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Investigation into the Economic Aspects of Small Wind Turbines in an Urban Environment

1 EXECUTIVE SUMMARY

Traditionally wind turbines have been placed in rural areas where they can take advantage of strong continuous wind regimes, high above the ground. As the need for generating electricity from renewable sources expands, there is increasing interest in sighting smaller wind turbines in areas not conventionally considered as suitable, such as urban and peri-urban zones.

This report examines the cost and economics of small wind turbines installed in the urban environment. The report will focus on the costs per installed kW for small wind turbines and the factors which most influence the economics of an installation.

Costs

Information on costs has been collected from manufacturers, installers, government agencies and urban wind turbine owners. The resultant data in Table 1 shows the estimated installation cost of 20 technologies currently available on the market.

Table 1. Estimated installed cost for 20 different urban wind turbines

Turbine model	Origin	Rated capacity / kW	Total cost* per kW / Euro	Energy yield per year / kWh	Warrantee / years	Turbine lifetime / years
WES Tulipo	Holland	2.5	6880	10000 (@ 6.5 m/s)	1	20
Fortis Montana	Holland	5.6	3017	8000 (@ 6.5 m/s)	5	20
Turby	Holland	2.5	6768	5400 (@ 5.3 m/s) 5100 (@ 5.1 m/s)	2	20
Windwall	Holland	3.6	5980	5200 (@ 5.6 m/s)	10	20
Ropatec	Italy	3	9200	2769 (@ 5.5 m/s)	unknown	30
Ropatec	Italy	6	9200	5415 (@ 5.5 m/s)	unknown	30
Atlantis VB	Germany	0.6	8200	1280 (@ 5.5 m/s)	unknown	20
Windside	Finland	0.6	26300	573 (@ 5.5 m/s)	unknown	30
Windside	Finland	1.2	24700	1134 (@5.5 m/s)	unknown	30
Eclectic Energy D400	UK	0,4	7975 - 9070	650 (@ 5.5 m/s)	1	20

Turbine model	Origin	Rated capacity / kW	Total cost* per kW / Euro	Energy yield per year / kWh	Warrantee / years	Turbine lifetime / years
Proven	UK	0,6	8700 - 15000	1030 (@ 5.0 m/s)	10	20-25
Windsave	UK	1	2175	1367 (@ 6.5 m/s)	unknown	10
Renewable Devices Swift	UK	1,5	4830 - 26100	4200 (wind speed unknown)	unknown	20
Proven	UK	2,5 (ground)	5220 - 14500	4282 (@ 5.0 m/s)	10	20-25
Proven	UK	2,5 (building)	10440 - 12180	4282 (@ 5.0 m/s)	10	20-25
Iskra	UK	5	3920 - 5080	9500 (@ 5.0 m/s) 13400 (@ 6.0 m/s)	2	20
Proven	UK	6 (ground)	4110 - 7730	14645 (@ 5.6 m/s)	10	20-25
Proven	UK	6 (building)	6040 - 6280	14645 (@ 5.6 m/s)	10	20-25
Proven	UK	15	3770 - 6200	30000 (@ 5.0 m/s)	10	20-25
Gazelle	UK	20	6890 - 7100	44700 (@ 5.5 m/s) 61100 (@ 6.5 m/s)	unknown	20-25

* Investment and installation cost

Factors affecting the economics of urban wind turbines

Cost per kWh produced and payback time are greatly dependent on factors which can vary greatly from project to project and country to country. Therefore, no specific information is given for each turbine, although further information can be found in the relevant chapters of the report. The factors which most greatly affected the economics of the installations examined were:

- Applied Discount Rate
- Grant funding (subsidies)
- Wind Speed and energy yield
- Ground Conditions
- Maintenance Costs
- Electricity tariffs and green certificates
- Electricity Consumption

These factors are examined in detail the country reports from France, the United Kingdom and the Netherlands.

Building mounted small wind turbines

Tall buildings and tower blocks seem to offer an opportunity to capture higher wind speeds, therefore making installations in cities more economically viable. Many of the issues facing the economics of today's small scale turbines will not be so significant in the building mounted sector. Building mounted turbines should be closer to the distribution board, will

be mounted higher above ground level, and some systems also claim to be maintenance free. However new issues which will affect the economics of an installation will start to emerge, such as:

- Planning permission
- Health and safety issues
- Structural surveys
- noise (both for building users and surrounding environment)
- flicker from the blades
- building strengthening costs and
- Possible electromagnetic interference with nearby electrical equipment

There are currently too few building mounted installations to be able to draw definitive conclusions about costs or success of the installations. However, the building mounted sector is growing and in the future there will be more data to draw upon for conclusions.

Wind resource data availability

With regards to wind data, there is clearly a need for more research on airflows and wind speeds in urban surroundings, particularly looking at airflows around buildings and other obstacles. More data must be collected, and computer models must be developed that can make predictions tailored to urban areas. Project developers should not have to rely on national data as it does not take into account local topography, and will very likely overestimate the wind speed.

