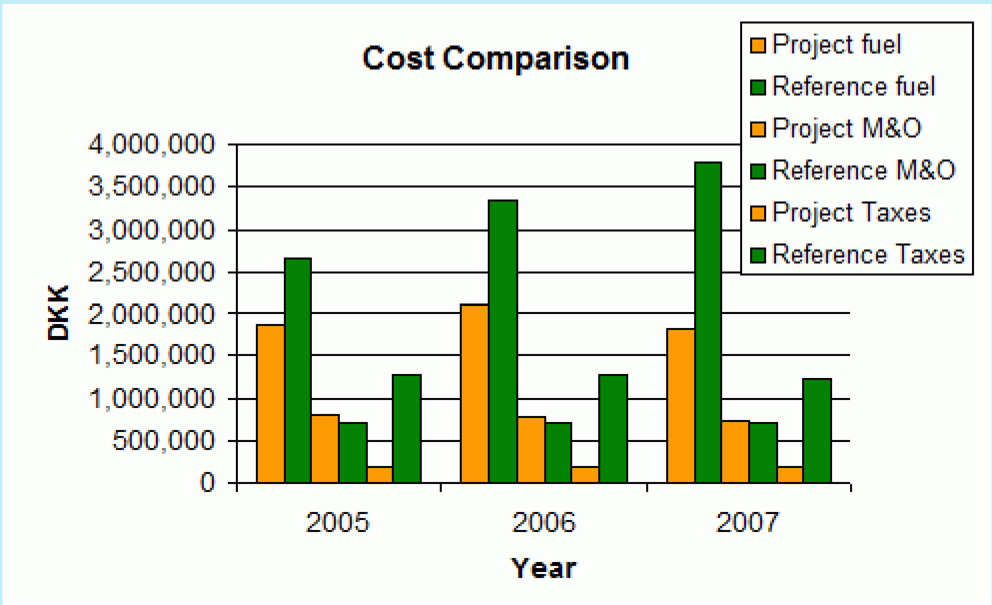
Table 1. Project and Reference Scenario Specifications

Specifications	Value	Project Scenario	Reference Scenario
Lifetime	Year	20	20
Investment	DKK	16 752 009	N/A
Gross demand	MWh/year	7 651.5	6 056
Electrical heat consumption	MWh/year	550.4	530.4
Oil fuel consumption	MWh/year	72	5 526
Net distribution loss	App. %	31.5	N/A
Boiler efficiency	App. %	84	84
Operation costs	DKK/year	363 149	432 608

CO2 emissions	Tons/year	486.7	1 923

In order to illustrate the net impact of the district heating plant, all calculations will be compared against a reference scenario, where local buyers reinvested in a private oil furnace rather than connecting to the district heating plant.

The graph below shows a cost comparison of annual payments to the district heating plant (orange bars) and the individual oil furnaces (green bars) to fuel, state taxes and maintenance and operation costs for the first three years of plant operation. All values are including VAT.

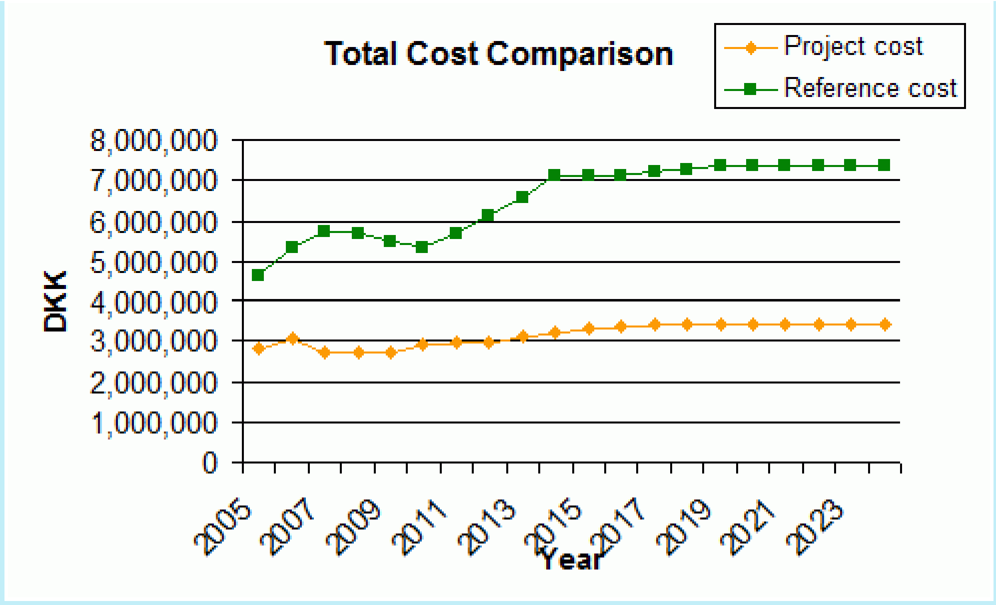


The first two bars for each year show the fuel costs, which increase for the oil-based consumers over the three years (the green bar). The changing fuel costs for the district heating users reflect changing real prices for oil and straw.

The middle two bars show the maintenance and operation costs for the individual oil furnaces (green) and the district heating plant (orange). Although the costs appear to be higher for the district heating plant, the costs of maintenance for the individual oil furnaces are understated - for example, time spent cleaning the oil furnace or waiting for oil deliveries have not been monetized and included. M&O costs for oil furnaces are assumed equal to 1 755 DKK per household.

The final two bars show the taxes payable on the emissions from either the straw-based district heating plant (orange) or from the individual oil furnaces (green). Specifically, oil-fired heating incurs an energy tax, a CO2 tax and a sulphur tax. Straw-fired heating only incurs a sulphur tax, which is why it is so much lower than the green bar.

The graph below shows the development of the costs for the project and the reference over time.



The bottom line represents projected fuel costs, taxes and maintenance and operation costs for the individual oil furnaces for 258 consumers. The top line represents the same costs for 258 district heating consumers. All projections are based on averages from the 2009 Danish Energy Authority guidelines for socioeconomic assessments.

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Composition of heating demand in the area

A survey conducted in 2002 by the workgroup behind the Ballen-Brundby district heating plant received a total of 178 responses from a total of 290 potential consumers in the area.

The energy demand at the time consisted of the following:

- 171 households and 7 large consumers (industry, hotels)
- Avg. household size = 125.2 m2
- 145 households with an avg. oil-based heating demand = 2 150 litres/year
- 18 households with an avg. electrical heating demand = 10.73 MWh/year
- 8 households with an avg. combined oil/electrical heating demand = 1 763 litres + 9.79 MWh /year
- Avg. heating demand from large consumers equal = 67 MWh/year (for simplification, we are going to assume the large consumers are ordinary households in this example, with energy consumption like the oil-based households).

Given that the energy content of oil is 10 KWh/liter (Energy content) the energy consumption of oil is 21.5 MWh/year with solely oil-based heating demand(note that this is not equal to the energy demand, as this needs to be multiplied with the energy efficiency rate for an oil furnaces. Assuming that none of the furnaces are from before 1977, the average efficiency rate is 0.77 (Heat source efficiency) which gives a heating demand of 21.5*0.77 = 16.55 MWh).

In addition to oil consumption, an oil-based boiler uses electricity to work the burner, to circulate heat and for automatic responses, if the boiler is automated. The circulation pump alone uses at least 175 KWh annually in an average household (unless it is a new, energy efficient model), whereas the burner and the automation use a minimum of 100 KWh/year and 35 KWh/year, respectively (Campaign from the Danish Energy Agency) This sums to a minimum of 310 KWh/year per boiler.

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Costs in the Reference Scenario

Appraisal of Renewable Energy Projects with Cases from Samso > Cost Benefit Analysis of the Ballen-Brundby Plant > Costs in the Reference Scenario

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Reference scenario heating costs

Appraisal of Renewable Energy Projects with Cases from Samso > Cost Benefit Analysis of the Ballen-Brundby Plant > Costs in the Reference Scenario > Reference scenario heating costs

Assuming the respondents to the survey are representative of the area, the following calculation holds:

Total household heating demand

- Oil consumption: 85 % of the population own oil-based boilers and consume 2 150 liters of oil a year. 0.85*290*2 150 = 528 700 liters of oil/year
- Additional oil consumption: 4.7 % own a combination of oil and electrical heating, consuming 1 763 liters of oil/year. 0.047*290*1 763 = 23 919 liters of oil/year

- *Total oil consumption: 552 619 liters of oil annually = 5 526 MWh/year*

- Electricity consumption: 10.3 % own electrical heating and consume 10.73 MWh annually. 0.103*290*10.73 = 320.51 MWh/year
- Additional electricity consumption: 4.7 % own a combination of electrical and oil-based heating and consume 9.79 MWh a year. 0.047*290*9.79 = 133.44 MWh/year.
- Additional electricity consumption: 85 % own oil-based boilers which use a minimum of 310 KWh/year per boiler. 0.85*290*310 = 76 415 KWh/year

- *Total electricity consumption: 530.4 MWh/year*

Total household fuel costs

For simplicity, we will only be using the fuel costs of the base year. For 2004, the Danish Energy Agency estimated fuel costs ad household to be 74.4 DKK/GJ for heating oil and 63.2 DKK/GJ for electrical heating. Both prices are adjusted for inflation and in the 2007 price level.

- An oil consumption of 5 526 MWh equals app. 19 894 GJ, which results in fuel costs of 1 480 084 DKK excluding taxation costs etc.

- An electricity consumption of 530.4 MWh equals app. 1 909 GJ, which results in fuel costs of 120 677 DKK excluding taxation etc.

- *The above sums to total fuel costs for the area of 1 600 761 DKK in 2004.*

Greenhouse gas emissions from existing heating

The DEA table from Introduction to Cost Benefit Analysis gives the emission coefficients for certain types of fuels used in private and district heating plant boilers. In order to keep things simple, we will ignore other emissions and only concentrate on CO2 in this example. For oil-based private boilers, consumption of 1 GJ emits 74 Kgs of CO2. For electrical heating generated from central power plants, consumption of 1 GJ emits 236 Kgs of CO2. (Note that prior to 2008, the DEA did not estimate CO2 emissions for electricity ab household, as the price of CO2 is included in the household cost of electricity. The value used in this example is the estimate from 2008.)

- For an oil consumption of 5 526 MWh/19 894 GJ, corresponding emissions are 1 472 156 Kgs of CO2 (1 472.2 tons of CO2).
- For an electricity consumption of 530 MWh/1 909 GJ, corresponding emissions are 450 524 Kgs of CO2 (451 tons of CO2).
- *The above sums to a total of 1 923 tons of CO2 alone*

Cost of emissions

Up until 2010, a CO2 tax of 25-90 DKK/ton existed for the light and heavy industries, but this was slowly phased out in favour of a CO2 quota price in 2010, with prices rising from 105 DKK/ton in 2010 to 290 DKK/ton in 2030 (2008 price level). For simplicity, a CO2 tax of 90 DKK is assumed for the entire period in this example. This tax has to be multiplied by the net social impact factor of 1.17, resulting in a net cost of 105.3 DKK/ton of CO2.

Disregarding the fact that electricity prices already include the payment of CO2 taxes, total costs of CO2 can be assumed as:

- *1 923*105.3 = 202 492 DKK annually*

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Other reference scenario costs

Appraisal of Renewable Energy Projects with Cases from Samso > Cost Benefit Analysis of the Ballen-Brundby Plant > Costs in the Reference Scenario > Other reference scenario costs

Non-monetized costs

In order to keep the example as simple as possible, most of the other external costs are ignored.

Examples of ignored costs

- Nuisance costs of ownership of private oil furnace - smell, noise and space irritants
- Comparison of fuel lifecycle costs (above and beyond those included in the sales price) - straw as a bi-product of wheat harvest, and a renewable form of energy, relative to oil which has a bequest value for future generations
- Other emissions such as SO2, NOx etc.

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Total reference scenario heating costs

Total household heating costs

Total household heating costs sum to **4 739 119 DKK** annually for the reference scenario. The breakdown of the costs is given below.

Total oil heating costs

- Energy tax on oil consumption equal to 179.6 DKK/MWh, resulting in total energy taxes of 5 526*179.6 = 992 470 DKK annually
- Total oil consumption equal to 552 619 liters annually, resulting in fuel costs of 3 090 693 DKK incl. energy taxes and VAT of 25 %
- Total oil emissions of 1 472 156 Kgs of CO_2, corresponding to 155 018 DKK annually
- Total household operation and maintenance costs of 1 755 DKK per oil furnace (DEA 2007), equivalent to 1 755*0.85*290 = 432 608 DKK
- *Total oil costs equal to 3 678 319 DKK annually*

Total electricity heating costs

Assuming an electricity price of 2 DKK per kWh incl. VAT, CO_2 costs and taxes, zero M&O costs, and an electricity consumption of 530.4 MWh:

- *Total electricity costs equal to 1 060 800*

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Costs in the Project Scenario

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Project scenario heating costs

Assuming the respondents in the survey are representative of the local population, and based on an 85 % subscription rate to the plant, total estimated heating demand from the plant is:

- 0.85 * total heat demand for the area

Total Heat Demand for the Area

In Reference Scenario Heating Costs we calculated heating based on litres of oil consumed, equal to 5 526 MWh/year. Actual heating demand is a fraction of this, as there is some loss from the furnace to efficient heating demand. Assuming a furnace has an efficiency rate of 0.84 (a middle value based on new and slightly older models, see Heat source efficiency);

- 0.84 * 5 526 = 4 642 MWh total heat demand from oil

It is normally assumed that electricity used for heat has no loss once it has reached the household, so the electricity consumption from Reference Scenario Heating Costs still applies.

- Total electricity consumption for heating: 530.4 MWh per year

For simplicity in this example, we will assume that all those who own oil-based boilers switch to the district heating plant, and the remaining 15 % use electricity for heating.

This results in a demand for heat energy from the district heating plant equal to:

- 4 642 MWh (oil) + 76.4 MWh (electricity for oil-based boilers) = 4 718.4 MWh

The remaining demand (outside of the district heating plant) is assumed met by electrical heating, and is equal to:

- 454 MWh/year

Total fuel costs for the area

The heating demand does not correspond to the heating consumption, due to distribution net loss and boiler efficiency rates of below 100 %.

Assuming a boiler efficiency rate of 0.84 (same as for the private oil burner above) and a distribution net loss of 31.5 %, total heating consumption becomes (approximately):

- (4 718.4 + (4 718.4*0.315)) + (6 204.7*0.16)
- 4 718.4 + 1 486.3 + 992.8 = 7 197.5 MWh

Straw has a given combustion value of 14.5 GJ/ton (app. 4 MWh/ton), when it has a moisture content of 15 %. Oil has a combustion value of 0.036 GJ/liter (app. 0.01 MWh/liter).

Assuming the plant runs on 99 % energy derived from straw and 1 % energy derived from heating oil (at peak load), we have the following energy requirements:

- (0.99 * 7 197.5) / 4 = 1 781.4 tons of straw
- (0.01 * 7 197.5) / 0.01 = 7 197.5 litres of oil

Additionally, it is assumed that the district heating plant uses electricity equal to 13.4 kWh/MWh (average taken from the 2009 statistics on fjernvarme.dk, the Danish district heating website, based on reported values from straw-based district heating plants producing less than 20 GWh/year):

- 0.0134*7 197.5 = 96.4 MWh of electricity.

Based on figures from the DEA for 2004, fuel prices of oil are 74.4 DKK/GJ and fuel prices of straw are 31.4 DKK/GJ, excluding VAT and other taxes.

This gives the following fuel costs for household heating:

- 14.5*1 781.4*31.4 = 811 071 DKK for straw
- 0.036*7 197.5*74.4 = 19 278 DKK for oil

Electricity prices are 63.2 DKK/GJ and 550.4 MWh correspond to app. 1 981 GJ. For total electricity consumption for heating used in the area, total electricity costs are:

- 63.2 * 1 981 = 125 199 DKK/year

Total fuel costs for the area equal 955 548 DKK in 2004

Greenhouse gas emissions for project scenario

Consumption of heating oil of 1 GJ emits 74 Kgs of CO2. For electrical heating generated from central power plants, consumption of 1 GJ emits 236 Kgs of CO2. (Note that prior to 2008, the DEA did not estimate CO2 emissions for electricity ab household, as the price of CO2 is included in the household cost of electricity. The value used in this example is the estimate from 2008.) Straw heating emits 0 Kgs of CO2, as it is a CO2-neutral fuel.

- For an oil consumption of 7 197.5 liters, CO2 emissions equal 19.2 tons
- For an electricity consumption of 550.4 MWh/1 981 GJ, emissions are 467.5 tons of CO2
- *Total emissions of CO2 in the project scenario are 486.7 tons*

Cost of emissions

For simplicity, a CO_2 tax of 90 DKK is assumed for the entire period in this example. This tax has to be multiplied by the net social impact factor of 1.17, resulting in a net cost of 105.3 DKK/ton of CO_2.

- *Total costs of CO_2 can be calculated as 51 250 DKK for 2004*

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Non-monetized costs

Same as for Other Reference Scenario Costs, other external costs are ignored.

Other external costs:

- Disruption in harmony of landscape from construction of plant (location of plant)
- Impact on local wildlife – although this appears to be minimal, as the local nature school does not think there has been any adverse impact
- Nuisance costs from installation of district heating pipes etc.
- Other emissions such as SO_2, NO_x etc.
- Reduction in ferry transport revenues, as there is a switch to locally sourced fuel

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Total project scenario heating costs

Total household heating costs sum to **2 317 325** DKK annually for the project scenario. The breakdown of the costs is given below.

Total district heating plant costs

Total district heating plant costs sum to 1 409 325 DKK annually. The breakdown of the costs is given below.

Energy tax on oil consumption equal to 179.9 DKK/MWh, resulting in total energy taxes of 71.9 * 179.9 = 12 948 DKK annually

Total oil consumption of 7 197.5 liters annually incl. energy taxes and VAT of 25 %:

- *Resultant oil fuel costs of 40 283 DKK*

Assuming an electricity price of 2 DKK per KWh incl. VAT, CO2 costs and taxes and an electricity consumption for the plant of 96.4 MWh:

Total electricity costs for the plant equal 192 800 DKK

With an annual consumption of 1 781.4 tons of straw and a price of app. 455.3 DKK per ton;

- *Total fuel costs of straw equal 811 071 DKK*

Total emissions from the plant correspond to the emissions from oil consumption (emissions from electricity are included in the price))

- *Total CO2 emission costs for the plant equal 2 022 DKK*

Total plant operation and maintenance costs equal 363 149 DKK annually

Total other electricity heating costs

For an electricity price of 2 DKK per KWh incl. VAT, CO2 costs and taxes and an electricity consumption for other heating of 454 MWh:

- *454 000 * 2 = 908 000 DKK annually*

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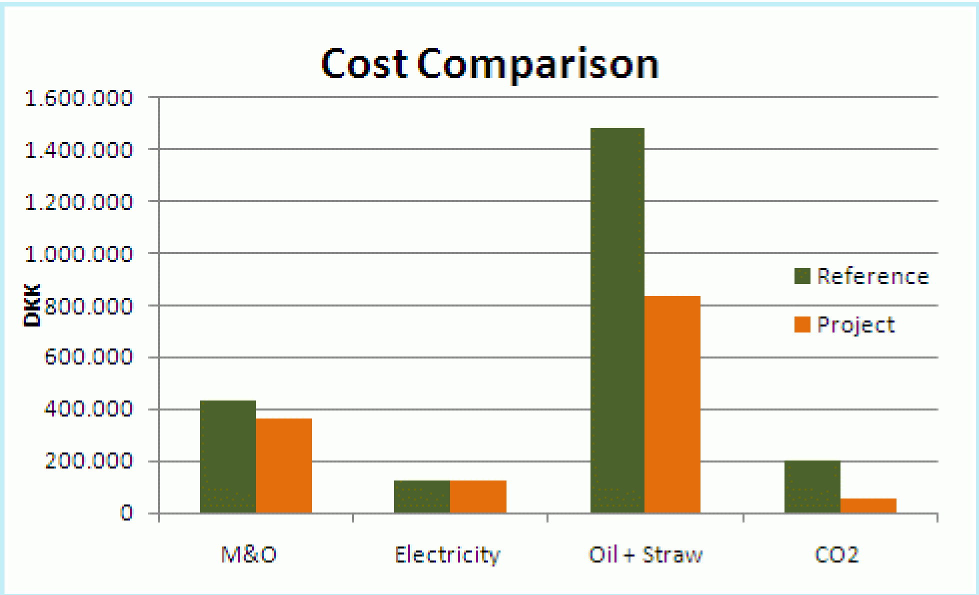
Cost Comparison

Cost Comparison

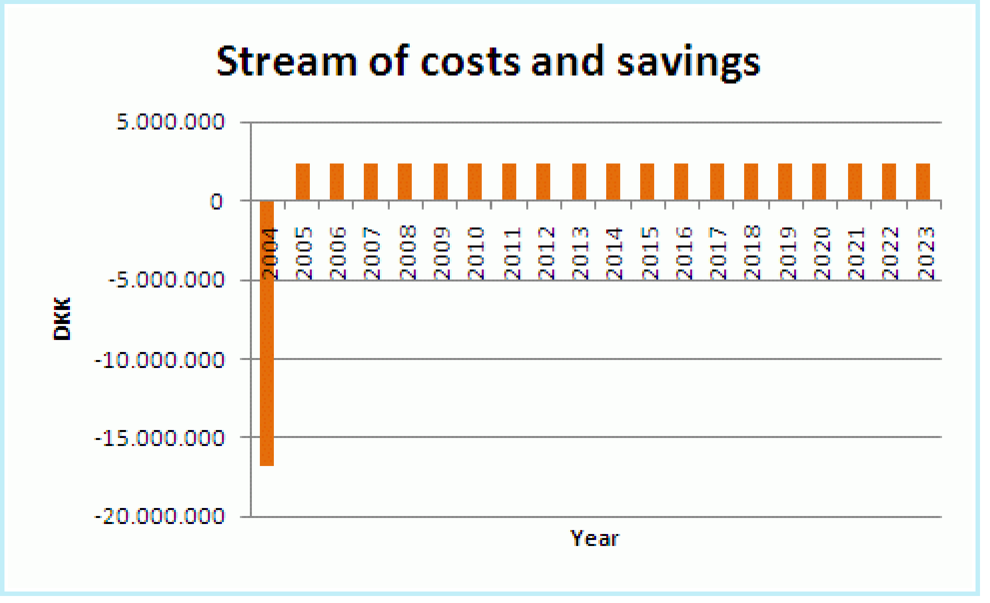
The graph below shows a comparison of fuel, maintenance and operation and CO2 emission costs from the project and reference scenarios.



The project scenario clearly has an advantage of lower annual costs than the reference scenario, but this is necessary since it also requires a significant up-front investment.

If we sum all the avoided costs and count them as savings relative to the reference scenario, we can generate an initial investment followed by a stream of increased income.

The image below gives the annual saved costs (Total reference scenario heating costs - Total project scenario heating costs) over time as a stream of income relative to the initial investement.



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NPV of the Ballen-Brundby Plant

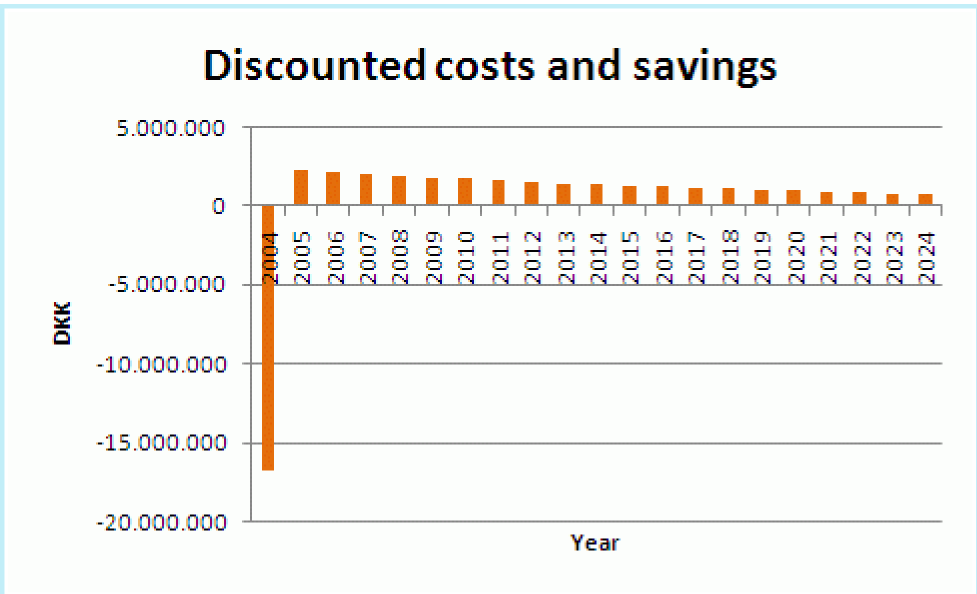
Appraisal of Renewable Energy Projects with Cases from Samso > Cost Benefit Analysis of the Ballen-Brundby Plant > NPV of the Ballen-Brundby Plant

Net Present Value

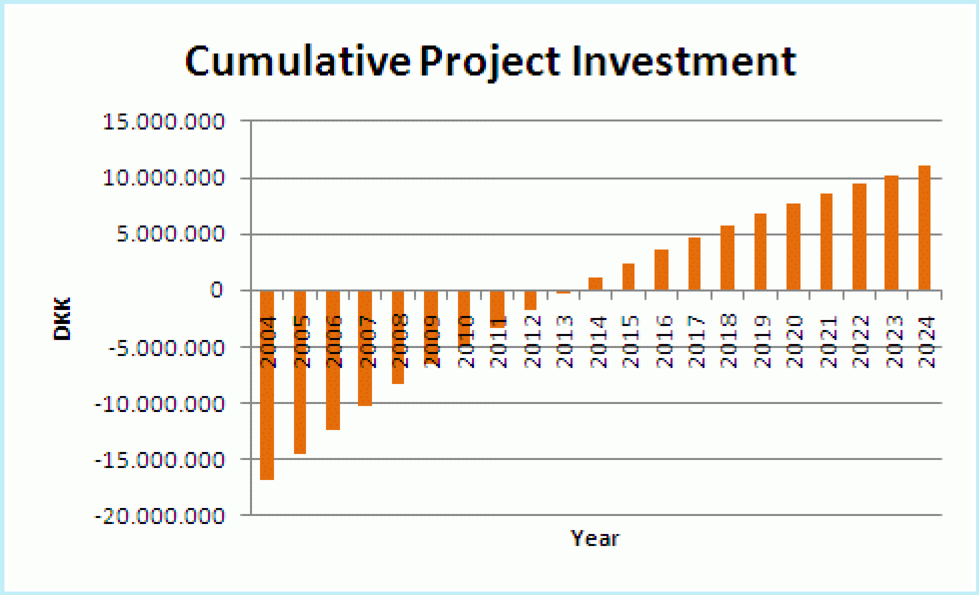
The stream of investment and savings in Cost Comparison is shown as a constant value over time. In an actual cost benefit analysis, costs and benefits over time have to be discounted to the year of analysis.

The Danish Energy Agency insists on the use of a discount rate equal to 6 %.

All prices are set to the 2007 price level (ruling out any effect of inflation) and all future savings from the project are discounted to the base year of 2004 using the recommended rate of 6 %. This results in the following discounted investment stream:



Relative to a scenario with continued use of oil-based heating, the straw-based district heating plant will pay itself off in 2014, in its 10th year of operation:



Assuming a scrap value of 0 and a lifetime of 20 years, the project has a positive NPV of app. 11 million DKK in 2004, after a discount rate of 6 %. Since this has been estimated relative to the a reference scenario of continued use of oil-based furnaces, the CBA strongly speaks in favour of the investment.

A NPV of 0 would indicate that the project was at least as good an investment as the reference scenario.

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Critique of the above CBA

Appraisal of Renewable Energy Projects with Cases from Samso > Cost Benefit Analysis of the Ballen-Brundby Plant > Critique of the above CBA

Some criticisms of the above analysis

The CBA conducted of the Ballen-Brundby District Heatin Plant is a strongly simplified version of what a real cost benefit analysis should look like. The aim of cost benefit analysis is to incorporate the social or communal element into a financial analysis, giving a broader picture of the associated costs and benefits of a given project above and beyond financial arguments.

A large number of factors was ignored in the above CBA, without which it is impossible to accurately present the full implications of a given project.

- The only externality taken into account is CO2 emissions. Other emissions (some of which increase when using straw as fuel relative to oil) were ignored, which skews the results in favor of the district heating plant.
- Transport of fuel in this project scenario is hugely relevant. Relative to importing half a million liters of oil each year, the project ensures a drop to 7200 liters of oil each year. Oil is mined and processed a very long distance away from its final use as heating fuel in Ballen and Brundby. As cost-benefit analyses are generally only concerned with the change in the *national* socioeconomic balance, we can ignore loss of revenue and work for non-national employees. However, the local ferry receives revenue for the truck transport of oil to the island, and the truck driver will probably also be affect the drop in demand.
- The substitution to locally grown and harvested fuel, which in this scenario is straw leftover from wheat harvests, increases the revenues of local farmers. CBA is notoriously lacking in terms of distribution evaluation. In some scenarios, there are additional benefits to redistributing income from one income group to another.
- In the scenario in this example, it is assumed that none of the oil furnaces will need to be replaced over the period. This is highly unlikely, as oil furnaces have a given lifetime of 15 years (Danish Energy Agency) and assuming they are not new at the beginning of the project, they will at least become substantially less efficient over the period calculated for.
- All prices are also assumed to remain constant at the 2004 level. However, specifically oil prices are expected to increase significantly over time, so the method of calculation in this example skews the results towards the oil furnaces.
- Taxes in this example have been included as a saved cost, but on a national level, they count as a loss of revenue to the Danish government.

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Energy Savings

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings

Created by jj. Last Modification: Sunday 26 September 2010 10:23:13 CEST by jj.

Introduction to Energy Savings

Created by system. Last Modification: Tuesday 10 January 2012 11:43:41 CET by jj.

Attitudes and behaviour

2/3 of the variation in electricity consumption comes from family attitude and behaviour

Fig. 1 Where do I put my food? (Photo: Kalmarhem, Sweden, via Energy Agency for Southeast Sweden.)

Group 1: Intentional energy saving behaviour

- Make a concerted effort to save.
- Possibly the result of upbringing: older generations or influences from abroad.
- A conscious choice to not waste money unnecessarily.
- For environmental concerns: reducing the strain on resources.
- Generally interested and easily reached. Continosly work at maintaining low consumption.

Group 2: Indifferent energy saving behaviour

- Agree in principle, but do little or nothing to save energy.
- Prioritize comfort over effort.
- Cannot be bothered to spend time on it.
- An appropriate group to approach, as their consumption is greater than necessary and they are not completely resistant to change.

Group 3: Refusal to alter energy consumption behaviour

- Smaller group, with high consumption. Unconcerned with high electricity bills. Unmoved by environmental concerns or limited resources.

- Despite the potential for large savings, there is little likelihood of successful communication.

(Gram-Hanssen 2005)

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How much can you save?

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Introduction to Energy Savings > How much can you save?

- A family of four in a house can save over 2 500 DKK/year (333 EUR/yr) tax free on the electricity consumption (Hurtigberegneren).
- The electricity consumption in houses is on the average twice as large as in apartments. Reasons are among others: that houses have a circulation pump, outdoor lighting, etc., which apartments do not have; that often fewer people live together in apartments; and that the household income in apartments is often lower than in houses, and thus the dwellers make a larger effort to save money.

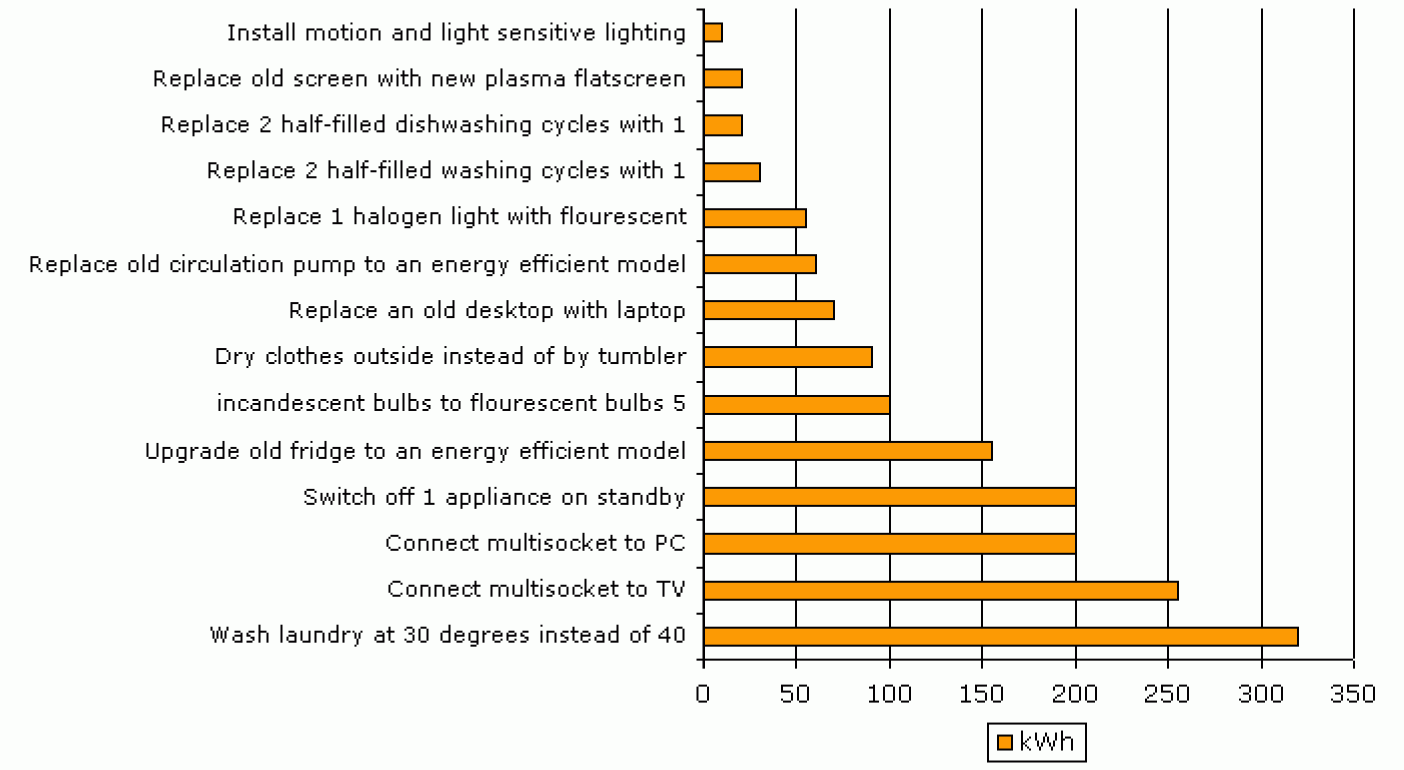

Fig. 1 Overview of savings (Elsparefonden, Hurtigberegneren).

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Electricity

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Who can save where?

Older consumers

- Homes with occupants over 60 years old often consume less electricity, as there are generally only one or two inhabitents. Per capita spending is generally at least as high as for younger generations.
- Older consumers use a smaller proportion of electricity on refrigeration and freezing. This may be due to older or oversized appliances from when their children still lived at home.
- Older consumers use more electricity on lighting.
- Older consumers use less electricity on dishwashing, laundry and drying.

Singles

- Singles have almost the same consumption patterns as the older consumers, i.e. more electricity goes to refrigeration/freezing and lighting.
- Less electricity is spent on cooking, dishwashing, laundry and drying.

Families with children

- Children under the age of 6 use less electricity than adults.
- Teenagers use 20 - 30 % more electricity than adults.
- More electricity is spent on dishwashing, laundry and drying when adults are between 30 - 50 years old.
- Smaller appliances and chargers consume more electricity.

(Gram-Hanssen 2005)

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Average apartment energy consumption

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Electricity > Average apartment energy consumption

If energy consumption is low, there is a lower savings potential

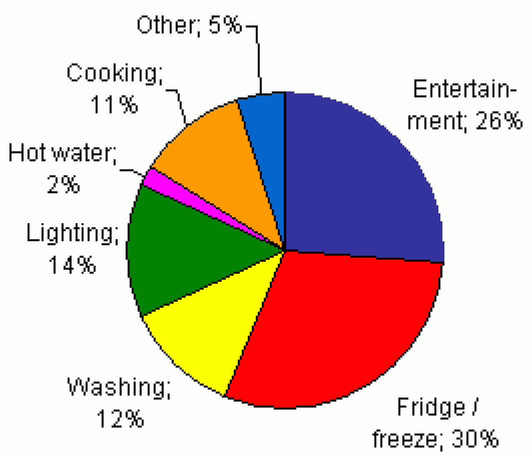

Fig. 1 Electricity consumption in an apartment (Source: Elsparefonden and Dansk Energi).

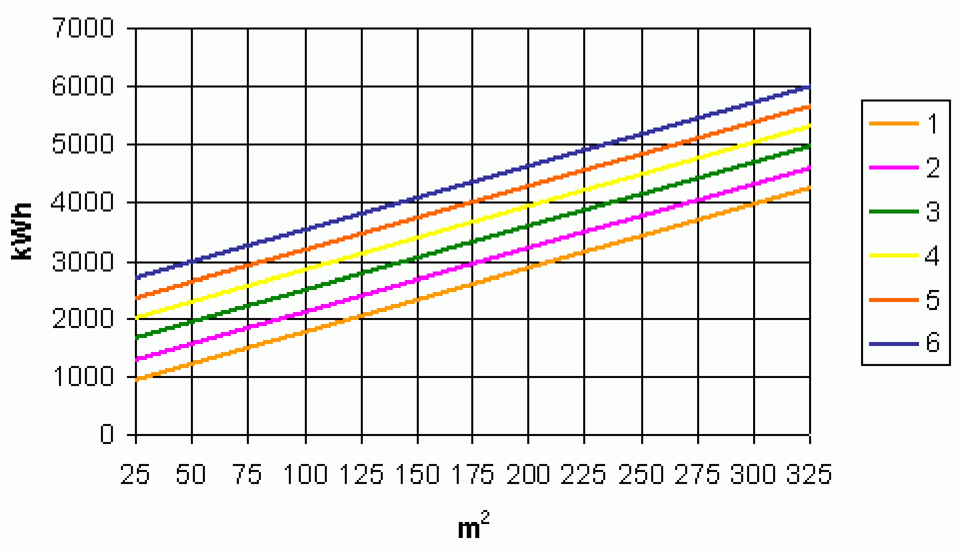

Fig. 2 Estimated average apartment electricity consumption.

Fig. 2 above shows the average consumption of electricity relative to apartment size in square meters. The legend on the right identifies the number of people in the apartment. The curves in figure 2 are based on the following formula (Gram-Hanssen 2005):

Annual consumption = 340 kWh + (area in square meters * 11 kWh/square meters) + (no. of persons * 350 kWh/person)

```
Example: area in square meters = 100, no. of persons = 2

Annual electricity consumption (kWh) = 340 + (100 * 11) + (2 * 350)
                            = 340 + 1100 + 700
                            = 2140
```

In some cases the formula may be easier to use than the graph. All values are approximations based on average readings.

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Average household energy consumption

If energy consumption is low, there is a lower savings potential

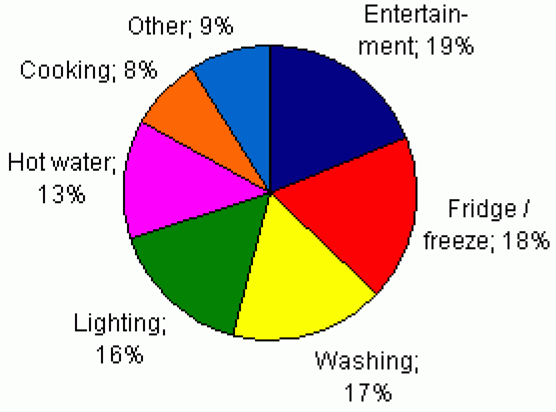

Fig. 1 Household electricity consumption
(Source: Elsparefonden og Dansk Energi).

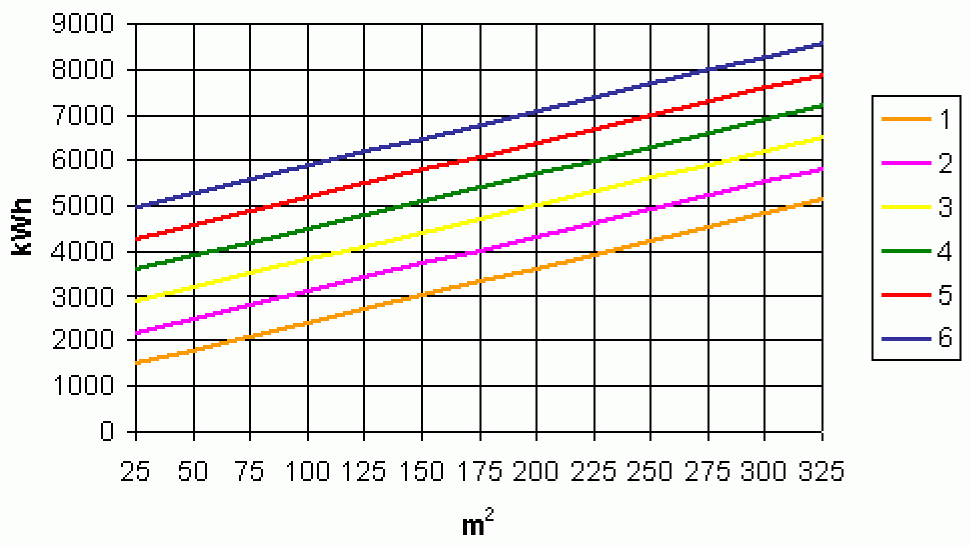

Fig. 2 Estimated average household electricity consumption.

Fig. 3 above shows the average electricity consumption relative to house size and number of residents (legend on the righthandside) The curves are based on the following formula (Gram-Hanssen 2005):

Annual electricity consumption = 530 kWh + (area in square meters * 12 kWh/square meter) + (no. of persons * 690 kWh/person)

```
Example: house size = 100, no. of persons = 2

Annual electricity consumption (kWh) = 530 + (100 * 12) + (2 * 690)
                     = 530 + 1200 + 1380
                     = 3110
```

In some cases it may be easier to use the formula than the graph. All values are approximations based on average readings.

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Light source lifetime

A flourescent lightbulb is a worthwhile investment in the long run, especially since has a longer lifetime

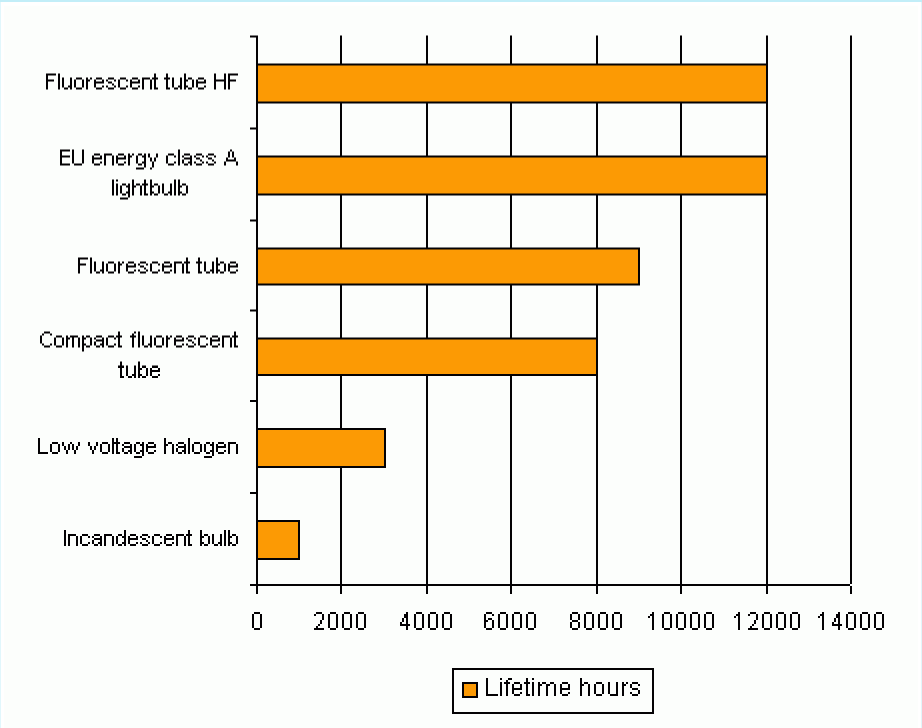

Fig. 1 Light source lifetime (Jacobsen 2002 p 121). Shorter lifetimes increase exchange costs. Comparatively, an LED source lights 30,000 - 50,000 hours.

Lighting optimization

Optimize light source and fixture. Substitute incandescent lamps with compact flourescent or LED lights.

- *Adjust to need*. Ambient or spot lighting, use of motion sensors.
- *Exploit natural daylight*. Incorporate daylight using light-sensitive sensors.

Table 1. Energy classes and lifetime (Source: boliglys.dk)

Light source	Energy class	Lifetime in hours	Adjustable light	Value for money
Incandescent	E-G	1.000	ja	*
Low voltage halogen	C-D	2 000 - 5 000	ja	**
230 v halogen	D-E	1 500 - 3 000	ja	*
Compact flourescent bulb	A-B	6 000 - 15 000	nej	****
Compact flourescent tube	A-B	8 000 - 20 000	not usually	****
Flourescent tube	A-B	6 000 - 20 000	not usually	*****

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Standby Losses

The standby loss factor corresponds to app. 10 % of energy consumption

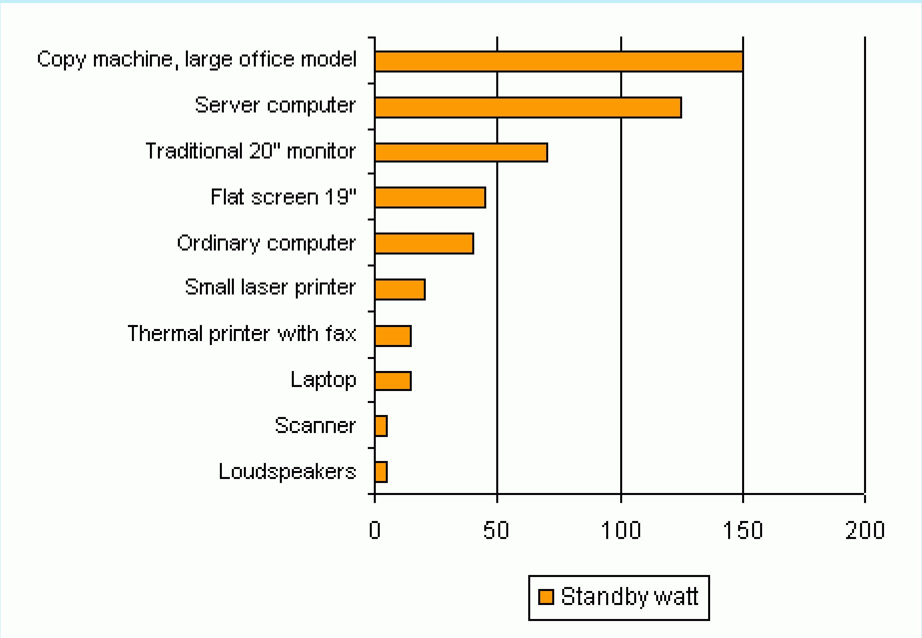

Fig. 1 Office supply standby losses (Jacobsen 2002 p 126). *Energy Star* appliances go into slumber mode when not in use.