Conclusions

In terms of costs, horizontal axis wind turbines (HAWTs) are currently far cheaper than vertical axis wind turbines (VAWTs) and have better energy yield. However, HAWTs present three particular issues, noise, vibration and safety, which arise less frequently with VAWTs.

In terms of improving the economics of small wind turbines, there are a number of areas where improvements are likely to be seen in the short to medium term. The reliability and energy yield of the systems will improve as the technologies mature. As the available quantity of wind data grows energy predictions will become more accurate and experience with siting wind turbines will improve, thus placing them in locations most likely to maximise wind capture. From the perspective of government support, a specific feed-in tariff for small wind electricity, such as that which exists for photovoltaics in certain countries, would certainly be beneficial. Another option would be a fixed subsidy on the capital costs per kW installed (similar to that of the ClearSkies programme in the UK).

Overall, most of the small wind turbines studied in this report are not economic today, but it is also currently true that economic factors are often not the primary reason for individuals and organisations installing wind turbines. Therefore, although improving the economics of the technology is necessary and feasible, in the meantime the industry can rely on other incentives such as improving environmental and educational awareness and achieving green electricity production and CO_2 emission reduction targets to stimulate the market.

2 FRANCE

2.1 Summary

2.1.1 Existing small-scale wind installations

There are very few installations of wind turbines in urban environment in France. This was outlined in the WINEUR report for work package 1, which can be downloaded from www.urbanwind.org .

Two examples from France that were examined are:

- High School "Léonard da Vinci" – Calais (2000): wind turbine 132 kW (horizontal axis),
- Community Town Hall - Bobigny (January 2004): Three wind turbine of 5 kW (Fortis horizontal axis).

We cannot consider the wind turbine of Calais which concerns large-scale wind energy technology (capacity 132 kW, height of the machine: 45 m). Indeed, it will be near to impossible to install this kind of machine in the urban environment in the future due to the increased strictness of legal requirements, such as the minimum distance of a wind turbine from any building, which must be at least 500 meters.

Regarding the wind turbines at Bobigny, no energy production information is yet available. Therefore, the Renson Company in Belgium, which also installed 3 Fortis machines of 5kW on its buildings, was contacted. Although of course the different sites would have different variables, as the machines were the same, some indication of energy yield would be possible.

The provided data indicate an annual production of approximately 10 000 kWh for an average speed of wind of 6,5 m/s. This represents a pay back period (under the Belgian legal and financial context) of 12 years. This would seem reasonable for a small-scale renewable energy technology and considering that the lifetime of a Fortis turbine is more than 15 years.

2.1.2 Grant policy

France chose to support the policy for national wind power development by the definition of a feed-in tariff of 8,30 Eurocents/kWh. Very clearly, this tariff encourages large-scale wind turbine development, whose technological maturity allows profitability of the projects on the basis of this tariff. However, the production and installation costs of small wind turbine technologies are higher than large scale wind and this tariff does not allow for economic feasibility of installations. There is currently no mechanism of subsidy set up by central government directly aimed at small wind turbines.

In the current national context, it thus seems particularly important to obtain from central government a specific feed in tariff for small wind turbines.

It would be particularly appropriate to regard the small wind energy technologies as units of small electricity production, similarly to solar photovoltaic technology, and thus to apply to the small wind turbines the same tariff that currently applies to electricity generated from solar photovoltaic, namely: 25 euros cents/kWh.

It is however possible to consider, within the framework of demonstration projects, subsidies from local authorities (region or department) whose contribution to development of small wind turbines is significant.

There is one last measure to note. A tax measure which applies to private individuals who can benefit from a 50 % tax credit on the amount of investment in renewable energy.

2.2 Methodology

Generally, it was particularly difficult to obtain precise cost data from small wind turbine manufacturers. Some manufacturers have still not answered the request for information made both in writing and by phone call at the data of writing this report. In particular, the French manufacturers which were questioned have not responded.

Thus the most thorough economic investigations were carried out on the technologies for which the best information could be obtained. The four manufacturers selected were:

Ropatech SRL : *Via Copernico 13A – 39100 Bolzano- Italy*

Fortis : *Botanicuslaan 14, 9751 AC Haren -The Netherlands*

Atlantis : *Holzstr. 10, 31556 Wölpinghausen - Germany*

Oy Windside: *Niemenharjuntie 85, 44800 Pihtipudas – Finland*

2.3 Techno-economic analysis

2.3.1 General economic data

Table 2. General economic data for Ropatec, Fortis, Atlantis and Windside turbines

Type of turbine	Investment: Average cost / Kw in €	Installation: Average Cost /kW in €	Total Average cost/kW in €	Total Cost (for turbine type) in €	Type of technology	Life Span
Ropatec						
WRE.030 -3 kW	6 700	2 500	9 200	27 600	Vertical axis	>30 years
Ropatec						
WRE.060 -6 kW	6 700	2 500	9 200	55 200	Vertical axis	>30 years
Fortis						
Montana 5000 - 5 kw	7 300	2 920	10 220	51 100	Horizontal axis	20 years
Atlantis						
VB - 0,6 kw	6 000	2 200	8 200	4 920	Horizontal axis	20 years
Windside						
WS 2 - 0,6 kw	24 000	2 300	26 300	15 780	Vertical axis	>30 years
Windside						
WS 4 A - 1,2 kw	22 000	2 700	24 700	29 640	Vertical axis	>30 years