On average a household has seven appliances on standby; if there are teenagers at home, the average increases. The most common standby appliances are:

- TV,
- video,
- hi-fi,
- DVD,

- satellite dish,
- PCs,
- printer, and
- fax.

The above sum to app. 85 % of the standby loss. Remaining appliances include:

- chargers,
- washing machine,
- dishwashing machine, and
- coffee machine

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Which appliances are the most expensive to run?

- Electrical floor heating
- Dehumidifier
- Espresso machine
- Video game consol
- New plasma screen tv
- Larger hobby tools
- Aquarium
- Water fountain/filter/pump
- Terrazzo heater
- Heated towel rack

(NRGi)

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Home Electricity Monitor

The *SparOmeter* is a watt-hour meter from the Danish Centre for Energy Savings (Elsparefonden) which measures the electriciy consumed by an appliance and converts it into a cost in DKK. Simply plug the "SparOmeter" into your power socket and then plug your appliance into the meter.

- The "SparOmeteret" estimates the electricity consumption in watt
- The "SparOmeteret" measures consumption over time in kWh
- The "SparOmeteret" converts consumption into DKK/year

The price per kilowatt hour charged by your local utility company can be typed into the meter.

You can find more information on the "SparOmeter" on the page References.

Fig. 1 Watt-hour meter "SpareOmeter" from Elsparefonden. Measures watt and kilowatt hours.

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Ways to save electricity

General advice (Nielsen and Dyck-Madsen 2006)

- switch to energy efficient luminescent lightbulbs
- check the timer on your circulation pump - alternatively, replace with an energy-efficient pump
- check that all appliances are completely turned off - especially chargers
- turn on only appliances in use
- purchase the most efficient appliances

Advice on lighting (Jacobsen 2002)

- switch off unnecessary lighting. Install timers and light and motion sensitive equipment.
- paint walls and ceiling with light colours. Also reduces discomfort from glare and light trespass.
- Choose the correct lighting. Use appropriate workplace lighting.
- Use halogen lighting for impact lighting, rather than area/flood lighting.
- Use high-frequency flourescent lighting, "HF". They have longer lifetimes and reduced flickering.
- Exploit daylight using automatic light sensitive monitoring.
- Regular maintenance.

Standby advice (Jacobsen 2002)

- Turn off all equipment when not in use.
- Install automatic slumber mode where possible.
- Turn off screens when absent for longer periods.
- Purchase appliances marked with "Energy Star" or equivalent.
- Choose flatscreens.

Table 1. Examples of energy saving advice. Electricity price of 2 DKK/kWh.

DKK	kWh	Advice

630	315	Substitute 1 desktop and 1 old desktop terminal with an energy efficient laptop
560	280	Exchange 7 incandescent bulbs with energy efficient ones
364	182	Exchange an old fridge and freezer to a new energy eficient model
122	61	Plug TV and miscellaneous into an energy saving multisocket
180	90	Plug computer and miscellaneous into an energy saving multisocket
560	280	Exchange manually controlled heat pump to energy efficient automated heat pump
56	28	Only run washing machines with full loads, saving every fourth wash (40 degrees, old machine)
824	412	Dry your clothes outside rather than in a tumbler half the time (old tumbler)

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Heating

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Heating Consumption

App 1/4 of the heating is lost through ventilation: bathroom, kitchen and leaks

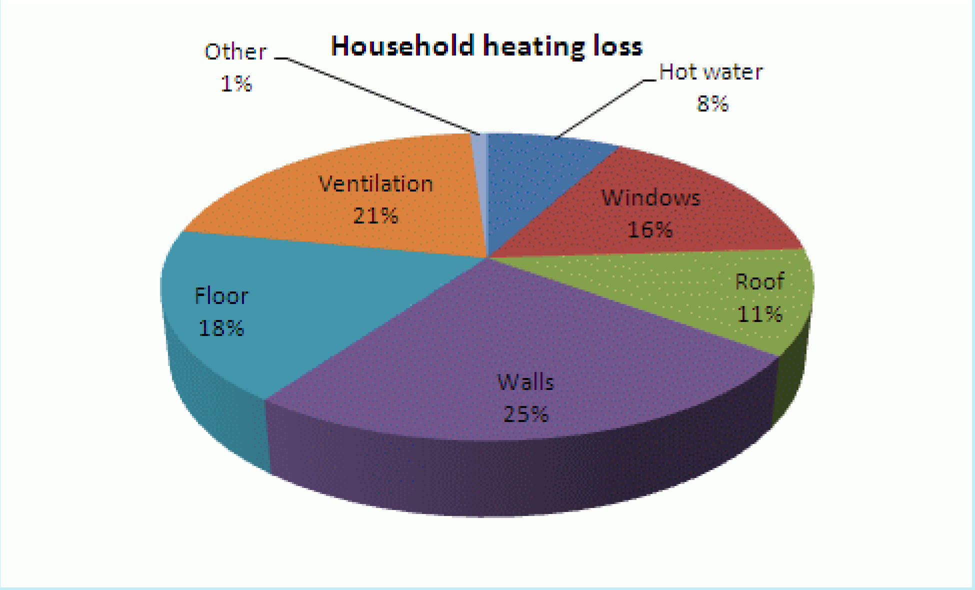

Fig. 1 Household heating loss (Birch & Krogboe in Nielsen and Dyck-Madsen 2006).

The total heated area in Denmark has increased over time, but actual heating consumption has decreased.That is, buildings use less energy per square meter today. This is due to:

- tightened energy regulation
- energy savings, and
- combined heat and power production, where excess heat from electricity generation is used for heating.

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Average apartment heating consumption

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Heating > Average apartment heating consumption

Low heat consumption means less potential for savings

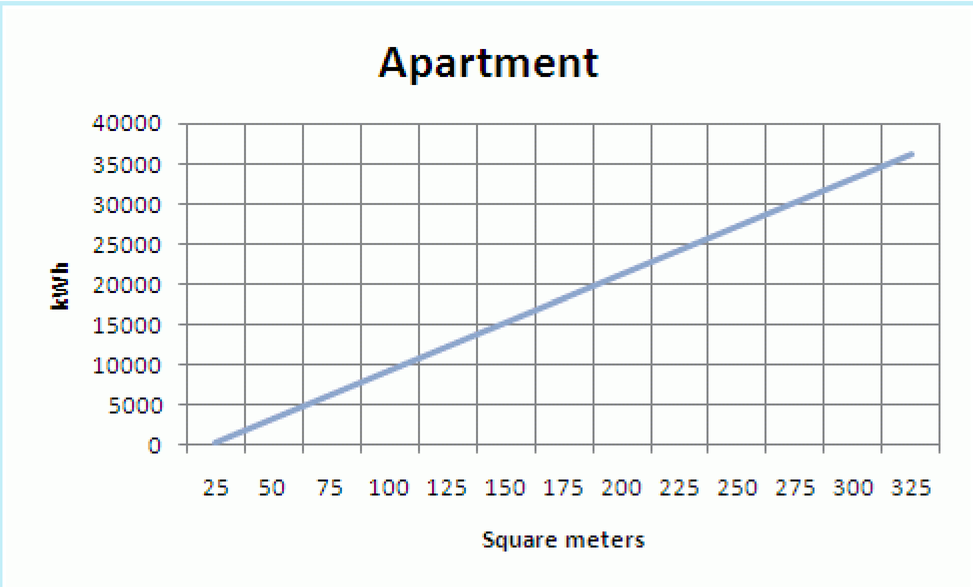

Fig. 2 Estimated average apartment consumption.

The graph in the above figure is based on the following formula (Gram-Hanssen 2005):

Annual heating consumption = -2 577 kWH + (area in square meters * 119 kWH/square meter)

```
Example: apartment area in sqm = 100

Annual heating consumption (kWH) = -2 577 + (100 * 119)
                                 = -2 577 + 11 900
                                 = 9 323
```

In some cases it can be easier to use the formula instead of reading the graph. The results are only approximations, as the formula is based on the median of numerous calculations.

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Average single home heating consumption

If heating consumption is low, there is less potential for savings

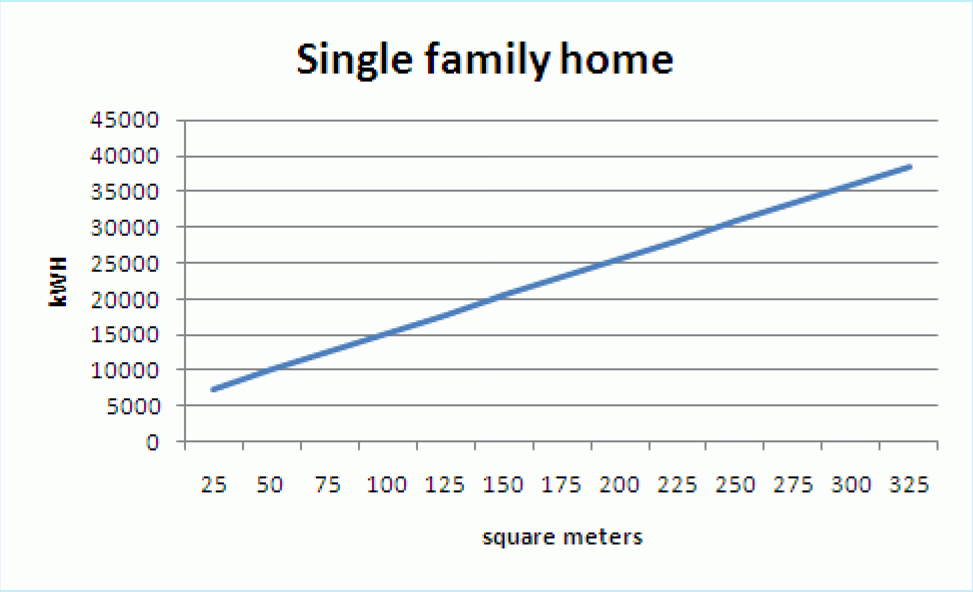

Fig. 3 Estimated average heating consumption in a single family home.

The graph in the above figure is based on the following formula (Gram-Hanssen 2005):

Annual heating consumption = 4816 kWH + (household area * 104 kWH/sqm)

```
Example: sqm housing = 100

Annual heating consumption (kWH) = 4816 + (100 * 104)
                                 = 4816 + 10400
                                 = 15216
```

In some cases it can be easier to use the formula instead of reading the graph. The results are only approximations, as the formula is based on the median of numerous calculations.

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Thermostat controlled radiators

If theromstats are used according to producer guidelines (Fig. 1), then they save energy (99 kWh/år, Average savings).

A *thermostat* on a radiator will maintain the room temperature it has been set to, e.g. 20 degrees in the living-room. If sunlight is streaming into the room, the thermostat will shut off, and if a chill wind blows, it will turn on.

When the room temperature drops below the optimal level, the thermostat-controlled valve will circulate hot water through the radiator. Once the radiator has heated the room, the thermostat will turn off the valve again.

In the summertime, the thermostat will turn itself off - thus there is no need to turn down the settings. The thermostat in Fig. 1 has two controls, which can be set so that they limit the amount the thermostat can be turned. This can prevent children and guests from altering the preferred heating settings.

There are good animations of how thermostat valves work available on the internet (refer to Danfoss under References; unfortunately, Danfoss does not allow direct links to the animation, so please find it yourself on their homepage under *Animerede præsentationer*).

Fig. 1 Thermostat for radiator (Danfoss). Bathroom setting 4 (23 C), living-room setting 3 (20 C), bedroom setting 2 (17 C), staircase and hallway setting (13 C), and anti-freeze setting * (7 C).

General guidelines

- Set all radiators in connecting rooms to the same approximate temperature. This provides the most efficient heating and the least exposure to drafts.
- Exercise the valve to prevent clogging. Turn it all the way up and all the way down several times.
- Air out the radiator. Airpockets prevent efficient circulation, and leaves the top of the radiator cool.
- If the radiator is warmer at the top and cooler at the bottom, then it is functioning normally; the radiator is cooling the water.
- Briefly open windows to air out the room, or set the thermostat on star (*).

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Household savings of CO2

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Heating > Household savings of CO2

Denmark taxes CO2 emissions, and the tax revenue is channeled to less developed countries

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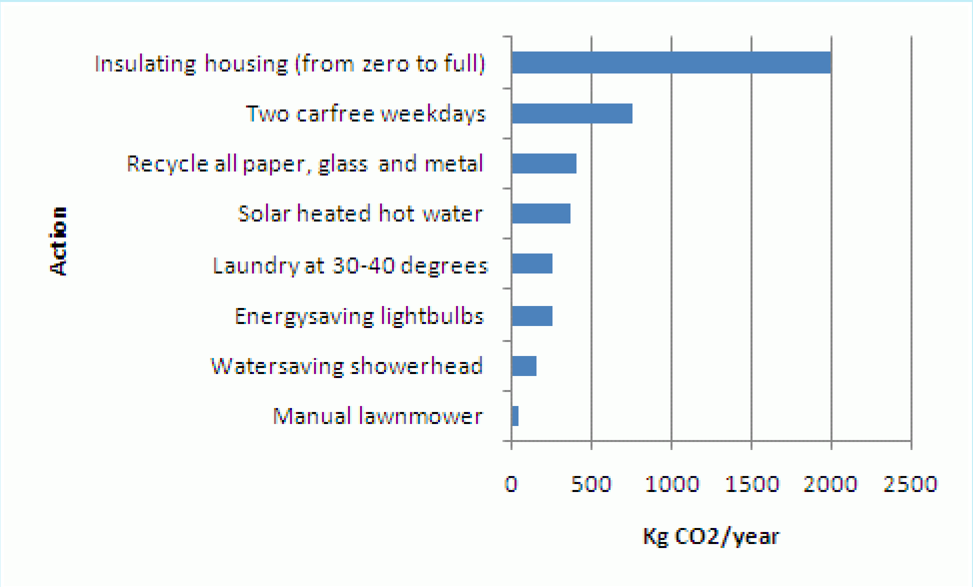

Fig. 1 CO2 reductions (WMO in Nielsen and Dyck-Madsen 2006).

Table 1. CO2 reductions (WMO i Nielsen og Dyck-Madsen 2006)

Action	kg CO2/year
Mowing your lawn with a manual lawnmower	40
Install a water saving showerhead	150

Exchange all lightbulbs with energysaving bulbs	250
Only wash at 30-40 degrees	250
Use a solar panel to heat hot water	360
Recycle all paper, glass and metal	400
Initiate two carfree weekdays	750
Insulate the house (from none to fully insulated)	2000

The figures are averages across family sizes, housing conditions and climate zones. They are applicable to houses in industrialized countries.

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Ways to save heating

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Heating > Ways to save heating

Many people would prefer redoing the kitchen or bathroom rather than adding insulation and renovating to save energy

- Upgrade your windows to energy-efficient windows. Note: some producers provide the heat loss (U-value) for the glass rather than for the whole window, as the heat loss is higher for the full window than for the glass alone.
- Ensure optimal insulation of the hot water container, heat exchanger and piping.
- Check to see that the roof and ceiling or properly insulated, and whether additional insulation of the walls is necessary.
- Check whether the floor is sufficiently insulated.
- Reduce your consumption of hot water - this saves both water and energy.

(Nielsen and Dyck-Madsen 2006)

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Water

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Water

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Water Consumption

Showers and toilets make up 2/3 of the consumption

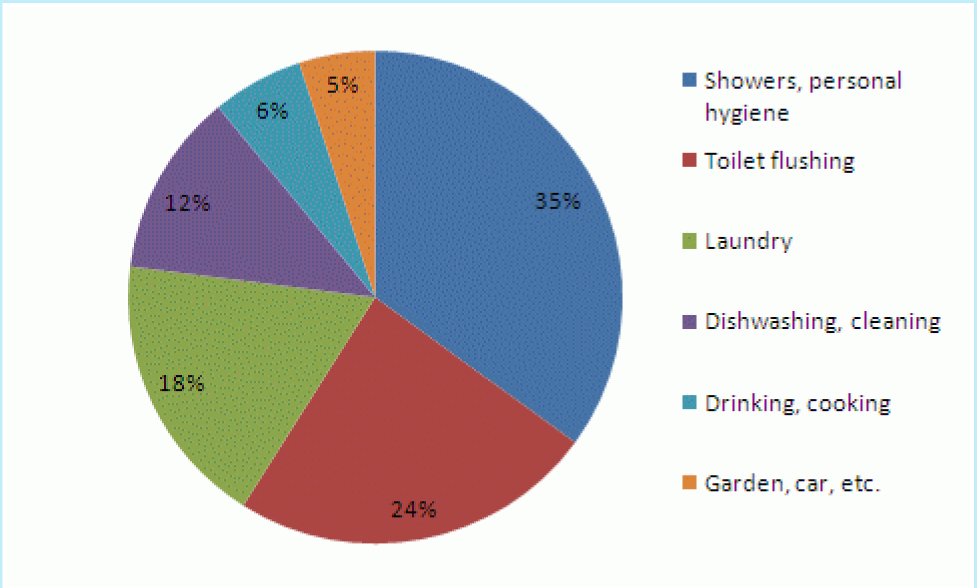

Fig. 1 Average Consumption per person (Jacobsen 2002 p 157).

- Household water consumption is falling over time.
- Loss due to leakages in piping are falling.
- Hot water can be twice as expensive as cold, due to the heating expense.

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Average apartment water consumption

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Water > Average apartment water consumption

If average consumption is low, the potential for savings is lower

Fig. 1 Average apartment water consumption.

The figure above is based on the following formula (Gram-Hanssen 2005):

Annual water consumption = 33 cubic meters + (no. of people * 21 cubic meters/person)

```
Example: no. of people = 2

Annual water consumption (cbm) = 33 + (2 * 21)
                               = 33 + 42
                               = 75
```

At times it may be simpler to use the formula rather than reading the graphs.

Note that the estimates are rough due to the presence of significant uncertainty.

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Average single home water consumption

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Water > Average single home water consumption

If water consumption is low, there is less scope for savings.

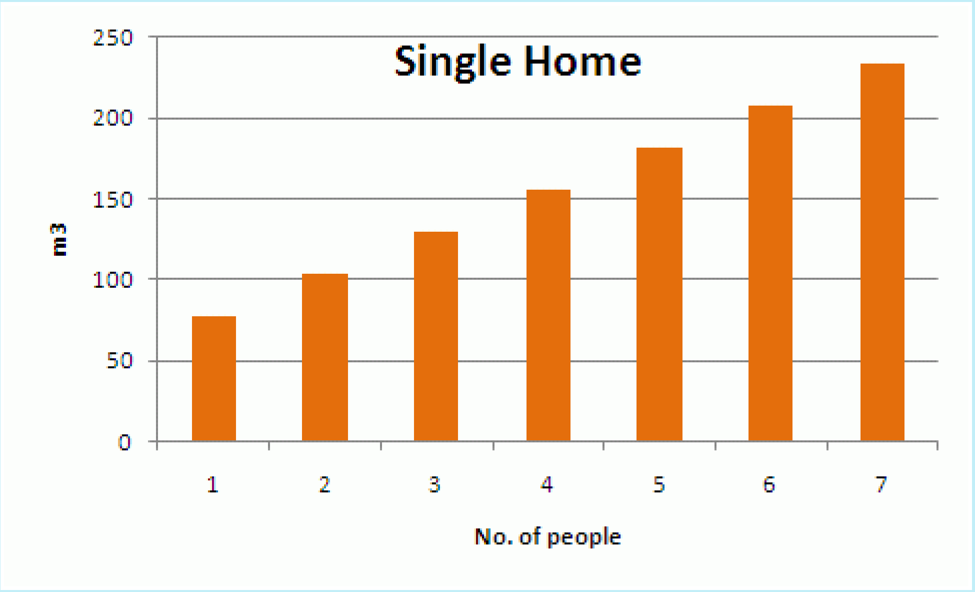

Fig. 1 Average water consumption in a single home.

The figure above is based on the following formula (Gram-Hanssen 2005):

Annual water consumption = 52 cubic meters + (no. of people * 26 cubic metres/person)

```
Example: no. of people = 2

Annual water consumption (cbm) = 52 + (2 * 26)
                               = 52 + 52
                               = 104
```

In some scenarios it is simpler to use the formula rather than reading the figure. The results are rough estimates, as the values can vary significantly from person to person.

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Ways to save water

General savings (Nielsen and Dyck-Madsen 2005)

- Use less water when bathing. Install a single lever thermostat. Supplement with a water-saving showerhead. This will save app. 6-12 liters per minute, and saving hot water saves energy.
- Choose a single lever tap. By installing taps with only one lever, you use less water than if there are two.
- Turn off your water immediately after use. An open faucet releases up to 16 liters of water per minute. Remember to turn the faucet off when washing dishes, peeling potatoes or brushing your teeth.
- By choosing a water-saving toilet with 3/6 liter flushing or 2/4 liter flushing you can save between 6-9 liters of water with each flush.
- You don't need to rinse plates before setting them in the dishwasher. It is sufficient to scrape off food remnants prior to placing them in the dishwasher.
- Fill the dishwasher and washing machine fully before starting them. This saves time, reduces wear and tear on the machines and reduces wter and electricity consumption. Many new washing programs automatically regulated the amount of water and electricity based on the weight of the clothes. Low-energy programs reduces the amount of water consumed.
- Be aware if the toilet continues to flush. Even the slightest amount of continual flushing can waste a lot of water and cost a lot of money.
- If you have an older toilet, consider exchanging it for a dual flush water saving system.

SparEnergi.dk (Danish energy saving website)

- A tap or WC that slowly drips water loses app. 20 liters/day (7.3 cubic metres/year); a fast drip loses 100 liters/day (37 cubic meters/year); a small stream (1.5 mm) loses 180 liters/day (140 cubic meters/year). If a cubic meter of water costs 50 DKK, this last figure equals 7,000 DKK.
- A water-saving showerhead uses 6-9 l/min, while an ordinary showerhead uses app. 15-20 l/min. If you do not wish to exchange the whole showerhead, you can purchase a flow restrictor kit at your local plumber or hardwarestore, which reduces the flow of water through faucets and showers. For ordinary faucets, you can also buy small aerators, which add air to running water and

reduce daily water consumption.

- An ordinary faucet releases up to 20 liters of water each minute.
- Even with a water-saving showerhead you can save 18 liers of water by getting out of the shower 2 minutes earlier.
- You use app. 35 liters of water in a 3-minute shower. A bath in a bathtub uses app. 80-100 liters of water.
- The heating element in a hot-tub uses app. 2.7-6 kW. Hot-tubs usually have a minimum consumption of 180-330 liters of water.
- A hole in a water hose the size of a pin can lose up to 70 liters a day.

See additional ways to save water on the website 100 Ways to Conserve Water

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Ambassador Checklist

Created by tanja.groth. Last Modification: Wednesday 14 July 2010 11:47:58 CEST by tanja.groth.

General Savings Advices

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Ambassador Checklist > General Savings Advices

Remember to switch appliances off. This simple advice is still the most efficient.

Table 1. Advice and Savings.

Advice	Potential savings	Source
20° is enough. In the living-room, kitchen and bathroom, a temperature of 20° is enough. Keep temperatures in the other rooms lower. Electrical heating should be switched off whenever it is not in use, unless a minimum temperature is required to keep a room frost-safe.	For each degree the temperature is lowered, 5-6% of energy consumption is saved.	NRGi
Use thermostats with day and night settings. Lower the household temperature by 5-6° at night — and during the day when there is no-one home. If there is no automatic night-setting on your radiator, you can install a timer and a thermostat on the mains.	Potential utility savings are app. 10%.	NRGi
Use zone heating and cooling systems. Motorized dampers and thermostats can regulate heating in different zones according to preference, e.g. a warm kitchen in the morning and evening, but cooler during the rest of the day. Remember to keep the zones seperate, by keeping doors closed etc.	Optimal zoning constructed according to room preferences can save up to 15-20% on the utility bill.	NRGi
Use a thermos. Use a thermos to keep coffee warm, rather than leaving it on the coffee machine's hot plate.	If you leave coffee on a hot plate for an hour, you use as much electricity as when you brew a liter of coffee.	NRGi
Remove hard water deposits from your coffee maker. Both your coffee machine and electric kettle need regular maintenance, especially in areas with hard water.	Too many mineral deposits increases electricity consumption, and increases the time it takes to brew coffee.	NRGi
Turn down settings. Set your ventilation hood to its lowest possible setting when cooking.	A ventilation hood uses app. 1.5 times as much electricity on its highest setting relative to its lowest setting.	NRGi
Use a lid. Use a tight-fitting lid on your pot.	Not using a lid requires 3 times as much electricity.	NRGi
Use pots. Where possible, use a pot on a stove for cooking rather than the oven.	Up to 70 % savings.	NRGi

Defrost food before cooking. Most frozen goods must be defrosted before use. Frozen vegetables are the exception to this rule, and it is usually recommended to cook them while frozen.	Electricity consumption will increase by up to 50 %, when pork chops are not defrosted before cooking.	NRGi
Defrost in the fridge. Defrost as many foods in the fridge as possible, rather than using warm water or a microwave. It takes longer, but it is better for the quality of the product.	This saves electricity.	NRGi
Keep the vents in the fridge and freezer uncovered. Fridges and freezers release heat in order to cool, and the vents need to be free from obstruction to ensure proper cooling. Ensure as much air as possible around your appliances. If you are installing built-in appliances, ensure that you follow the guidelines.	Without proper ventilation, the appliances have to work harder to keep things cool, which uses more electricity.	NRGi
Shut the door. Only open the fridge doors for the briefest amount of time.	Each time you open the fridge door, warm air enters the fridge, and it takes energy to cool it again.	NRGi
Plus 5° C in the fridge and minus 18° C in the freezer. Measure the temperature in your fridge by placing a thermometer in a glass of water and placing it in the fridge for 24 hours. This will give you the most accurate result.	Each degree below the optimal temperature increases electricity consumption by 5%, because the fridge has to work that much harder.	NRGi
Low temperature - short cycle. Always use the shortest possible rinse cycle and the lowest possible recommended temperature when doing dishes.	Washing at 50/55° uses 10-20 % less electricity than a program at 65°.	NRGi

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Savings Advices

Bath / laundry

1. [ ] Reduce use of bathtub (use the shower instead)
2. [ ] Reduce shower time (shorter showers, turn it off while soaping up)
3. [ ] Reduce water flow (water-saving showerhead, combined single lever faucet)
4. [ ] Fix leaks in faucets and toilets
5. [ ] Turn off the faucet when brushing your teeth
6. [ ] Fill your washing machine
7. [ ] Dry your clothes on a clothesline rather than a tumbler
8. [ ] Use the economy program on the washing machine

Køkken

1. [ ] Keep the fridge at 5 degrees and the freezer at -18 degrees celcius
2. [ ] Defrost your fridge and freezer
3. [ ] Clean and vacuum the back of the fridge and freezer
4. [ ] Defrost frozen foods in the fridge (instead of using hot water or a microwave)
5. [ ] Cool heated foods before placing them in the fridge or freezer
6. [ ] Use a pan that fits on your cooker
7. [ ] Use lids
8. [ ] Boil water in an electric kettle
9. [ ] Turn off the oven if it is empty for more than 30 minutes
10. [ ] If you are using the oven for cooking, time it so that you can bake after cooking
11. [ ] Use a plugged sink or a dishwashing tub for dishwashing
12. [ ] Fill the dishwashing machine completely
13. [ ] Set the dishwashing machine at a lower temperature

Living-/Bedroom

1. [ ] Switch to energy-saving or LED lightbulbs

2. [ ] Turn off the lights whereever possible
3. [ ] Air out your house by opening all the windows for a short period of time
4. [ ] Use a timer to regulate lighting on plants, aquariums and other places where the lighting does not need to be on all the time
5. [ ] Maintain an indoor temperature of 20 degrees, lower in the bedroom. Set the temperature to 15 when not at home
6. [ ] Use an energy-saving power socket for multiple plugs to avoid stand-by time
7. [ ] Unplug chargers and transformers when not in use
8. [ ] Switch to renewable batteries in childrens toys

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Average savings

Appraisal of Renewable Energy Projects with Cases from Samso > Energy Savings > Ambassador Checklist > Average savings

Table 1. Estimated annual savings for an average single home.

Saving	Area	Advice	Source
18 kWh	Lighting	Exchange incandescent lightbulb to energy saving lightbulb (25 W to 7 watt)	Danish Energy Agency (DEA)
29 kWh	Lighting	Exchange incandescent lightbulb to energy saving lightbulb (40 W to 11 W)	DEA
45 kWh	Lighting	Exchange incandescent lightbulb to energy saving lightbulb (60 W to 15 W)	DEA
55 kWh	Lighting	Exchange incandescent lightbulb to energy saving lightbulb (75 W to 21 W)	DEA
77 kWh	Lighting	Exchange incandescent lightbulb to energy saving lightbulb (100 W to 23 W)	DEA
25 kWh	Lighting	Install motion sensors on outdoor lighting (7 W)	DEA
39 kWh	Lighting	Install motion sensors on outdoor lighting (11 W)	DEA
53 kWh	Lighting	Install motion sensors on outdoor lighting (15 W)	DEA
70 kWh	Lighting	Install motion sensors on outdoor lighting (20 W)	DEA
81 kWh	Lighting	Install motion sensors on outdoor lighting (23 W)	DEA
88 kWh	Lighting	Install motion sensors on outdoor lighting (25 W)	DEA
140 kWh	Lighting	Install motion sensors on outdoor lighting (40 W)	DEA
210 kWh	Lighting	Install motion sensors on outdoor lighting (60 W)	DEA
263 kWh	Lighting	Install motion sensors on outdoor lighting (75 W)	DEA
350 kWh	Lighting	Install motion sensors on outdoor lighting (100 W)	DEA
8.5 kWh	Lighting	Exchange a halogen bulb (10 W) with LED	DEA
13 kWh	Lighting	Exchange a halogen bulb (15 W) with LED	DEA
17 kWh	Lighting	Exchange a halogen bulb (20 W) with LED	DEA
25 kWh	Lighting	Exchange a halogen bulb (30 W) with LED	DEA
30 kWh	Lighting	Exchange a halogen bulb (35 W) with LED	DEA
41 kWh	Lighting	Exchange a halogen bulb (50 W) with LED	DEA
21 kWh	Lighting	Exchange an incandescent bulb (25 W) with LED	DEA

34 kWh	Lighting	Exchange an incandescent bulb (40 W) with LED	DEA
280 kWh	Lighting	Exchange 7 incandescent bulbs with energy saving bulbs	DEA
197 kWh	Circulation pumps	Exchange a step-regulated circulation pump to an automatically regulated circulation pump	DEA
280 kWh	Circulation pumps	Exchange a step-regulated circulation pump to an Energy Star automatically regulated circulation pump	DEA
73 kWh	Circulation pumps	Install a timer on the circulation pump for hot water	DEA
172 kWh	Fridge-freezer	Exchange the household fridge w/o freezer to a A++ fridge, single family home	DEA
175 kWh	Fridge-freezer	Exchange the household fridge w/o freezer to a A++ fridge, apartment	DEA
182 kWh	Fridge-freezer	Exchange the household fridge with built-in freezer to a A++ fridge, single family home	DEA
182 kWh	Fridge-freezer	Exchange the household fridge with built-in freezer to a A++ fridge, apartment	DEA
301 kWh	Fridge-freezer	Exchange the household fridge with separate freezer to a A++ fridge, single family home	DEA
301 kWh	Fridge-freezer	Exchange the household fridge with separate freezer to a A++ fridge, apartment	DEA
292 kWh	Fridge-freezer	Exchange an upright freezer to a A++ freezer, single family home	DEA
319 kWh	Fridge-freezer	Exchange an upright freezer to a A++ freezer, apartment	DEA
225 kWh	Fridge-freezer	Exchange a chest freezer to a A++ freezer, single family home	DEA
251 kWh	Fridge-freezer	Exchange a chest freezer to a A++ freezer, apartment	DEA
55 kWh	Office supplies	Exchange a 15" CRT screen with a 15" LCD screen	DEA
65 kWh	Office supplies	Exchange a 17" CRT screen with a 17" LCD screen	DEA
93 kWh	Office supplies	Exchange a 20" CRT screen with a 20" LCD screen	DEA
42 kWh	Office supplies	Exchange standard desktop (when obsolete) to best desktop	DEA
34 kWh	Office supplies	Exchange standard laptop (when obsolete) to best laptop	DEA
228 kWh	Office supplies	Exchange standard desktop (when obsolete) and 17" CRT screen to best laptop	DEA
90 kWh	Office supplies	Install energy-saving multisocket on all office equipment	DEA
61 kWh	Office supplies	Install energy-saving multisocket on all television equipment	DEA
53 kWh	Office supplies	Install energy-saving multisocket on Playstation 2 consoles	DEA
32 kWh	Office supplies	Install energy-saving multisocket on Playstation 2 Slim consoles	DEA
26 kWh	Office supplies	Install energy-saving multisocket on Wii consoles	DEA
196 kWh	Office	Install energy-saving multisocket on Xbox 360 consoles	DEA

	supplies		
32 kWh	Office supplies	Install energy-saving multisocket on Gamecube consoles	DEA
315 kWh	Office supplies	Exchange 1 desktop and 1 average thick screen with an energy-efficient laptop	Consumption
33 kWh	Cooking	Exchange a traditional electric stove (when obsolete) to an induction stove	DEA
29 kWh	Cooking	Exchange a ceramic stove (when obsolete) to an induction stove	DEA
28 kWh	Cooking	Exchange a traditional electric stove (when obsolete) to an "A" rated electric stove	DEA
32 liters of petrol	Transport	Bike instead of drive, every 5th time	Consumption
24 liters of diesel	Transport	Bike instead of drive, every 5th time	Consumption
7.3 m3	Water	Fix a slowly dripping leak on a tap or WC	Consumption
37 m3	Water	Fix a quickly-dripping leak on a tap or WC	Consumption
140 m3	Water	Fix a flowing leak on a tap or WC	Consumption
6 m3	Water	Exchange a normal showerhead with a water-saving showerhead	Consumption
1.8 m3	Water	Shower for 1 minute less (with water-shaving showerhead)	Consumption
0.8 m3	Water	Use a water-saving showerhead instead of a bath every 10th time	Consumption
70 liters/day	Water	Fix a hole in a waterhose the size of a pinprick	Consumption
5.4 m3	Water	Exchange a normal showerhead with a watersaving showerhead	Consumption
99 kWh	Heater	Exchange from manual to thermostat valves, pr. piece	DEA
790 kWh	Heater	Automated valve exchanged with weather-compensating motorised valve, pr. piece	DEA
150 kWh	Heater	Insulating piping from bad to average, pr. meter	DEA
175 kWh	Heater	Insulating piping from bad to good, pr. meter	DEA
25 kWh	Heater	Insulating piping from bad to good, pr. meter	DEA
420 kWh	Heater	Annual servicecheck on oil furnace	DEA
625 kWh	Heater	Biannual servicecheck on oil furnace	DEA
181 kWh	Heater	Regular servicing of district heating	DEA
362 kWh	Heater	One-off servicing of district heating	DEA
118 kWh	Home appliances	Exchanging worn-out dishwasher with new "A"-rated dishwasher, single family home	DEA
96 kWh	Home appliances	Exchanging worn-out dishwasher with new "A"-rated dishwasher, apartment	DEA
79 kWh	Home appliances	Exchanging worn-out washing machine with new "A"-rated washing machine, single family home	DEA
57 kWh	Home appliances	Exchanging worn-out washing machine with new "A"-rated washing machine, apartment	DEA
479 kWh	Home appliances	Exchanging worn-out tumble dryer with new "A"-rated tumble dryer, single family home	DEA
314 kWh	Home appliances	Exchanging worn-out tumble dryer with new "A"-rated tumble dryer, apartment	DEA
37 kWh	Home appliances	Substitute 90 degree wash with 60 degree wash, old washing machine, single family home	Consumption
30 kWh	Home appliances	Substitute 90 degree wash with 60 degree wash, old washing machine, apartment	Consumption
48 kWh	Home appliances	Substitute 60 degree wash with 40 degree wash, old washing machine, single family home	Consumption
34 kWh	Home appliances	Substitute 60 degree wash with 40 degree wash, old washing machine, apartment	Consumption

412 kWh	Home appliances	Substitute clothesline for tumbler half the time, old tumbler, single family home	Consumption
270 kWh	Home appliances	Substitute clothesline for tumbler half the time, old tumbler, apartment	Consumption
28 kWh	Home appliances	Fill the washing machine fully and save every 4th wash, old washing machine, single family home	Consumption
21 kWh	Home appliances	Fill the washing machine fully and save every 4th wash, old washing machine, apartment	Consumption

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2. Brdr. Stjerne home page
3. Danish Wind Turbine Owners Association home page
4. Deme -- Dredging, Environmental and Marine Engineering, home page
5. Difko International Finance House home page
6. Difko Samsø 1 home page
7. Difko turbine production Online press Online / Park view / find turbine T07
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30. Scheuten Solar home page

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32. Siemens Wind Power home page
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34. State of Green home page
35. Sweco Architects home page
36. Vindinfo, genvej til statslig information om vindmøller vindinfo.dk
37. Wikipedia Canola
38. Wikipedia Cash flow
39. Wikipedia Compact fluorescent lamp
40. Wikipedia Discounted cash flow
41. Wikipedia Incandescent light bulb
42. Wikipedia Inflation
43. Wikipedia Internal rate of return
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IMPLEMENT

January 2012 to December 2014

Links

- The IMPLEMENT home page

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Night Hawks

The name Night Hawks refers to energy checks at night time in order to discover unnecessary idle consumption. The project lasts from 1 Apr 2013 to 30 Sep 2015.

The Night Hawks will raise awareness and implement energy and climate work, by methods tailor made for shopping centres, retail parks and shops. The core in the project is the “night walks”. The partners will use night walks as an effective tool to find energy leakages during “off-production” time – when the shopping centres, retail parks and shops are closed. A night walk is an energy check in a shopping centre, retail park and shop which will be a kick off for the energy efficiency work in the organisation.

Work packages

1. Management and coordination
2. Development of training kit
3. Trainings
4. Night walks
5. Results and measures
6. Communication and dissemination
7. EACI dissemination activities

Partners

- Coordinator: Energy Agency for South East Sweden Ltd, Sweden (http://www.energikontorsydost.se/english.php)
- Prioriterre, France (http://www.prioriterre.org)
- Severn Wye Energy Agency, UK (http://www.swea.co.uk)
- Ekodoma, Latvia (http://www.ekodoma.lv/index.php?lang=en)
- Samsø Energy Academy, Denmark (http://www.energiakademiet.dk)
- Stratagem Energy Ltd, Cyprus (http://www.stratagem-ltd.com)

- Sächsische Energieagentur, Germany (http://www.saena.de)
- C.R.A.C.A. SOC. COOP, Italy (http://www.craca.it/homeEN.aspx?lang=EN)

Financing

The total budget is 1 million euros, of which the EU contributes 75% under the Intelligent Energy Europe (IEE) program. The contract is with the Executive Agency for Competitiveness and Innovation (agreement no IEE/12/671/SI2.644734).

Links

- Night Hawks home page
- Night Hawks fact sheet

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

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SMILEGOV

Links

- SMILEGOV home page

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D2D

Appraisal of Renewable Energy Projects with Cases from Samso > EU projects > Current Projects > D2D

- The D2D project (‘Dissemination to Development’ and vice versa) is an Interreg IVB North Sea Region Project with 9 partners from six countries around the North Sea.
- Leading vision: D2D concept as a sustainable innovation and business accelerator approach facilitating business incubation process via establishment of transnational incubation facility
- Main goal: to create a process that enables innovations developed during the C2CI project to be realized across the NSR and beyond.
- Project duration: from September 2013 to 31 March 2015.
- Total budget: € 700.000 (50% European funding, 50% co financing by partners).
- The partnership: Province of Fryslân (Lead Beneficiary)(NL), Samsø Energy Academy (DK), Delft University of Technology (NL), International Resources and Recycling Institute – IRRI (UK), Lund University (SE), Landkreis North Friesland (DE), Insel-und Halligkonferenz (DE), Flanders inShape (BE), Aalborg University (DK).

Links

- The D2D home page

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Past Projects

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Contents

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PROMISE

Promise
IEE Island Project

Supported by INTELLIGENT ENERGY EUROPE

The name PROMISE stands for Promoting Best Practices to Support Energy Efficient Consumer Behaviour on European Islands. The project lasts from 1 Jun 2011 to 30 Nov 2013.

Energy Efficiency

Maximising energy savings and reaching high energy efficiency levels are crucial challenges currently faced by the EU. Residential energy demand is rapidly increasing due to larger homes, new services and additional appliances, putting a strain on the economies and energy infrastructures of EU regions. Moreover, domestic energy use is still largely invisible to the user and this is a prime cause of wastage. Most people have only a vague idea of how much energy they use for different purposes and what difference they could make by changing day-to-day behaviour or investing in energy efficiency measures.

Project Objective

The overall goal of the project PROMISE is to support better information provision by tackling the main barriers that still exist today for taking up energy efficient behaviour among consumers.

Through PROMISE, households will be approached and supported in choosing the most energy efficient products and encouraged to reduce household consumption in gas and electricity. Furthermore, they will learn about successfully implemented measures which generate, through financial incentives and ownership models, a more participatory involvement in energy concerns.

Work packages

1. Project management and coordination
2. Assessment of good practices and guidelines for knowledge transfer fine tuning
3. Capacity building and Awareness campaign design
4. Pilot action implementation

Target Group

PROMISE focuses its activities on insular regions located in European areas with different climatic and geomorphologic conditions: Samsø (Denmark), Iceland, Tenerife (Spain) and

Ios (Greece). The main reason why the project targets insular regions is that islands have a vital need to guarantee energy supply and adopt energy conscious behaviours that promote energy efficiency. Alongside with their manageable size with regard to population and consequently, a high probability to reach a wide range of households, the deep connection and identification of the inhabitants with their territories is a reason to a greater interest in safeguarding the territory and thus also in the willingness to adopt behaviours that support energy efficiency and the rational use of resources.

Partners

- Coordinator: INNOVA S.p.A, Italy (http://www.innova-eu.net)
- Samsø Energy Agency, Denmark (http://www.seagency.dk)
- Energy Agency Iceland, Iceland (http://www.orkusetur.is)
- Ios-Aegean Energy Agency, Greece (http://www.aegean-energy.gr)
- Tenerife Energy Agency, Spain (http://www.agenergia.org)
- Forventi Media Limited, UK (http://www.forventi.com)

Financing

The total budget of PROMISE is 1 million euros, of which the EU has granted 75%. The project is under the Intelligent Energy Europe (IEE) program. The contract is with the Executive Agency for Competitiveness and Innovation (agreement no IEE/10/312/SI2.589421).

Links

- Intelligent Energy Europe, IEE
- PROMISE Fact Sheet
- PROMISE home page

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INRES

Appraisal of Renewable Energy Projects with Cases from Samso > EU projects > Past Projects > INRES

INRES

Apr 2009 - end of Mar 2012

The INRES project will aim to enhance the integration and the cooperation among three European insular regions:

- Canary Islands (Spain),
- Crete (Greece), and
- Samso (Denmark).

The three regions establish a mutual learning process and collaborative relationships.

The consortium, formed of 10 partners, targets the development of an inter-regional strategy for innovative measures.

Considering the previous experience in regional policies and networking, the project partners have decided to form the consortium based on the idea of

- putting together regional research-driven clusters dealing with renewable energy concerns, and
- gathering entities from governmental, research and industrial side in order to address energy-related problems, and
- create a common strategy for the development of renewable energy technologies,
- supporting finally the self-sustainability of the islands.

The project is supported 90% by the European Union as a Support Action under SP4-Capacities, seventh framework programme FP7.

External Links

- The INRES home page, http://www.inresproject.eu
- Seventh Framework Programme, Capacities, support actions

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Enabling energy plans in Energy Cities and municipalities

Appraisal of Renewable Energy Projects with Cases from Samso > EU projects > Past Projects > Enabling energy plans in Energy Cities and municipalities

In the spring of 2010 Samso Energy Academy initiated the project "Enabling energy plans in Energy Cities and municipalities" to continue Samso Energy Academy's international relations and targeted services to municipalities in the Region of Central Jutland on energy and climate issues.

The project includes the creation and updating of the municipal energy and climate balances and assistance to municipalities to draw up action plans on energy and climate issues.
Furthermore, the project includes activities with the participation of municipalities with a special effort on climate and energy, including the official Energy Cities.

The project is scheduled for completion 31. December 2011.

The project is supported by the European Regional Development Fund

DEN EUROPÆISKE UNION
Den Europæiske Fond for Regionaludvikling
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and the Central Denmark Region.

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BioMob

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BioMob: Biomass Mobilisation (energy from biological material), led by Shannon Development with partners in Denmark, Hungary and Bulgaria, promotes research-driven regional clusters for biomass: regional challenges, international benchmarking, action plans, business development (stimulating R&D for the Shannon region’s biomass sector)

External links

- Biomob project home page

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Energy Ambassadors

Appraisal of Renewable Energy Projects with Cases from Samso > EU projects > Past Projects > Energy Ambassadors

Energy Ambassadors

Project period: May 2009 - Oct 2011

Energy Ambassadors are people already working in local authorities, non-profit organizations, healthcare or social organizations. They will follow trainings to become energy referents within the organizations they work. In a second step they will take care of the energy issues of their usual public (with home visits, phone advice, awareness raising meetings / neighbourhood conferences).

Dealing with energy issues and social difficulties we can find solutions for the concerned people to save money and energy, and to gain other benefits as comfort and health improvement, then to improve their social situation.

Target groups

- Our first target group is the social actors (from local authorities, social or healthcare organizations, social housing organizations, etc.), energy providers, owners and tenants (individuals, private and public companies).
- Our final target group is the people in a situation of fuel poverty and/or with low income (unemployed people, elderly people, new immigrants, single parent families, etc.).

Main objectives

- To implement sustainable and practical solutions to fight against fuel poverty and generate energy savings in households;
- To duplicate and adapt the French Energy Ambassadors concept: phone advices, home visits, trainings, conferences;
- To aware and inform our final target group on energy savings and to achieve behaviour changes;

- To train professionals working with this public on energy savings and energy efficiency;
- To enable an exchange of knowledge and experience among the Energy Ambassadors and the Consortium partners;
- To transfer, replicate and sustain the Energy Ambassadors Campaigns in other regions and other social organizations.

The project is supported 75% by the European Union under the Intelligent Energy Europe programme.

Intelligent Energy Europe

External Links

- The Energy Ambassadors home page, http://www.energyambassadors.eu
- The Intelligent Energy Europe programme, http://ec.europa.eu/energy/intelligent
- SEA 2010 *Energy Ambassadors plakat* (in Danish), Samso Energy Agency. PDF
- SEA 2009a *Energy Ambassadors brochure* (in Danish), Samso Energy Agency. PDF

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BIORES

Appraisal of Renewable Energy Projects with Cases from Samso > EU projects > Past Projects > BIORES

BIORES (closed)

Nov 2007 - Apr 2010

BIORES aims to promote technologies for energy production from biogas derived from municipal waste in European islands. Work started in November 2007 and the project has a duration of 30 months.

Work focuses on 6 European islands, namely:

- Samos (Greece),
- Samso (Denmark),
- Sardinia (Italy),
- Tremiti islands (Italy),
- Porto Santo (Portugal), and
- the Outer Hebrides of Scotland.

The project addresses two important issues faced by islands:

- energy dependency from the mainland, and
- waste management.

BIORES will promote small-scale decentralised energy production from renewable energy sources. It will also link it with the energy end-use needs of the island communities. In addition, it will promote sustainable waste management.

A software decision support system (DSS) will be developed, taking into account all the parameters that affect decisions for investing in small-scale RES applications based on biogas from waste. The DSS tool will assist potential investors to assess the existing situation, identify barriers that are present in each case and evaluate possible investments.

The project is supported 50% by the European Union under the Intelligent Energy Europe programme.

Intelligent Energy Europe

External Links

- The Biores home page, http://www.biores.eu
- The Intelligent Energy Europe programme, http://ec.europa.eu/energy/intelligent
- BIORES fact sheet PDF
- BIORES brochure - English PDF
- BIORES brochure - Danish PDF

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ARTECLAND

ARTECLAND (closed)

Apr 2005 - Nov 2008

ARTECLAND established three regional/urban energy management agencies in the county of Aarhus (Denmark), Tenerife (Spain) and in Iceland.

The three agencies are

- Agencia Insular de Energia de Tenerife, AIET (home page)
- Energy Agency Iceland, EAI (home page)
- Samsø Energy Agency, SEA (home page)

Each agency had to meet the following conditions for the establishment.

- (a) The agency is established as a new legal entity.
- (b) The statutes of the agency have been approved by the European Commission.
- (c) A management board has been set up with at least one local elected representative.
- (d) The first permanent staff member has been recruited by the agency.
- (e) Evidence of supplementary funding from other sources.
- (f) The agency has been set up in suitable premises at its exclusive use.
- (g) A bank account has been opened under the name of the agency.

The total cost of the action was estimated at 1.387.660 EUR. The European Union contributed 43 percent under the Intelligent Energy Europe programme.

The following special condition applies (grant agreement, amendment 2).

- In case an agency cease activities at any time from the signature of Amendment No 1 to the agreement to the end of the fifth (5th) year after the last payment made by the Commission, the Commission reserves the right, subject to due analysis of the case, to recover the total Community contribution related to the establishment and actual start-up of this particular agency.

The project ended 30 Nov 2008, but the last payment was in Feb 2010.

External Links

- Argyraki V 2009 *Final Report*. European Commission, EACI, assessment of ARTECLAND final reports PDF
- ManagEnergy: Energy agencies in the ManagEnergy network

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Cradle to Cradle Islands

cradle to cradle islands

C2CI

Cradle to Cradle Islands (C2CI) is about lifecycle energy projects on islands, especially for waste reduction.

External Links

- The C2CI home page, http://www.c2cislands.org

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ISLE-PACT

Project period: 1 Jan 2009 - 31 Dec 2012

The ISLE-PACT project is committed to developing Island Sustainable Energy Action Plans and a pipeline of bankable projects with the aim of meeting or exceeding the EU sustainability target of reducing CO_2 emissions by at least 20% by the year 2020. The ISLE-PACT project is an initiative of 12 groups of European island authorities.

The duration of the project is 30 months starting from 1 January 2010.

External links

- ISLE-PACT home page
- ISLENET home page

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Leteff R 2012 Determining the Necessary and Sufficient Conditions for Sustaianble Energy Development: A Case Study of Samsø, Denmark's Energy Island Project. University of Wyoming, Dept of International Studies (MA thesis) PDF	2012	2
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UPATRA 2009 *Finansiering af biogas*. 25 slides, University of Patra, oversat og modificeret af Samsø Energi- og Miljøkontor (jj). PDF	2009 0.17
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Appendix A: Engineering Economics

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Cash flow

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Introduction

Simply put, cash flow is the movement of money in and out of a business, project or financial product. Measurements of cash flow can be used to evaluate the value of a given project, most commonly by listing all the costs and gains from the project over its lifetime. Figure 1 below shows the initial cost of an A++ fridge and the subsequent positive stream of annual energy savings.

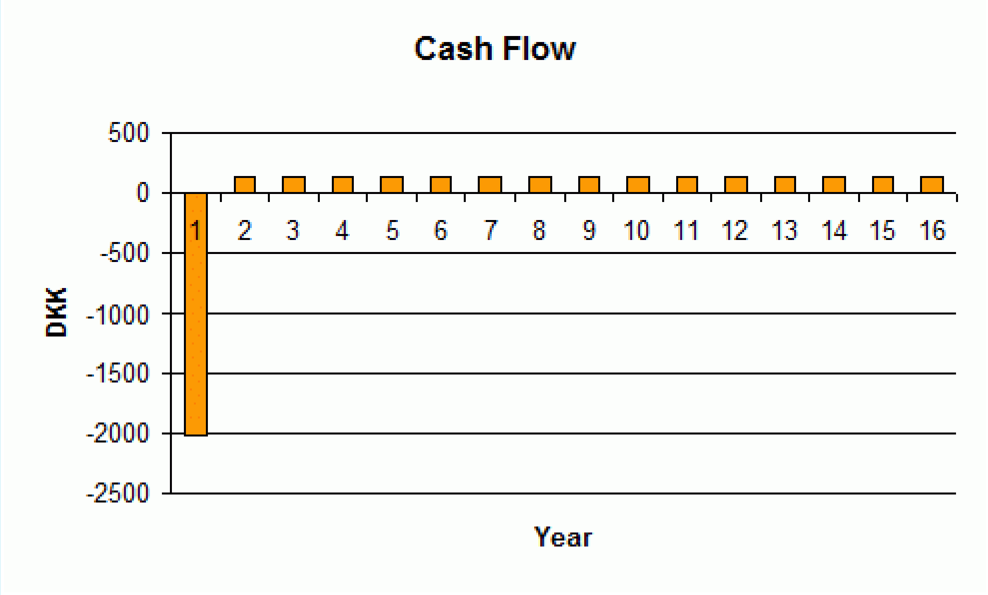

Fig. 1 Cash flow. The initial investment is negative (year 0) while the savings each following year are positive.

For example, if you were to invest in a new fridge you can choose between spending more money on an energy efficient fridge, saving in the long run, or buying a less efficient but cheaper fridge, saving in the short run. This is illustrated in the table below

Table 1. Comparison of fridges. Numbers are based on data from Elsparefonden.dk; the KWH price is assumed to be 2 DKK.

Brand	Volume	Classification	Price	KWH/year	El. cost	Savings relative to A++
name	liters	grade	DKK	KWH	DKK	DKK
Liebherr	156	A++	4 069	84	168	-
Bosch	154	A+	2 959	117	234	66
Liebherr	151	A	2 055	154	308	140

Prices from elsparefonden.dk and lavpriskøkken.dk from the 10.12.2009.

Problem Statement

If you decided to invest in the most energy efficient fridge, classified as A++, then how long would it take before the savings from your electricity bill paid for the extra cost of the fridge? The simplest way to illustrate this is to simply compare the initial cost of the fridge against the saved energy costs over time. The saved energy cost can be considered a cash bonus, as it represents money you would otherwise have spent on the electricity bill. The initial cost of the fridge is a cash outlay, i.e. money you invest in a new product.

Simple Cash Flow

Table 2 below shows the relative cash flow over time for each of the three fridges. Energy savings are relative to the base case of buying the cheapest fridge, the Liebherr A model. Figure 1 above is the cash flow of the Liebherr A++ model.

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Note that in the 15th year, both the A++ fridge and the A+ fridge have ended up costing the owner less than the cheapest fridge.

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Internal rate of return, IRR

Appraisal of Renewable Energy Projects with Cases from Samso > Appendix A: Engineering Economics > Internal rate of return, IRR

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Introduction

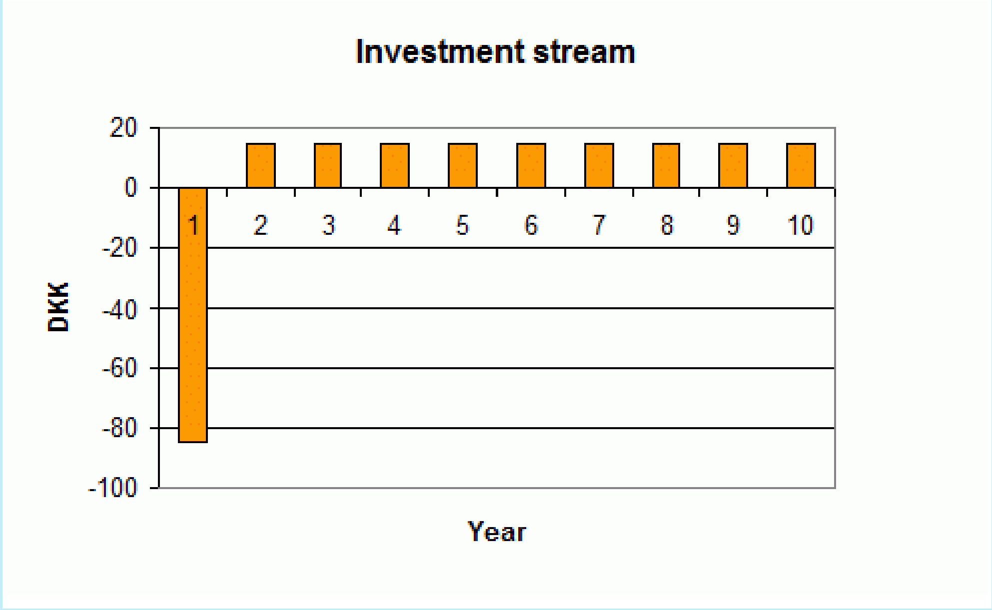
The simplest version of internal rate of return (IRR) determines the rate of return that will set the stream of benefits from a project equal to the initial outlay.

That is, for an initial investment of 100 DKK with annual returns of 15 DKK for 10 years and a scrap value of 0, what rate of return must be applied to make the two equal?

- 100 = 150/(1+?)

If one ignores the time value of money, the relevant rate would be 50 % (1 + 0.5). However, IRR takes into account the time value of money, such that future benefits are weighted lower than initial outlays.

The simple stream is illustrated graphically below.

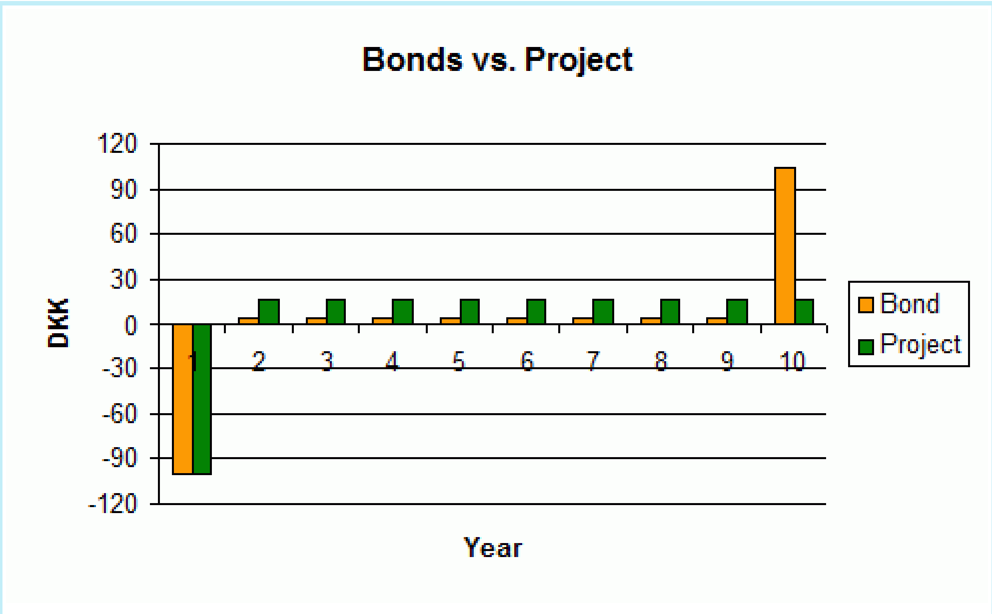


Note that the investment stream in Year 1 sums to -85 (-100 + 15).

For what rate of return are the two equal in Year 1? Using the internal rate of return function in a spreadsheet reveals an IRR for the full period equal to 10.41 % (1 + 0.104) for the above example.

A different way of calculating this would be to discount all amounts to present value, income (plus) and investment (minus). The discount rate which will set the result to 0 is the internal rate of return. (The easiest way is to guess an appropriate interest rate and reiterate the calculations until you reach a value of zero).

Calculating IRR is useful for comparisons of returns from a project investment relative to, for example, returns from investment into government bonds. Assuming an annual returns of 3 percent on the government bonds, the IRR equals 3.36 percent over the full period. The investment stream is shown in the graph below.



In the above graph, a project and government bonds costing 100 DKK are purchased in year 1. From year 2 to year 10 (9 years) they provide a return of 15 % and 3 % respectively. At the end of the period, the original bond is returned to the owner whereas the scrap value of the project is 0. The IA for the project is 6.46 % and for the bonds 3.36 %. For a person investing in both government bonds and the project, the project will provide the larger payoff. (Note that this calculation assumes that the positive returns are reinvested in the project each year - which explains why government bonds with a 3 % annual return has a total return rate of more than 3 %).

Limitations of the simple IRR

There are two key problems with the simple IRR.

- in some situations a project will require additional investment during its lifetime. If this additional investment is larger than the benefit in the period, then there will be a negative value in the stream of benefits. For an investment with an initial cost of 100 DKK, a benefit in year 2 of 420 DKK and an additional investment in year 3 of 400 DKK, there are two solutions for IRR, namely 46 percent *and* 174 percent, both of which are mathematically correct. Additional scenarios could result in more than 2 (mathematically) correct solutions.

- while the simple IRR is sufficient for evaluating single project proposals, it is not suitable for comparisons of mutually exclusive projects; i.e. it is not capable of accurately ranking different project proposals. This is because the IRR assumes that all returns are reinvested at the rate of return calculated by the IRR, and no distinction is made between a rate of interest charged for borrowing and a rate of interest earned on lending, i.e. these are assumed equal, which is rarely the case - banks frequently charge more for loans than the give on deposits. This is clear from comparisons with net present value (NPV) calculations of the same projects. Instead, a variant of IRR known as 'Incremental IRR' can be used to compare competing project proposals. An example is given below.

Practical Example

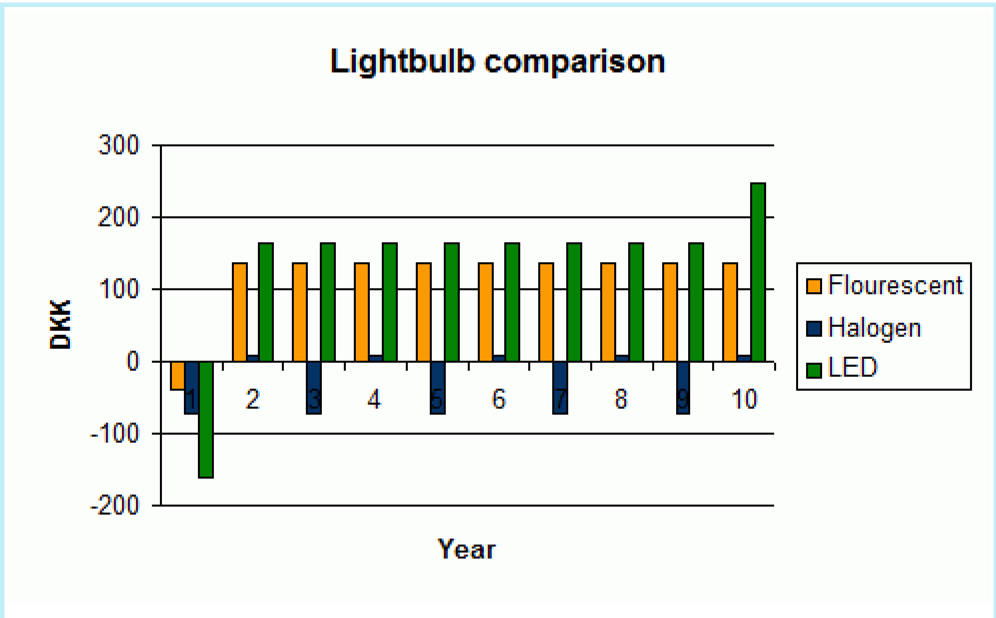
The following example compares initial costs and costs over time of three types of energy efficient lightbulbs; compact flourescent light, light-emitting diodes (LED) and halogen light. Table 1 describes the specifications of the lightbulbs used.

Table 1. Comparison of lightbulbs

Type	.	Flourescent	Halogen	LED
Fitting	.	E27	E27	E27
Watt/Effect	W	15/60-75	60	6/60
Lifetime	hours	10 000	2 000	20 000 - 50 000
Price	DKK	45	79	168
Annual energy usage	KWH	21.9	87.6	8.8

Note that all prices are wholesale estimates, and all other values are approximate only. Energy estimates are based on a lamp being in use 1 000 hours a year. A KWH is assumed to cost 2 DKK

The graph below illustrates the investment stream over time for the above 3 lightbulbs relative to a traditional incandescent lightbulb with similar specifications. Savings are composed of electricity savings and reinvestment savings, as the traditional incandescent lightbulb has a lifetime of only 1 000 hours, app. 1 year. However, the cost of the traditional lightbulb is also substantially lower, app. 6 DKK. Given the much longer lifetime of the LED bulb, the remaining years are included as scrap value at the end of the period.



In year 1, the investment for the three lightbulbs is negative, reflecting the greater cost relative to the traditional incandescent lightbulb. The fluourescent lightbulb is 7.5 times more expensive, the halogen bulb is 13.2 times more expensive, and the LED bulb is 28 times more expensive than the traditional lightbulb.

The halogen lightbulb has a lifetime only twice that of a traditional lightbulb, uses the same power (60 W) and costs significantly more (although the lighting is said to be superior). This explains why the investment is negative every second year, and why the overall savings are quite low. The two other types of lightbulbs are obviously superior investment-wise, with a lifetime extending throughout the period, and a much lower energy consumption than the traditional lightbulb. Given that the traditional lightbulb has to be replaced each year, both the fluorescent and LED lightbulbs represent significant annual savings after the initial investment. The table below gives the simple IRR and the net present value (NPV) for the three lightbulbs:

Table 2. Investment evaluation

Type	Year 1	Year 2	Year 10	IRR	NPV
Flourescent	-39	137.4	137.4	352	1 031
Halogen	-73	6	6	n/a	-300
LED	-162	163.6	247.6	101	1 176

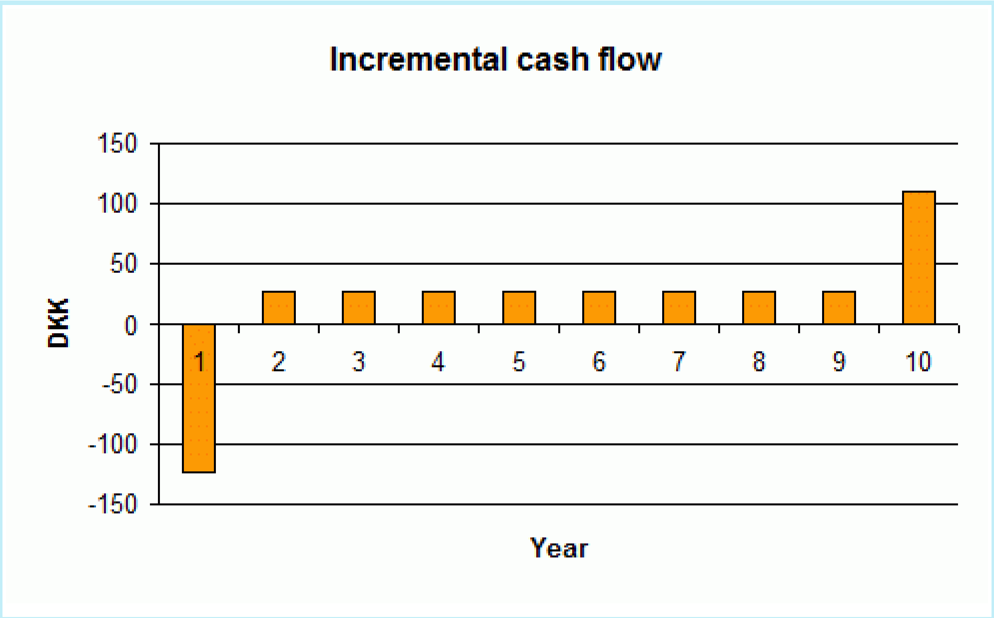
All values are in DKK except for IRR, which are in percentages. The NPV calculations are based on a discount rate of 3 percent.

The table above shows the inital investment of each lightbulb less the cost of the traditional bulb (6 DKK) which has to be replaced annually. For the case of the halogen bulb, which has to be replaced biannually, this results in an alternating positive/negative stream of benefits since there are no gains from energy savings. The IRR could not be calculated for the halogen bulb, as IRR calculates a solution every time the value changes from positive to negative; in this case there were 5 solutions, all of which are mathematically correct.

The IRR method clearly favours the flourescent bulb over the LED, despite the larger energy savings of the latter, and the scrap value in year 10 from the longer lifetime of the bulb. The NPV ranks the LED bulb over the flourescent bulb, with the halogen bulb having a negative value; unsurprising, given the amount of reinvestment needed over the period for this type of lighting, and the lack of other savings.

Incremental IRR

The ranking from the NPV in Table 2 above can be replicated by using incremental IRR rather than simple IRR. Since the flourescent lightbulb (A) is a low-cost option relative to the LED bulb (B), you subtract A from B to find the incremental cash flow:



The above yields an IRR of 20 percent, which is high enough to consider the LED lightbulb a better investment than the flourescent lightbulb.

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Net present value

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Introduction

Present value is simply the current value of an investment or monetary quantity. For example, if you were given 100 DKK today, the present value would equal 100 DKK. However, if you were given 100 DKK on the same date next year, the present value would be less than 100 DKK.

The reasoning is simple: if you were given 100 DKK today, you could invest the money in a bank, and next year it could be worth

100 DKK + interest

Alternatively, you could use the money immediately instead of investing it by purchasing goods worth 100 DKK, e.g. 20 liters of milk. However, if you waited until next year to purchase milk with the same 100 DKK bill, you would no longer be able to buy 20 liters. Prices increase slightly on average across all goods every year, an effect known as *inflation*, corresponding to an increase of 1-2 % annually. A sum of money that can buy 20 liters of milk this year will only be able to buy 19.5 liters of milk next year.

Interest rates set by banks are generally slightly above expected inflation rates, such that money deposited in a bank does not lose purchasing power over time.

Discounting

Discounting is a practice used to take into account the lesser value of a given amount of money in the future relative to the present. If the discounting rate were set equal to the bank's interest rate, then the value of future income is adjusted downwards to take into account the lost interest that could otherwise have been earned. In other words, 100 DKK earned next year is worth less than 100 DKK earned this year. For example, if the bank's interest rate were set to 3%, then 103 DKK earned next year would be equal to 100 DKK earned this year.

Other factors than interest rates and inflation contribute to the discounting rate, such as personal preference or uncertainty. For example, if you were given the choice between receiving 100 DKK today and maybe receiving 120 DKK next year, you might prefer the 100 DKK today if you wanted to use the money right away. This form of argument is often used when evaluating investment decisions, which depend on giving up a set amount today in order to receive a larger amount in the future - for example, saving up for a pension plan.

Discounting is also commonly used when there is some degree of uncertainty involved in a project proposal. If you were asked to invest in a ferry which would *probably* transport 500 people a day, but *maybe* only 200 people a day, then you might insist that the ferry should be able to pay for itself even if only 200 people a day used it. You would strongly discount potential profits based on the transportation of 500 people a day, since the likelihood of earning such profits would be very low. High discounting rates are used when there is substantial uncertainty about the outcome of a project.

Practical example

If you wanted to buy a new television, and were unsure whether a plasma screen or an LCD would be more expensive in terms of electricity over time, you could set up the following table:

Table 1. Comparison of televisions

Screen type	Annual electricity consumption	Estimated annual cost
Inches	KWh	DKK
LCD 20	60-110	120-220
LCD 32	110-260	220-520
LCD 42	160-390	320-780
Plasma 42	260-480	520-960
Plasma 50	360-660	720-1320

The data on electricity consumption is taken from www.elsparefonden.dk and is based on average daily tv usage of 4 hours (1 460 hours annually), with the remaining hours on standby. One KWh is expected to cost 2 DKK.

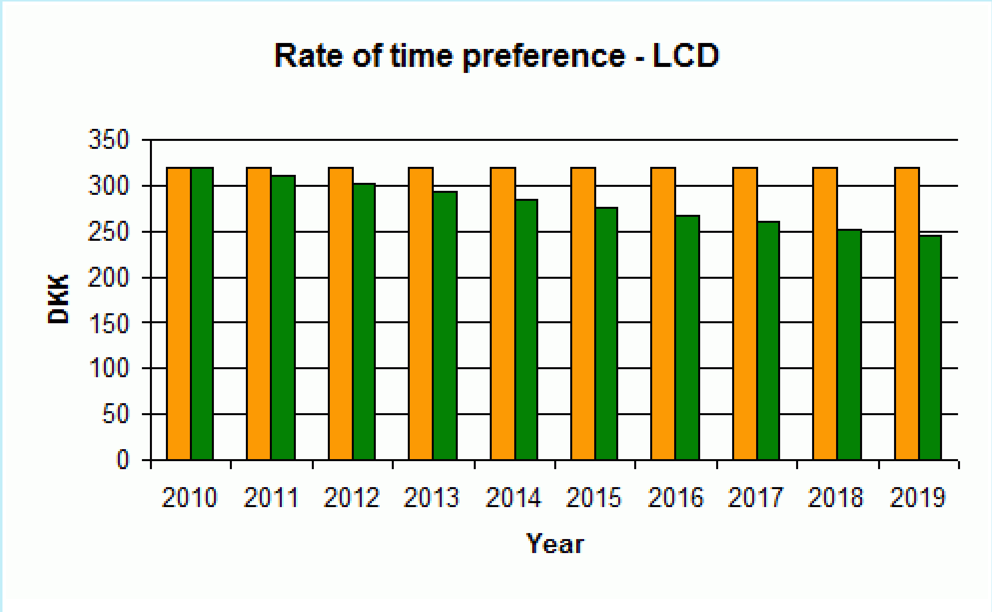
A 42-inch plasma screen TV has a higher KWh consumption than an LCD screen of the same size, due to its superior contrast and picture quality. In terms of electricity cost, the difference is approximately 180-200 DKK annually. Simply calculated, the difference amounts to an extra 2 000 DKK cost for the plasma screen TV over a ten-year period. However, due to the reasoning explained above, 200 DKK in ten years time is not the same as 200 DKK today.

Using a discount rate of 3 %, the annual minimum electricity costs of a 42-inch plasma screen and LCD screen TV in present value are presented in the table below:

Table 2. Present value of electricity costs over time

Time	Annual electricity costs		Present value of electricity costs	
Year	Plasma screen	LCD screen	Plasma Screen	LCD screen
Present	320	520	320	520
2011	320	520	310.7	504.9
2012	320	520	301.6	490.1
2013	320	520	292.8	475.9
...	...	...	...	...
2019	320	520	245.3	398.5
Sum	3 200	5 200	2 811.6	4 568.8

Although annual electricity costs remain constant over the period, the present value falls each year. The longer the time frame, the more the cost is discounted. Note that the present value depends on the year selected. The present value in 2010 of the electricity cost of the LCD screen in 2019 is 245 DKK, but the present value in 2019 of the electricity cost in 2019 is 320 DKK. In other words, although the electricity costs remain the same, the future cost is discounted by 75 DKK relative to its value today. The graph below illustrates this trend for the LCD screen.



Discounting versus Depreciation

Discounting should not be confused with depreciation. While discounting reflects time preference in valuing money today over money tomorrow, depreciation reflects the decrease in value of an object over time. Using the previous example, a new television is expected to have a lifetime of 20-30 years, after which it will be turned into scrap metal. The value of the TV at the end of its useful lifetime will be substantially lower than its initial cost (if not zero).

The value of a television screen worth 3 999 DKK today, over its lifetime with a constant rate of depreciation and a scrap value equal to zero is shown in the graph below.

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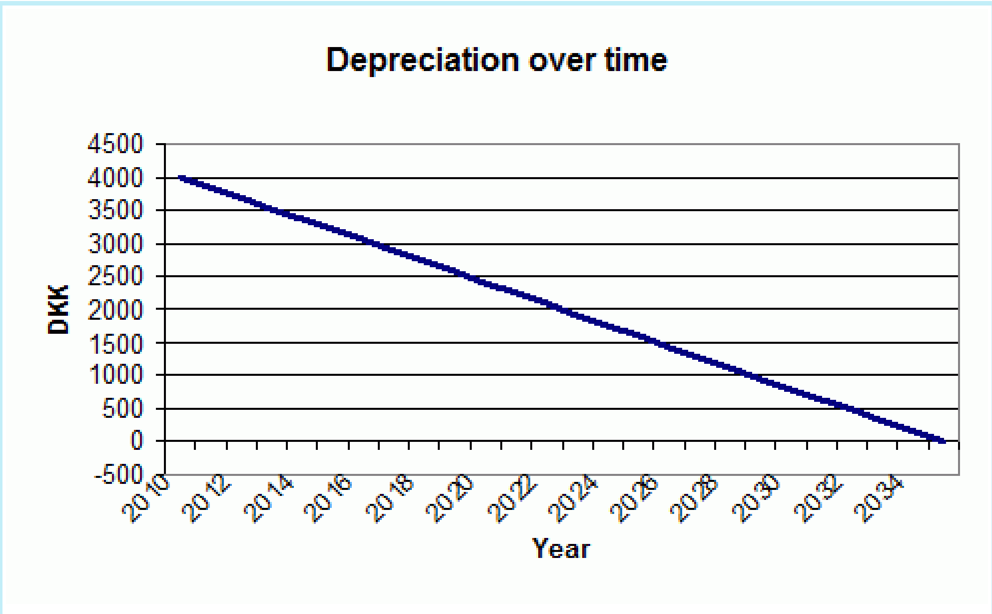

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Appendix B: Energy

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Calculating in KWh

Appraisal of Renewable Energy Projects with Cases from Samso > Appendix B: Energy > Calculating in KWh

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Summary

The following approximate conversion factors are used to calculate in kilowatt-hour units.

Fuel	Factor
Oil	8 kWh useful heating/liter
Firewood	1 000 kWh useful heating/cubic meter
Solar panels	400 kWh useful heating/square meter
Woodpellets	3.7 kWh useful heating/kg
Wooden briquettes	3.4 kWh /kg
Wooden briquettes, 1 pallet	3 300 kWh useful heating

Using the above figures — and the assumptions underlying them — one cubic metre of firewood, not stacked neatly, corresponds to 125 litres of oil. A solar panel of 2.5 square meters also corresponds to 125 liters of oil a year.

If there are more known details, such as the type of wood or its heating efficiency, the calculations can be amended with the below formulas to generate more accurate conversion factors.

Oil furnaces

The heating needs of a household are calculated in kilowat-hours. What if a homeowner calculates heating needs in terms of liters of oil consumed a year?

We need to be able to calculate the energy content of oil in terms of kilowatt-hours,taking into consideration the efficiency rate of the boiler. Specifically, the

useful heating (kWh) = oil (liter) * overall mass (kg/liter) * energy content (kWh/kg) * boiler efficiency

For example, if we use just one liter of oil, and assume that the boiler efficiency is 0.8, then the

```
useful heating (kWh) = 1 liter * 0.84 kg/liter * 11.86 kWh/kg * 0.8
                     = 1 liter * 10 kWh/liter * 0.8
                     = 8 kWh
```

In the introduction above we stated that the expected useful heating from oil is 8 KWH/liter; this works as a rough approximation. Note that the energy content of oil pr liter is a straightforward whole number: 10 kWh/liter.

If the efficiency rate is different from 0.8, remember to substitute it into the equation. Efficiency rates usually lie in the range +/- 15% af 0.8, so the final result will also usually lie within +/- 15% af 8 kWh/liter.

For example, if a homeowner states his oil consumption as 2 000 liters a year, then the

```
useful heating (kWh) = 2 000 liter * 8 kWh/liter
                     = 16 000 kWh
```

This number can be compared to the normal heating consumption in a house of the same size (Average single home heating consumption). The *normal* heating consumption is given effective heating (living room heating). This figure is fixed, so to facilitate comparison we have to take into account heating method and efficiency rates.

Firewood

If a homeowner uses a private stove as a supplementary source of heating, and states annual consumption partly in terms of steres (cubic meters) of wood a year, then what?

We have to calculate the combustion value of firewood in terms of kilowatt-hours, but we also have to include the efficiency rate of the stove. Specifically, this is

useful heating (kWh) = firewood volume(steres/cubic meters) * solid mass coefficient (cubic meters/stere) * density (kg/m3) * energy content (kWh/kg) * efficiency rate

Firewood is sold by volume, in *steres* (EU) or *cords* (US), but the amount of free space in a stere or cord can vary, because wood is stacked differently (Danish Institute of Technology, website on stoves). One stere corresponds to the volume of a box measuring one meter on each side (1 m height * 1 m length * 1 m width = 1 cubic meter). One stere corresponds roughly to 0.276 cords.

Solid mass coefficient is the fraction of the mass that is actually solid (firewood).

- Cubic meter: a cubic meter of wood; the unit cubic meter is used when considering a piece of wood, even though an average piece of wood is significantly smaller than a cubic meter. Solid fuel coefficient 1, i.e. no air pockets from wood stacking in this case.
- Stacked cubic meter: Short pieces of firewood stacked efficiently. Solid fuel coefficient of app. 0.7, i.e. 70 % solid wood and 30 % air pockets.

- Loaded cubic meter: the firewood is stacked haphazardly. The solid fuel coefficient is app. 0.45 , i.e. 45% solid mass and 55% air pockets.

The firewoods *solid mass* is the proportion of dry mass per cubic meter in one piece of firewood (kg/cbm), which depends on how much air is in the piece of firewood relative to its solid mass.

The firewoods *density* is the proportion of dry mass per cubic meter in a single piece of firewood (kg/cbm), and it depends on how large the air pockets are relative to the dry mass. This measurement is in *stere*, not cubic meters. The density depends on how fast the tree grows, so the value is dependent on the tree sprecies and the growth conditions.

The dry mass *energy content* is always 5.25 kWh/kg. Firewood with 18% moisture, equivalent to *dry* wood stored for a year, has a lower energy content, 4.2 kWh/kg.

The efficiency rate for a woodfuelled stove depends on the construction, but on average corresponds to 0.7.

Fig. 1 Estimated solid fuel coefficient: 0.45.

Fig. 2 Estimated solid fuel coefficient: 0.70.

Fig. 3 Estimated solid fuel coefficient: 0.80 (assuming a dense core).

Using a stere of birch firewood (18% moisture content), not neatly stacked (solid fuel coefficient 0.55, i.e. 45% air pockets), then the

```
useful heating (kWh) = 1 stere * 0.55 cbm/stere * 620 kg/cbm * 4.2 kWh/kg * 0.7
                     = 1 000 kWh
```

The conversion factor used here is equivalent to the one at the top of page (Summary). It depends on several assumptions, so if the actual figures for solid fuel coefficients, density, combustion values and efficiency rates are known, the average of 1 000 kWh/kg can be modified.

Table 1 contains modified conversion factors for wood from different tree species. The figures in the table range between +/- 10% of the average estimate of 1 000 kWh/stere.

Table 1. Useful heating in firewood (data from Energy Service Denmark, spreadsheet *Estimates of wood*). Assumption: moisture 18%, efficiency rate 0.7, solid fuel coefficient 0.55, efficient heating 4.2 kWh/kg.

Tree species	Density (kg/cbm)	Useful heating (kWh/stere)
Beech	710	1 150
Oak	700	1 130

Ash	700	1 130
Elm	690	1 120
Maple	660	1 070
Birch	620	1 000
Mountain fir	600	970
Willow	560	910
Alder	540	870
Forest fir	520	840
Larch	520	840
Small-leaved lime	510	820
Pine	450	730
Poplar	450	730
Deciduous trees	680	1 100
Spruce trees	593	960

Solar heating (Solar panels)

Solar panels consist of a piping system containing water and anti-freeze solution. The pipes are black, so that they can absorb as much sun as possible, and they are encapsulated in a box with a glass or plastic surface to minimize loss due to wind.

The yearly production varies with the number of sunlight hours in the geographic area, but estimated production is app. 400 kWh per square meter solar panel, with deviations of app. +/- 25% (Danish Technological Institute, Life cycle estimates, p. 25, table 5.5). A panel on a house is typically 2 - 3 square meters.

The efficiency of a solar panel depends on its placement relative to the sun, as well as the outside temperature.

Woodpellets

An average woodpellet boiler has an efficiency rate of 0.75, and the combustion value for woodpellets is 4.9 kWh/kg. Thus the conversion factor is 4.9 kWh/kg * 0.75 = 3.7 kWh/kg.

Wood bricquettes

Wood bricquettes consist of glue-free sawdust, shavings and bark which is pressed into bricquettes.

The moisture content is normally around 6 - 8% in bricquettes, unless they have been exposed to moisture. Assuming a moisture content of 6%, the energy content is 4.9 kWh/kg (Figure 4), equivalent to woodpellets. With a boiler efficiency of 0.7, the conversion factor becomes 4.9 kWh/kg*0.7 = 3.4 kWh/kg.

One pallet of wood bricquettes weighs 960 kg, so the useful heating at 6% moisture content is 3.4 kWh/kg * 960 kg = 3 264.

Moisture

The higher the moisture content in wood, the lower the energy content, because the boiler will waste energy on heating up the water to boiling point and then evaporating it. Figure 4 shows that the energy content drops to less than half if there is 50 % moisture in the fuel (e.g. newly lumbered logs)

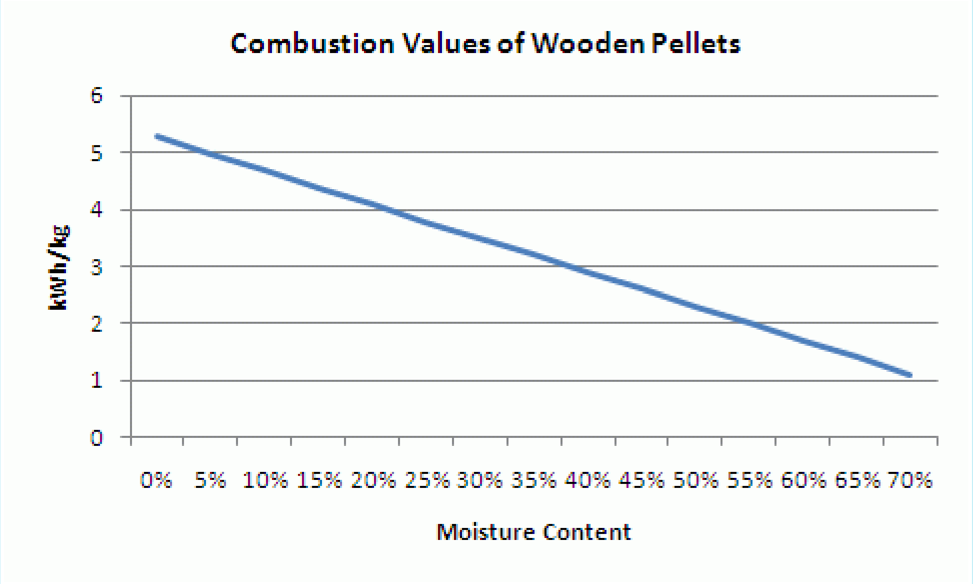

Fig. 4 Wood energy content. The more moisture, the less energy.

The energy content for one kg of wood is reduced by the heat needed for evaporatation and for heating the water to boiling point

```
energy content = energy content dry mass - evaporation heat loss - heating loss
```

If the moisture content is *f*, then the formula for one kg of fuel at living room temperature 20 degrees C,

```
energy content [kWh] = 5.25*(1-(f*0.01)) - 0.6274*f*0.01 - 0.001163*f*0.01*(100-20)
```

5.25 is the energy content for dry mass (kWh), the value 0.6274 is the thermal energy needed to evaporate a kg of water, and the value 0.001163 is the thermal energy in kWh required to heat one kg of water by one degree. The difference 100 - 20 = 80 is the number of degrees the wood has to be heating to reach boiling point.

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Degree Days

One November could be twice as cold as another, and fuel demand for space heating can vary by a factor of two between corresponding months. The number of *degree days* is a measure of how cold it has been: the larger the number, the colder.

Degree days are generally calculated on a 24-hour basis, but a cumulation of, say, a week's measurements would indicate the heat demand of that week. Figure 1 illustrates that the number of degree days depends on the season and the location.

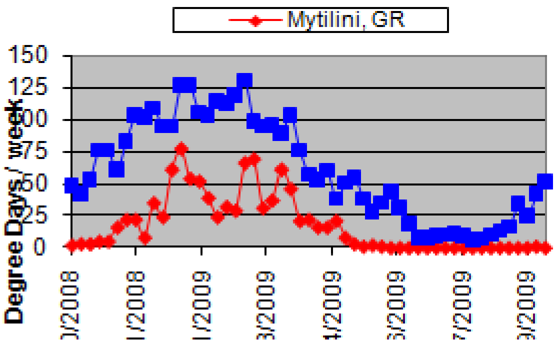

Fig. 1. Degree day recordings (degreedays.net). Every week of the year, from the start of the heating season in October 2008, Mytilini (Greece) had a lower number of degree days than Tirstrup (Denmark). The summer period with low numbers is longer in Mytilini, and it starts about two months earlier.

Definition

The number of *Heating Degree Days* (HDD) indicates the amount of energy needed to heat a building, and the number of *Cooling Degree Days* (CDD) indicates the amount of energy needed to cool a building. They are defined relative to an outdoor base temperature, beyond which the building does not need heating / cooling.

The Danish Meteorological Institute uses 17 C (62.6 F) as the base temperature for the HDD. They reason that electrical equipment and radiation from human beings raise the indoor temperature by 3 C, and also no space heating is required beyond 17 + 3 = 20 C. The textbook definition is the following,

$$HDD = 17 - m \{\text{for } m < 17, \text{ otherwise } 0\}$$

The number *m* is the mean value (average) of temperature measurements in degrees celsius over a 24-hour period.

Example. Heating degree days

1) The mean value of 24 hour-by-hour measurements is m = 15, thus

$$HDD = 17 – m = 17 – 15 = 2$$

That is, two degree days.

2) The mean value of 24 hour-by-hour measurements is m = 18, thus

$$HDD = 0$$

That is, zero degree days.

The number of degree days indicates the demand for space heating. For example, a supplier of fuel oil for domestic furnaces can estimate when a customer needs a refill, by watching the number of degree days.

Some years are colder than others, and Figure 2 shows a variation of almost +/- 20 percent in the number of degree days per year.

Given the number of degree days, one can estimate the fuel consumption and discover if the actual fuel consumption is unusually large. A standard year in Denmark is 2 906 degree days, and it is thus a matter of scaling to find the standard heat demand of the house.

The Danish Meteorological Institute publishes every month degree day measurements from about 35 different stations in the country. There is none at Samsø, but *Røsnæs fyr* is probably the one with weather conditions most similar to Samsø.

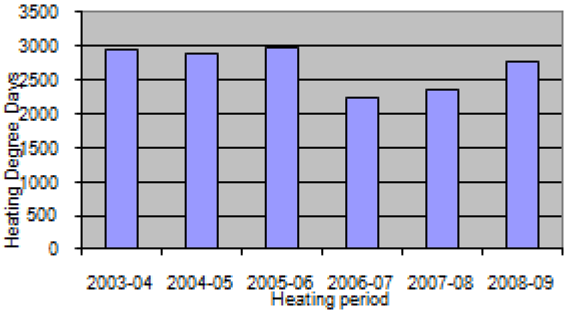

Fig. 2. Degree days per year at Rosnas, Denmark (dmi.dk). The heating period 2006-2007 was warmer than the surrounding years in Rosnas (Denmark) and households saved energy accordingly. A standard year in Denmark (average of many years) is 2906 degree days.

External links

- degreedays.net: Custom Degree Day Data
- dmi.dk, The Danish Meteorological Institute: Graddage
- Wikipedia: Heating Degree Day

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Energy content


Fig. 1 Supplementary heat. The output depends on fuel weight, moisture, and boiler efficiency rate.

Wood has an *energy content*, i.e. the full heat generated during incineration. All wood has the same energy content per kg, but density and stacking methods make a difference. The energy content for fuel oil is 10 kWh/liter.

For example, there is a lot of space in a stere, where wood has been thrown haphazardly in a box measuring a cubic meter.

Definition

The energy content is the amount of energy released during incineration of one kg of a fuel.

Examples

1. *Firewood*

Stored, split beechwood has an energy content of 4.2 kWh/kg with a moisture content of 18% (Danish Technological Institute, webpage Household stoves).

2. *Oil*

The energy content in heating oil, which is similar to diesel oil, is slightly above 11 kWh/kg. Converted to liters it corresponds to 10 kWh/liter.

Firewood

The energy content in firewood is affected by the amount of moisture, since the water must be heated and evaporated, and none of it contributes to useful heating. The moisture content is app. 18 % , if the firewood has been split and dried 1-2 years.

All types of wood have the same energy content, i.e. 4.2 kWh/kg. However, wood has differing weights depending on the amount of air pockets. Beech, oak, ash and elmwood are relatively dense, whereas pine and poplar are less dense. Danish tree species have densities which vary app. +/- 8% (Danish Energy Service, spreadsheet *Beregning af braende energitjenesten2.xls*).

Table 1. Selected energy contents (Centre of Biomass Technology, *Overview of fuel energy content*, factsheet 67).

Fuel	Moisture content (%)	Energy content (kWh/kg)
Straw, yellow	15	4.00
Straw, grey	15	4.17
Straw pellets	8	4.44
Corn	15	4.17
Beechwood, stored	20	4.08
Beechwood, fresh	45	2.61
Woodpellets	6	4.90
Heating oil		11.86

Also see

- Energy costs and heating methods

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Energy costs and heating methods

Cheap installation costs often coincide with high operation costs

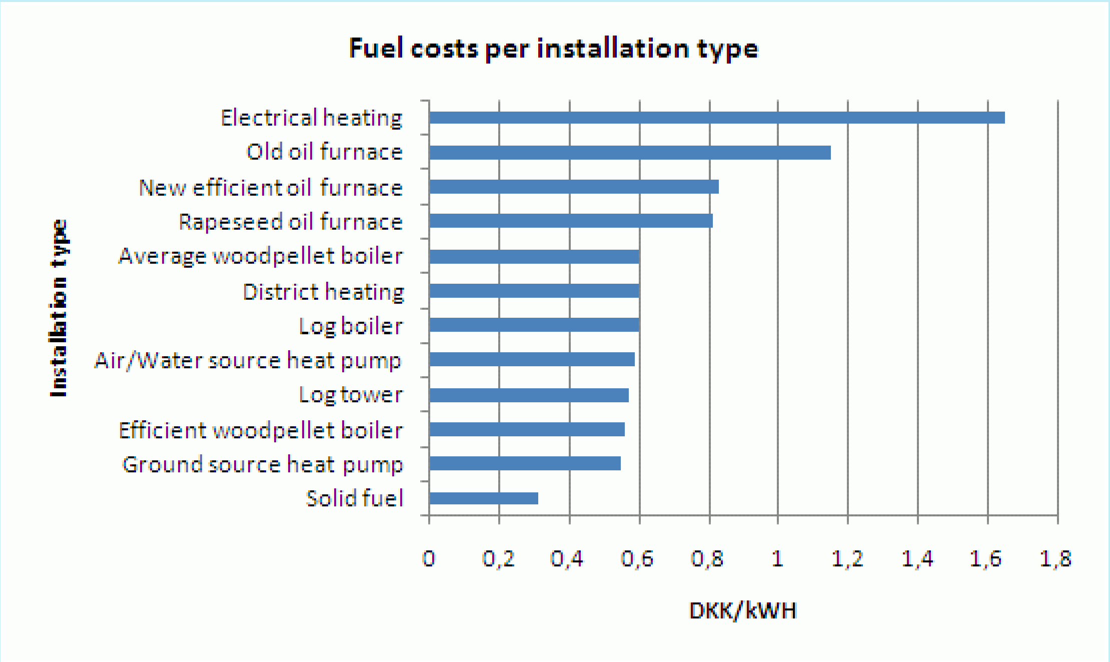

Fig. 4 Fuel prices pr. household kWH (Danish Energy Agency spreadsheet 2009).

Table 1. Energy prices (Danish Energy Agency spreadsheet 2009)

Installation	DKK/kWH
Old oil furnace	1.15
Efficient woodpellet boiler	0.56
Average woodpellet boiler	0.60
Log boiler	0.60

Log tower	0.57
District heating	0.60
Ground source heat pump	0.55
Air/Water source heat pump	0.59
Solid fuel	0.31
New efficient oil furnace	0.83
Rapeseed oil furnace	0.81
Electrical heating	1.65

Also see

- Heat source efficiency

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Heat source efficiency

Almost all furnaces suffer heat losses, which is why the *thermal efficiency* expresses the amount of heat a furnace can provide, relative to the available energy supply.

For example, an oil furnace loses heat through the chimney, or if your burner is sooty, then it is only using part of the energy available in the oil. The efficiency rate is measure of the installations useful effect.

Fig. 1 Oil boiler. The black box at the bottom is the furnace (Statoil), and the tall blue container is the boiler (DFJ Salamander C). The furnace is new, but the boiler is old and not insulated, with low efficiency.

Definition

The efficiency rate measures the relationship between the energy produced and the energy supplied, in other words

efficiency rate = useful energy out / total energy in

The term 'useful energy' corresponds to 'living-room temperature'. It is not possible to produce more useful energy than is supplied, so the efficiency rate lies between 0 and 1, or in percentage terms, between 0 and 100 %.

Examples

1. *Old oil furnace*

An oil furnace from 1977 or earlier loses energy to the chimney, boiler room and from incomplete combustion. If the oil tank is stored outside, and the oil is cold, there is an additional loss from heating up the oil.

Unless you've measured the efficiency rate directly, it can be assumed to be 0.6 or 60 % (Table 1).

~hs~efficiency rate oil furnace 1977  0.60

The green bar displays useful heating, while the red bar shows the loss. The whole bar corresponds to 100 % of the supplied energy from fuel.

2. *New oil furnace*

A new, good-quality oil furnace with an optimized injection pump and an insulated furnace has an efficiency rate of 0.9, or 90 % (Table 2).

~hs~efficiency rate new oil furnace~hs~~hs~  0.90

Your chimney sweep may have measured the efficiency rate and left a note by the furnace with the written rating.

3. *Electrical heating*

Electrical heating has an efficiency rate of 1.0:

~hs~efficiency rate electrical heating~hs~~hs~~hs~~hs~~hs~  1.00

While this might appear to be ideal, the price of elctricity is so high that in reality, this is the most expensive form of heating.

(Naturally, there are losses in the electricity transfer from the meter to the appliances, but arguably, these should not be counted. The same loss occurs for heating, and if that heating is used for the general household, then the efficiency rate becomes 1.0)

Tables

Table 1 (below) contains officiel figures from the Danish Energy Agency, while table 2 contains the unofficial historical figures from Energy Service Denmark.

Table 1. Standard efficiency rating values (Danish Energy Agency 2009)

Appliance	Efficiency rate
Oil furnaces from 1977 or earlier, cast or sheet iron boiler	0.60
Oil furnaces after 1977, cast or sheet iron boiler	0.77
District heating installation	0.95
Conventional warm air gas furnace	0.74
Induced draft gas furnace	0.83

Table 2. Efficiency rates (Energy Service Denmark spreadsheet 2009)

Appliance	Efficiency rate
New condensing oil furnace	0.97
New efficient oil furnace	0.90
Rapeseed oil furnace	0.85
Best wood pellet boiler	0.80
Average wood pellet boiler	0.75
Wood bricquettes	0.70
Ground source heat pumps (COP)	3.00
Water source heat pumps (COP)	2.80

Household stove	0.70
Electrical heating	1.00

Also see

- Energy costs and heating methods

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Kilowatts and Kilowatt-Hours

Appraisal of Renewable Energy Projects with Cases from Samso > Appendix B: Energy > Kilowatts and Kilowatt-Hours

The electricity bill is an account of spent kilowatt-hours, and a kilowatt-hour is a unit for measuring electrical energy. It is equivalent to the energy consumed by a device the size of one kilowatt in one hour. Kilowatt is the speed at which it consumes energy.

Table of contents

Introduction

The unit kW means *kilowatt* and kWh means *kilowatt-hours*. Kilowatt-hours (kWh) is a unit of energy, and a consumer pays the electricity bill based on the kWh consumption (Fig. 1). It can be difficult to distinguish kW from kWh, but first of all,

1 kW = 1 000 W

much like 1 kilometer = 1 000 meters. However, watts are more abstract than meters.

Fig. 1 Old electricity meter. The thin metal disc in the window rotates in the arrow's direction. Number of rotations indicates energy consumption. Modern meters blink and release electrical pulses which are monitored by computer.

Energy (kWh)

An electricity meter measures kilowatt hours in units of kWh. That is, a quantity of kilowatts is multiplied by a number of hours. Households report their consumption to the electricity company, the company reads it off the meter, or the company measures it automatically by means of a smart meter.

On average, a Dane uses app. 1 400 kWh electricity per year (excluding heating). If the price is app. two crowns (DKK) per kWh including VAT, this sums to annual costs of app. 2 800 DKK a year.

The more appliances that are switched on, the faster the meter counts. The longer an appliance is on, the more the meter turns. If no appliances are turned on, the meter stays still. Electrical consumption depends on time in use, which is why kilowatt hours (kWh) is the measure of kilowatt (kW) multiplied by the number of hours (h). Smaller or larger unit measures can be applied according to preference (Table 1).

Power (kW)

The size of an electrical engine is measured in kilowatt, written as kW. This is the power used by the engine, as well as its consumption of electricity. Power is energy per unit of time. If an engine is constantly running, and uses a number of kilowatt hours (kWh) and we divide this by the time in use (h), we get the power (kW). A wide variety of appliances and engines exist (Table 2). Both small and large units of measurement are useful here, and reduce the need for decimals.

Example. Vaccuum cleaner.

A vacuum cleaner with a power of 1.8 kW (or 1 800 W) which runs for half an hour will use

$$\text{energy} = \text{power} * \text{time} = 1.8\text{ kW} * 0.5\text{ h} = 0.9\text{ kWh}$$

The meters' wheel in the image in Fig.1 will have moved 0.9 units.

Other examples

- One kWh corresponds to an electrical heater of 1 000 W heating for an hour. If the heater is on for two hours, total energy used is 2 kWh.
- One liter of heating oil corresponds to 10 kWh energy. If the oil-based furnace is 10 kW, it can burn for one hour using one liter of oil.
- A human will typically consume 2000 calories in one day, equivalent to 0.0023 kWh. This is equivalent to a 100 watt light bulb shining for 24 hours.

Analogy

The electricity meter is similar to the speedometer in a car in Fig. 2.

- Power corresponds to the speed dial
- Energy corresponds to the distance counter

Energy is power accumulated over time, as distance is speed accumulated over time.

Fig. 2. Speedometer from a car (photo: Wikimedia commons).

Table 1. Units of energy

Name	Symbol	Magnitude
watt-hour	Wh	1
kilowatt-hour	kWh	1 000 Wh
megawatt-hour	MWh	1 000 kWh
gigawatt-hour	GWh	1 000 MWh

Table 2. Sources of power

Quantity	Example
1 W	an LED light bulb
10 W	an energy saving light bulb
100 W	an incandescent light bulb
1 kW	an electrical heater, small vacuum cleaner, solar panel
10 kW	a large heating pump, a stove
100 kW	a car engine
1 MW	one of Samsø's 11 land-based windmills
10 MW	four ocean-based windmills
100 MW	engine on the container ship, Emma Mærsk
1 GW	Asnæsværket (Danish Power Plant; district heating unit excluded)

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Price of a kWh

One kWh costs app. 2 DKK with VAT

The kWh price is based on taxes, distribution charges and supplier prices for the consumed kWh. The price is constant throughout the year.

Customers purchase electricity from any supplier. The utility companies charge different prices (please see the price chart 'Elpristavlen' under References). The customers who do not wish to choose a supplier themselves are supplied by the company nominally responsible for the given area. On Samsø this would be NRGi.

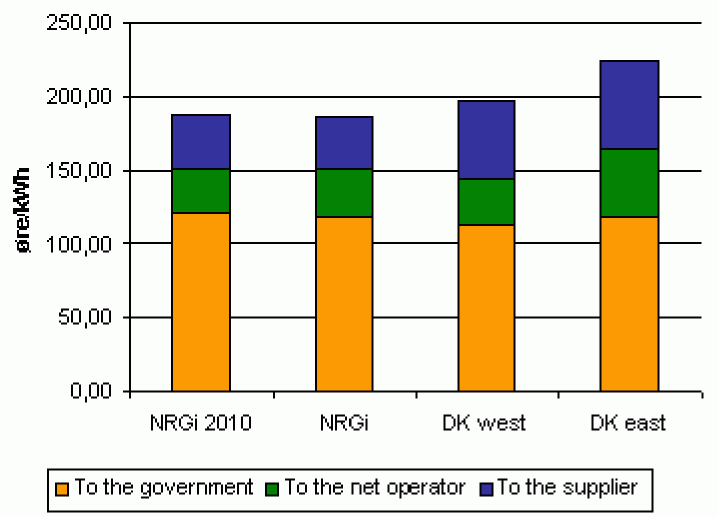

Fig. 1 A kWh costs app. 2 DKK. The price on Samsø is app. equal to the average West of Storebælt. Government taxes are app. 2/3 of the price. The calculations are based on an annual consumption of 4 000 kWh pr 1 Jan 2009
(Source: Elpristavlen, Dansk Energi 2009; NRGi).

Electricity supplier and network operator

- The electricity supplier delivers the electricity.
- The network operator owns the distribution system and electricity cables.
- You are free to choose your electricity supplier.

Network operator charges for

- Use of their distribution net.
- Regulation requirements (PSO).
- Government taxes.

Electricity supplier charge

- Quarterly fee based on estimated consumption.
- Fixed annual fee.
- Possible remote utility meter reading.

Electricity competition
: The utility company's product. The supplier must present a fixed price each quarter to be approved by the Danish Energy Regulatory Authority.

Local net tariff
: The local network costs for the transport of electricity, energy advisory etc. NRGi owns the local network on Samsø.

Energinet.dk transmission
: Distribution net at peak load. It is administered by energinet.dk both east and west of Storebælt.

Public commitments, PSO
: Ensuring a balance of electricity provision, stocks, research and development etc.

PSO
: Public Service Obligation.

Government taxes 2009

- 0.55 DKK pr kWh for energy tax
- 0.04 DKK pr kWh for electricity distribution tax
- 0.006 DKK pr kWh for energy savings donation (Elsparefonden)
- 0.089 DKK pr kWh for CO_2 tax
- 25 % VAT after all above taxes have been added to the total

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Appendix C: Under Development

Created by jj. Last Modification: Saturday 12 December 2009 18:58:33 CET by jj.

Economic Appraisal of Paludans Flak Windturbine

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Simple Investment Stream

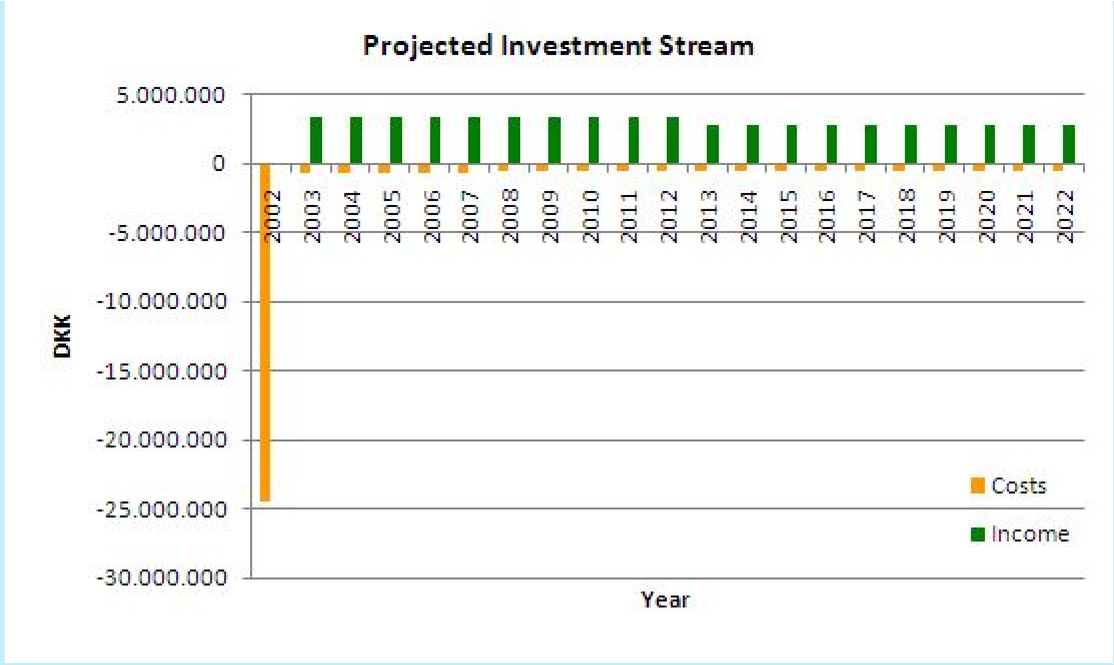
Appraisal of Renewable Energy Projects with Cases from Samso > Appendix C: Under Development > Economic Appraisal of Paludans Flak Windturbine > Simple Investment Stream

Simple Investment Stream

The following disregards *rate of time preference*. Normally, with any investment there will be a minimum return in the future that will make an investor forgo using the money elsewhere now. The rate of time preference is important when calculating net present value, roughly defined as the value of an investment today relative to its alternate use elsewhere. The rate of time preference includes the value of this alternate use directly in the calculations of net present value (see Net present value) - i.e. a positive present value means the investment provides greater returns than the closest alternate use (e.g. interest from a savings account) and a negative present value means that the investment would be better off spent elsewhere.

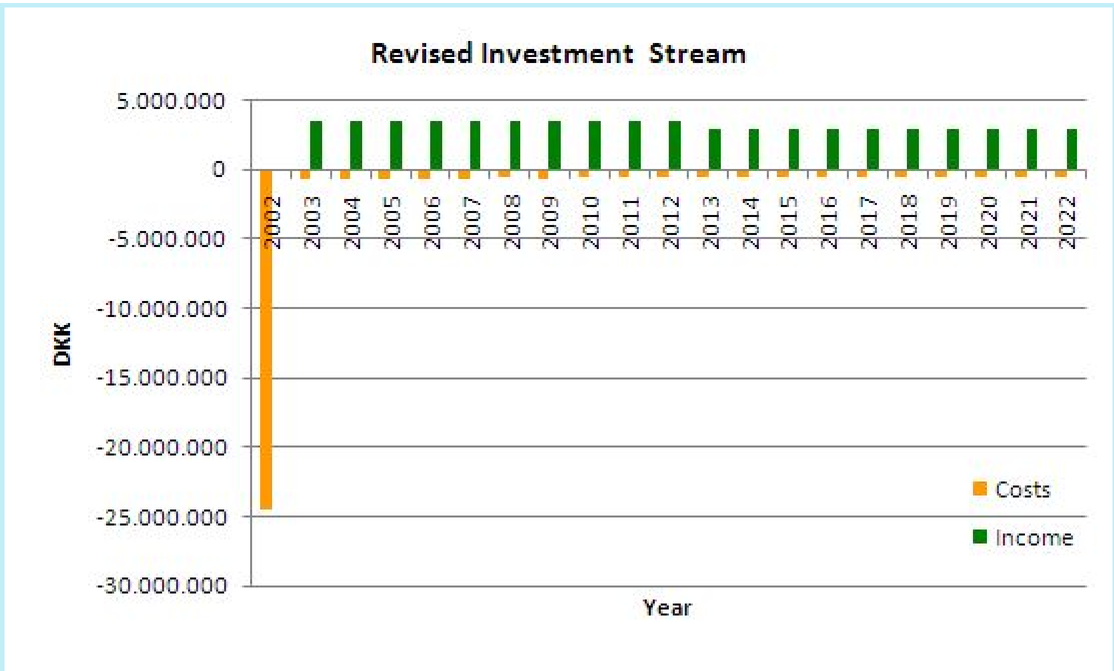
The rate of time preference is included in a later section NPV. The below calculations assume that 100 DKK received in 10 years is equal to 100 DKK now.

The graph of the total investment stream below is based on an initial investment of 24 459 750 DKK in 2002, annual expenses ranging between 690 300 DKK to 600 000 DKK, and a price per kWh of 0.43 DKK/kWh for the initial 10 year period and 0.36 DKK/kWh for the remaining 10 year period. Annual production is 7 765 MWh.

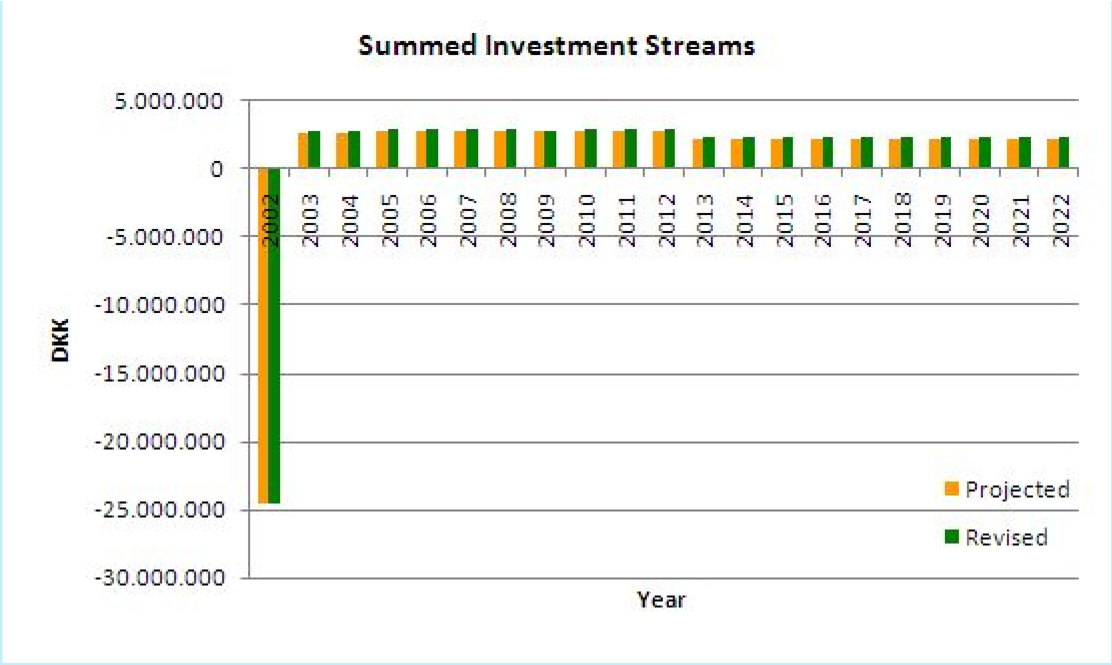


In 2002, there was no income as the mill was being constructed. The initial outlay represents the total construction costs. Each corresponding year shows the income from sale of electricity and the costs of operation and maintenance. Income drops slightly from the year 2013, reflecting the lower feed-in tariff available for electricity sales. Operation and maintenance costs are assumed constant over the period. Given a lifetime of 20 years, there are no costs or income after 2022.

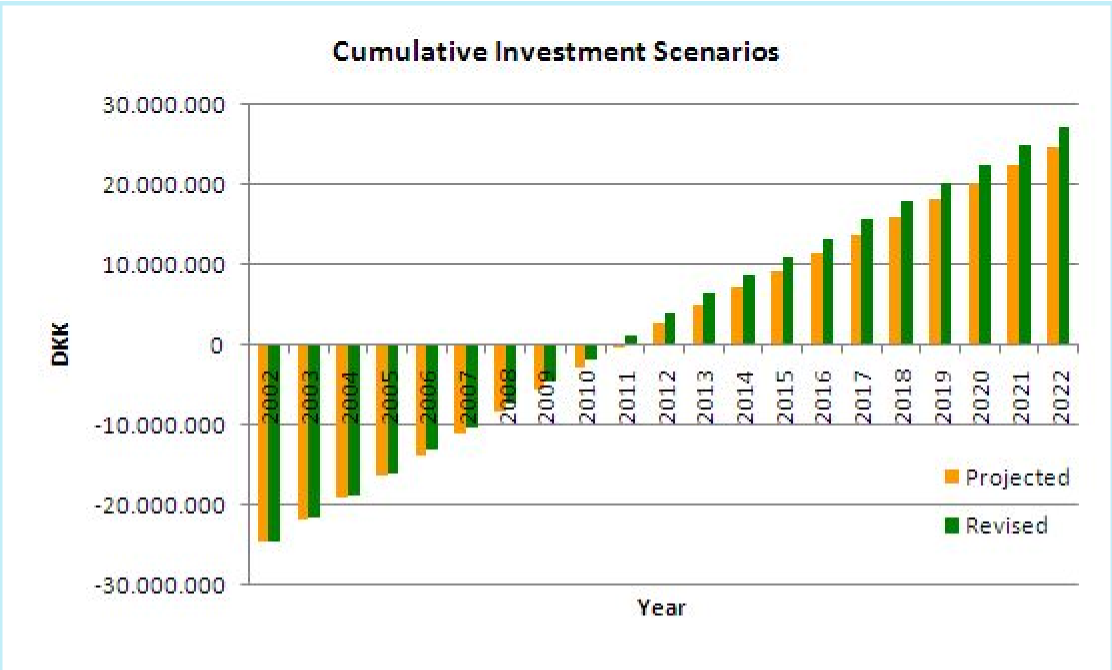
However, in 2009 a gear box in another wind turbine had to be replaced. Since the cost was shared between eight wind turbines the cost was 1/8 of 1 million DKK. Additionally, energy production was found to average 8 100 MWh annually, significantly more than the 7 765 MWh initially assumed. The revised investment stream is given below:



The differences between the two investment streams are not obvious from the graphs above. Taking the sum of the investment stream, i.e. the total investment flow for the given year, allows for a comparison of the projected and revised investment flows:



This difference becomes clearer when taking the cumulative value of the investment streams, i.e. the reduction each year in the money owed for the initial investment:



As can be seen in the graph above, the offshore wind turbine is expected to provide positive returns in the 9th year of operation for the revised scenario (2011) and in the 10th year of operation for the initial scenario (2012).

The total period in the revised scenario provides total gross profits equal to app. 27.2 million DKK, or 3 499 DKK per share (after repayment of the initial investment of 3 150 DKK per share). The original projected scenario would have provided gross profits of app. 24.6 million DKK, or 3 174 DKK per share.

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Pay-off period rate of return

Pay-off period rate of return

Using the calculations from Simple Investment Stream, the number of years necessary to recoup the initial investment in the *projected* scenario is between 9 and 10, or more precisely, 9.02 years, in it's 10th year of operation. Since 100 percent is paid off in 9.02 years, the average is

- 100% / 9.02 years = 11.09 %/year

The pay-off period rate of return equals 11.09 percent per year, reflecting the long time it takes for the initial investment and subsequent re-investment to be paid off.

The *revised* scenario takes about 8.61 years to recoup the initial investment, which occurs in it's 9th year of operation. The average is

- 100% / 8.61 years = 11.61 %/year

This method of calculation favors projects which are short-term. Using the example of lightbulbs from ((Internal rate of return, IRR)), a flourescent lightbulb would cost 39 DKK more than an incandescent lightbulb, but save 137.4 DKK annually, both from lower energy usage and from lack of replacement. This means the additional costs of the flourescent lightbulb is repaid in less than a year, namely 3.4 months. This is equivalent to:

- 100% / 0.284 years = 351.8 %/year

So the pay-off period rate of return equals 351.8 percent per year. The above calculations clearly illustrate that this method is only useful for weighing the *rate* at which the initial investment is paid off.

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Average rate of return

Average rate of return

Continuing with the example from Simple Investment Stream, the average annual return of the *projected* scenario is simply the net return over the 20 year operating period divided by the number of years:

- 49 104 311 DKK / 20 years = 2 455 216 DKK/year

To find the average rate of return, this sum is then divided by the initial investment:

- 2 455 216 DKK / 24 459 750 DKK = 0.1004

That is, the average annual rate of return is 10.04 percent.

For the *revised* scenario the annual rate of return is:

- 51 625 811 DKK / 20 years = 2 581 291 DKK/year

To calculate the average rate of return:

- 2 581 291 DKK / 24 459 750 DKK = 0.1055

Equal to 10.55 percent.

The main issue with this method of calculation (besides ignoring the value of time preference) is similar to the one arising from the internal rate of return. Since all the values are simply summed, it makes no difference to the result whether all the returns from the investment are distributed evenly over the period (as is true for this example) or only occur in the last two years of the operating period - but to an investor a return received annually might be preferred to receiving a larger one only after 18 years of waiting.

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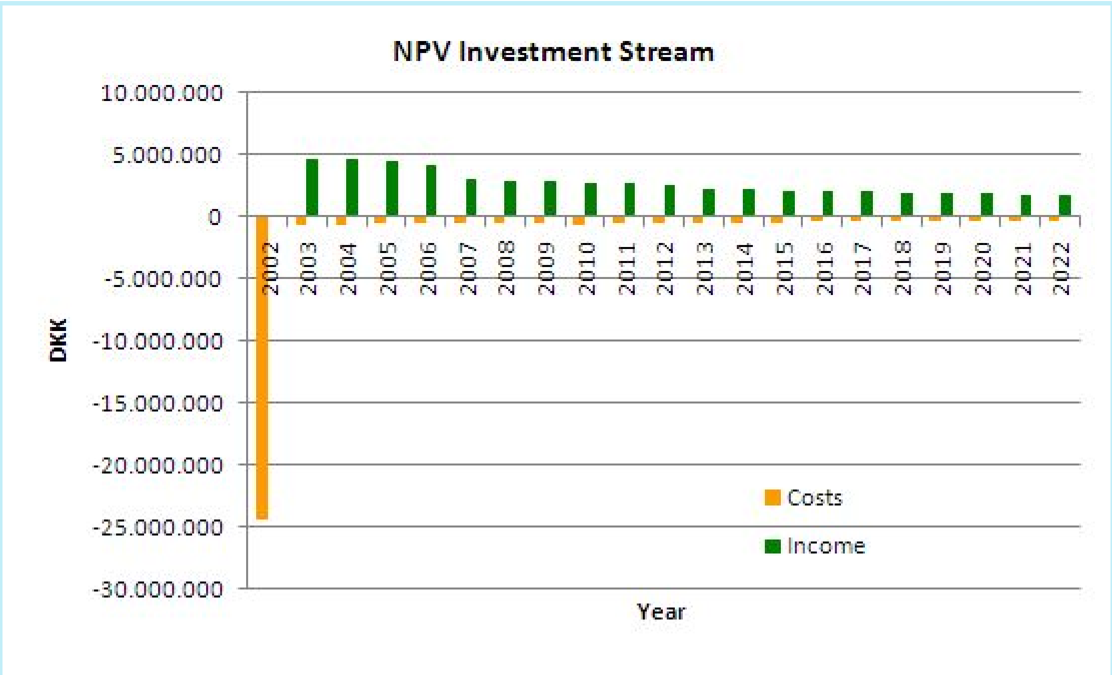
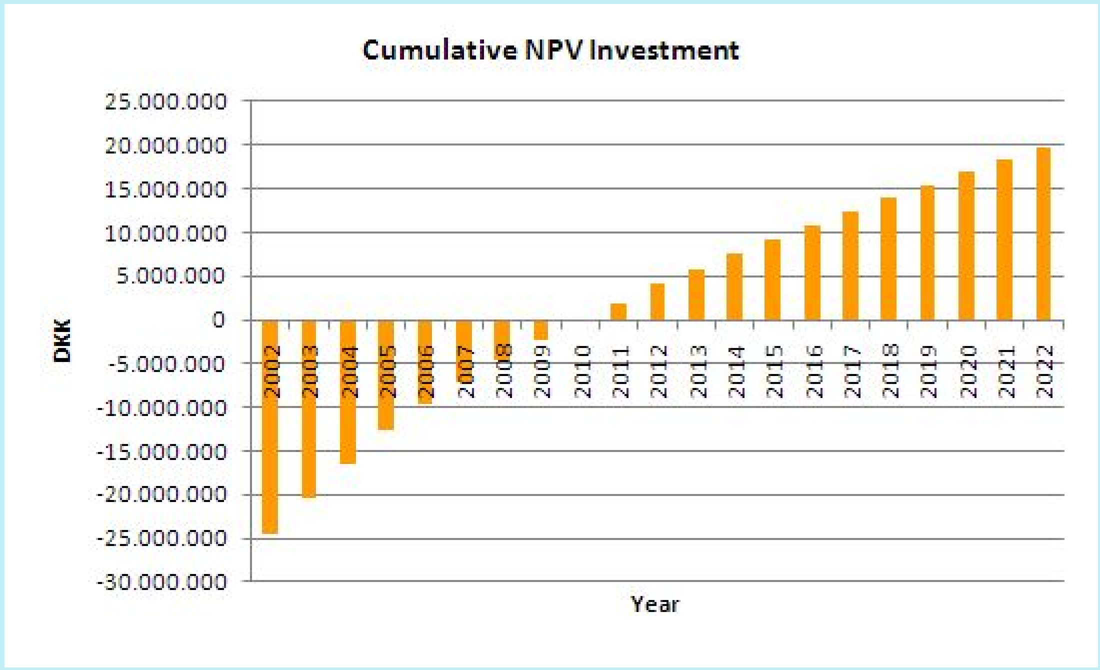
NPV

Net present value

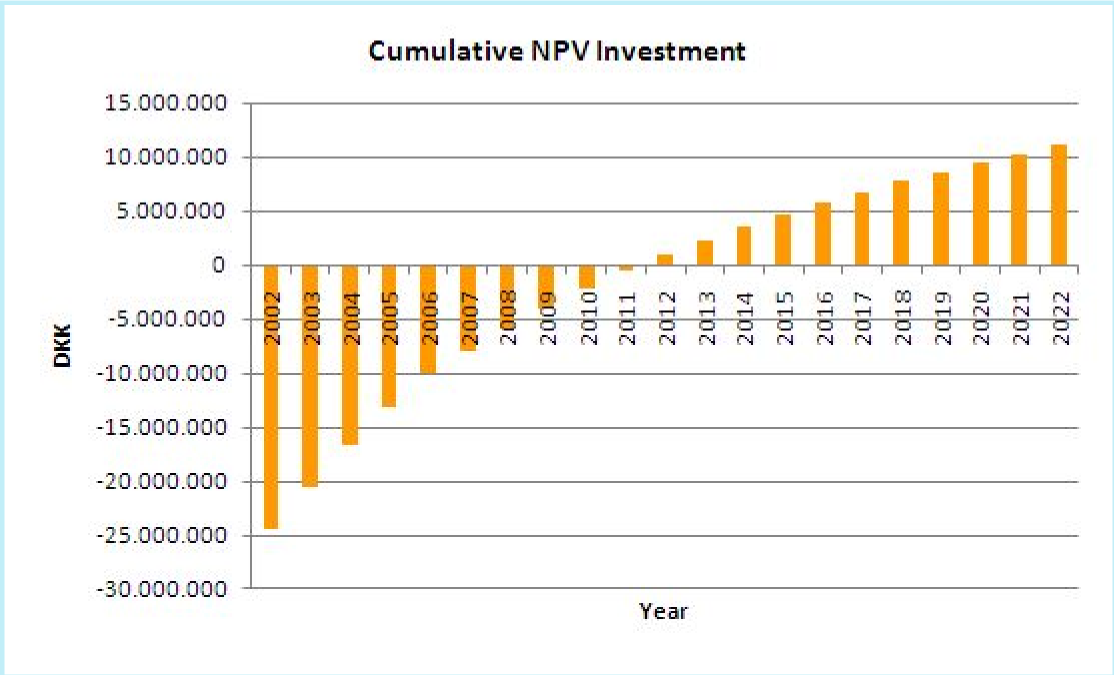
Net present value (NPV) was introduced in more detail in Net present value. The calculation incorporates a discount rate to take into account the time value of money. The NPV in 2002 for the whole 20-year investment period ending in 2020 takes into account the lower value attached to future income than to present income. Applying a discount rate of 3 percent to the revised example from Simple Investment Stream results in a net present value in 2002 equal to **19 648 393** DKK, or 2 530 DKK per share. The investment will break even in its 8th year of operation, in 2011. The stream of investment returns is shown below.



This stream of investment returns reduces the initial investment as illustrated in the graph below:



The issue with this method of calculation is its sensitivity to the assumptions used. If the discount rate is 6 percent instead of 3 percent, the investment will break even in 2012, in its 9th year of operation, as is illustrated below.



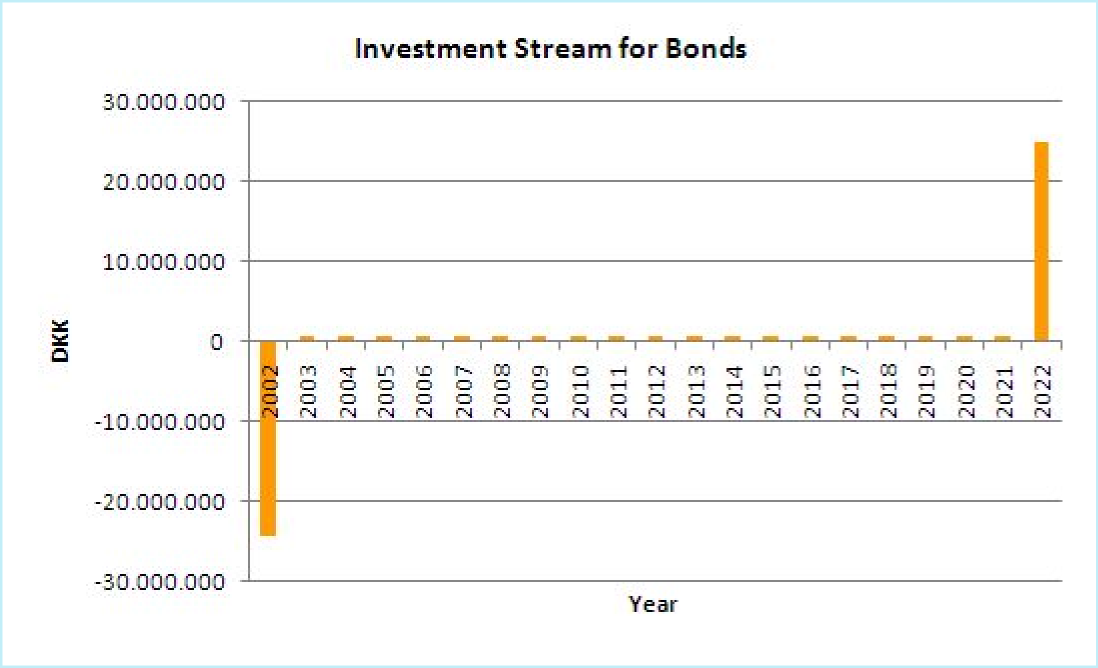
Using a discount rate of 6% the total profit over the operating period amounts to app. 10.6 million DKK, or 1 362 DKK per share.

Government Bonds

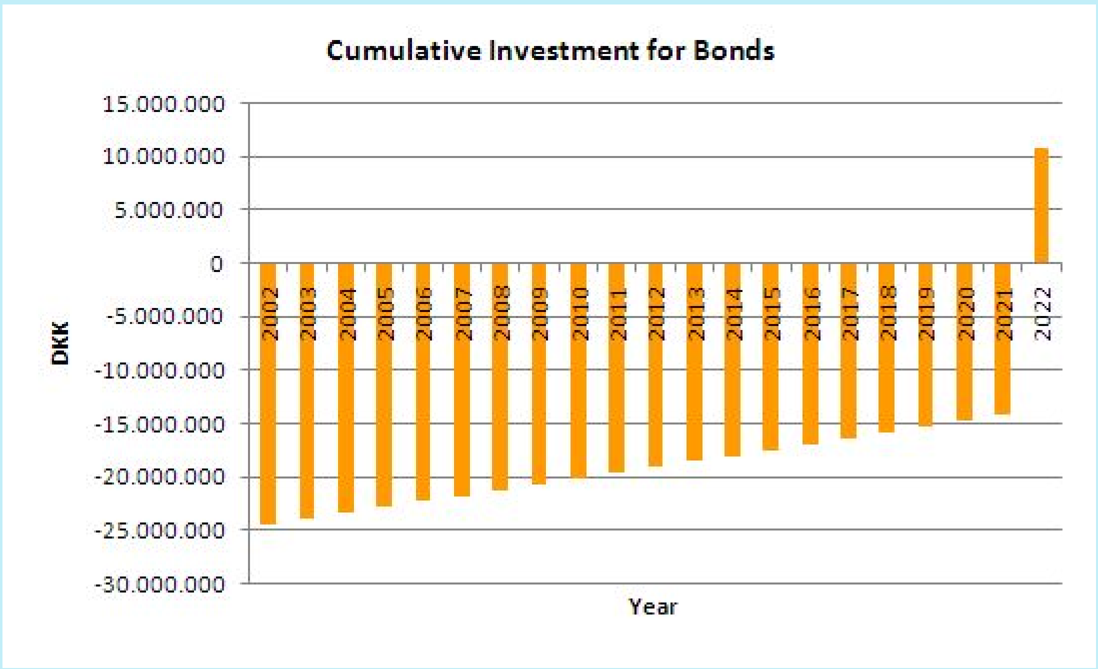
Alternatively, the original investment sum (24 459 750 DKK) could have been invested in government bonds. With government bonds, you invest the full sum at the start of the period, receive an interest payment annually, and at the end of the period the initial investment is returned to you. Like in the previous example, income tax is disregarded for simplicity.

Average returns on government bonds for a selection of EU countries vary between 3.8 and 4.4 percent. For the example below, an average yield of 4.2 percent is assumed. As the above example is in 2002-DKK, i.e. ignores inflation, an average rate of inflation (2 percent) is subtracted from the bond interest rate. This results in a normalised government bond rate of return of 2.2 percent.

The graph below illustrates the simple investment stream for 24 459 750 DKK invested in government bonds yielding a 2.2 percent annual return (in 2002 prices).



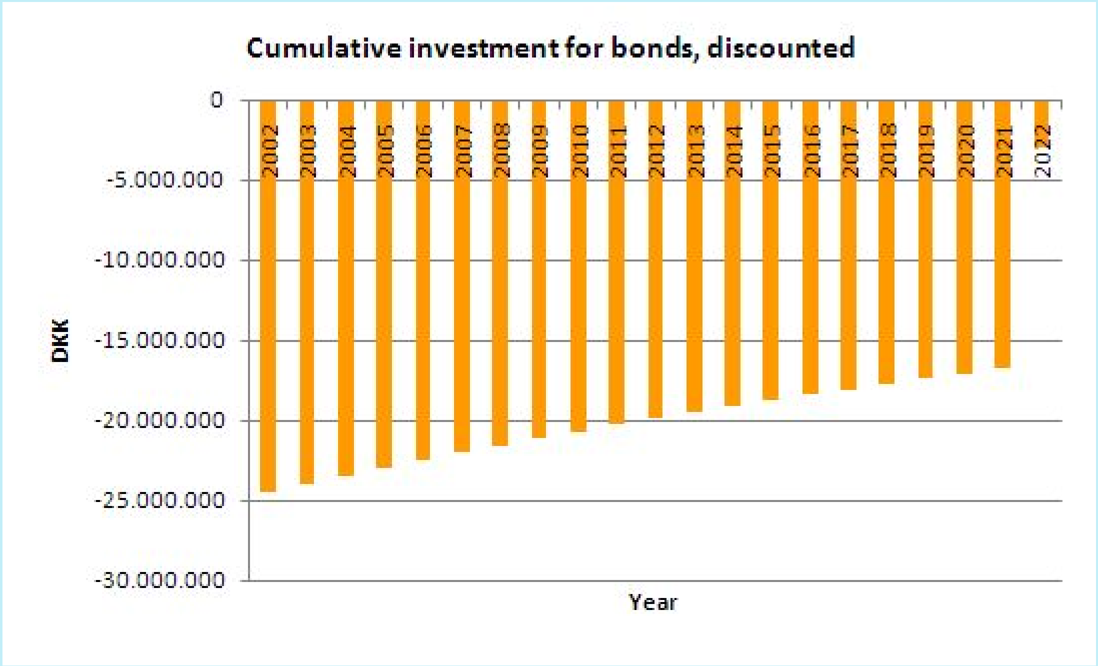
The investment generates annual returns of 538 115 DKK, or 69 DKK per share. The graph below illustrates the cumulative investment over time:



Unlike investing in the windmill park above, investing in government bonds only fully repays itself after the initial investment (*principal*) is returned at the end of the period.

The total profits for the period sum to 10 762 290 DKK, or 1 386 per share.

Using a discount rate of 3 percent over the period results in a NPV of the investment in 2002 equal to **negative** 2 911 195!!! In other words, this corresponds to a loss of 375 DKK per share for the full period. This is because using a discounting rate places lower value on income generated in the future relative to today. Since the principal is not returned until the end of the period 20 years later, it suffers a substantial discount. 24.5 million DKK in 20 years time with a discount rate of 3 percent is only worth 13.8 million in 2002.



If the discount rate is 6 percent instead, then receiving 24.5 million DKK in 20 years is only worth 7.8 million DKK in 2002. The total *loss* in terms of net present value would be 10.7 million DKK.

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Conclusion

Appraisal of Renewable Energy Projects with Cases from Samso > Appendix C: Under Development > Economic Appraisal of Paludans Flak Windturbine > Conclusion

Conclusion

The methods above which do not include values of time preference are indisputably positively biased in favor of the investment.

Table 1. Comparison of economic methods

Method	Millions DKK (2002 prices)	Percentage	Years
Simple Investment Stream	33.1	-	7.01
Pay-off period rate of return	-	14.27	7.01
Average rate of return	-	11.76	7.01
NPV 3% in 2002	19.6	-	8.11
NPV 6% in 2002	10.6	-	9.66

The breakeven target in terms of years is app. 7 for the first 3 measures of calculation, and slightly higher for the 2 net present value methods of calculation.

Note that the ((Internal rate of return, IRR)) is the same across all scenarios, equivalent to 11.74 %. This (in this case) corresponds approximately to the average rate of retun.

The NPV accounts for rate of time preference by including a discount rate. For the given discount rate of 3 percent, a NPV equal to zero is the **same** as an investment return of 3 percent (excluding inflation). Given a normal rate of inflation of app. 2 percent, a 3 percent return on investment after inflation would roughly correspond to a 5 percent return on investment nominally, which is significantly more than can be expected from e.g. a savings account.

For the example used, the discount rate would have to be app. 3.7 percent (after controlling for inflation) for the NPV to equal zero.

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Standard Saving Values

Tab. 1. Standard values (selection from Teknologisk Institut 2013)

Advice	Savings [kWh]	Comment
Replace 1 halogen lamp (35 W) by an LED lamp (5.1-7 W)	27	Usage 1000 h / yr
Replace a 3-speed circulation pump by a continuous class A pump	280	
Install a timer on the circulation pump for hot water.	58	
Replace an old hot water tank (with jacket), size 100 litres, by a new standard tank	1206	Losses: 4 W/K
Bi-annual service check of an oil boiler	935	
Bi-annual service check of district heating unit	815 (small), 1358 (large)	
Install a standby switch on IT devices	90	

The original document is available at http://seacourse.dk/wiki/tiki-index.php?page=Standard+Saving+Values

Standard Saving Values

Energy Checks in Shops: Night Hawks Handbook for Energy Advisers > ECS Appendix A. Technical Annex > Standard Saving Values

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Colophon

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