2.3.2 Comparison of the capital costs

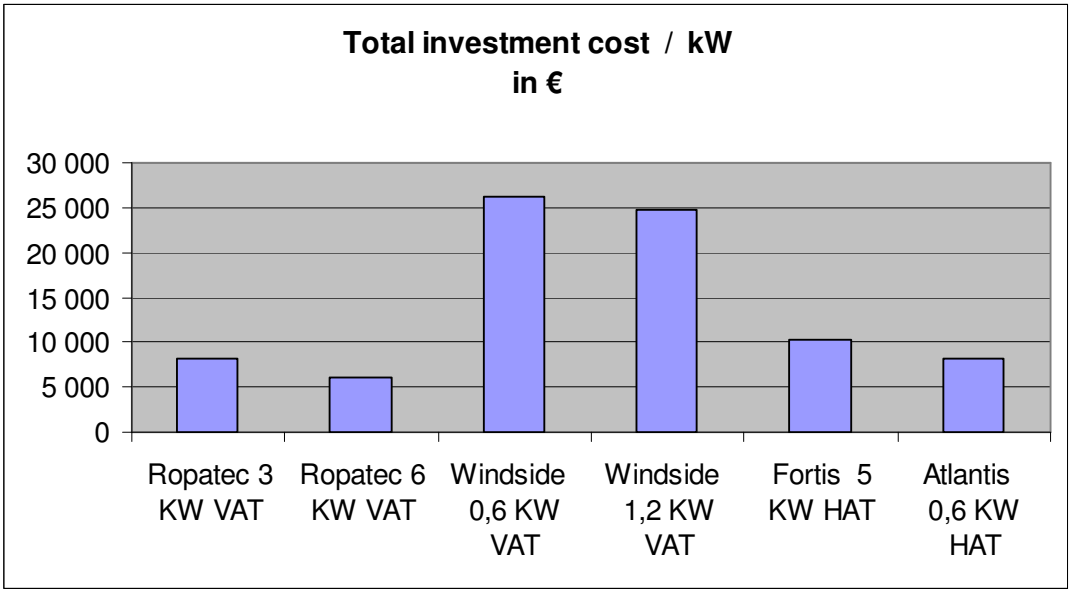

Figure 1. Comparison of investment cost for each turbine, France

2.3.3 Productivity of the different wind turbines

By using the power curves provided by the manufacturers the yearly operating time, as well as annual productions, for each one of these machines was estimated. The estimates were carried out at a variety of wind speeds.

Average Wind Speed 5,5 m/s

	Load factor (in hours/year)	Energy production (in kWh)
Ropatec 3 KW *VAT*	923	2 769
Ropatec 6 KW *VAT*	903	5 415
Windside 0,6 KW *VAT*	955	573
Windside 1,2 KW *VAT*	945	1 134
Fortis 5 KW H*AT*	1 309	7 569
Atlantis 0,6 KW H*AT*	1 700	1 280

Average Wind Speed 6 m/s

	Load factor (in hoursyear)	Energy production (in kWh)
Ropatec 3 KW *VAT*	1 168	3 567
Ropatec 6 KW *VAT*	1 168	7 006
Windside 0,6 KW *VAT*	1 154	692
Windside 1,2 KW *VAT*	1 141	1 369
Fortis 5 KW H*AT*	1 600	9 247
Atlantis 0,6 KW H*AT*	2 000	1 550

Average Wind Speed 6,5 m/s

	Load factor (in hoursyear)	Energy production (in kWh)
Ropatec 3 KW *VAT*	1 484	4 452
Ropatec 6 KW *VAT*	1 461	8 766
Windside 0,6 KW *VAT*	1 343	806
Windside 1,2 KW *VAT*	1 326	1 592
Fortis 5 KW H*AT*	1 904	11 005
Atlantis 0,6 KW H*AT*	2 400	1 820

2.3.4 Average cost of produced Kwh

By using the data defined above, the cost of kWh is established in the following way:

The kWh cost is equivalent to the electricity selling price for which the sum of financial flows of the project, for twenty years duration, is equal to the amount of the initial investment.

KWh cost (kWhc) = KWh price (kWhp).

*(KWhp x Yearly functioning hours)x20 years= Investment costs+ (O&M costs*20 years)*

Cost of kWh produced in Euro cents			
	Average Wind Speed 5,5 m/s	**Average Wind Speed 6m/s**	**Average Wind Speed 6,5 m/s**
Ropatec 3 KW *VAT*	70	55	43
Ropatec 6 KW *VAT*	62	50	38
Windside 0,6 KW *VAT*	102	96	87
Windside 1,2 KW *VAT*	99	92	80
Fortis 5 KW H*AT*	41	34	28
Atlantis 0,6 KW H*AT*	43	35	30

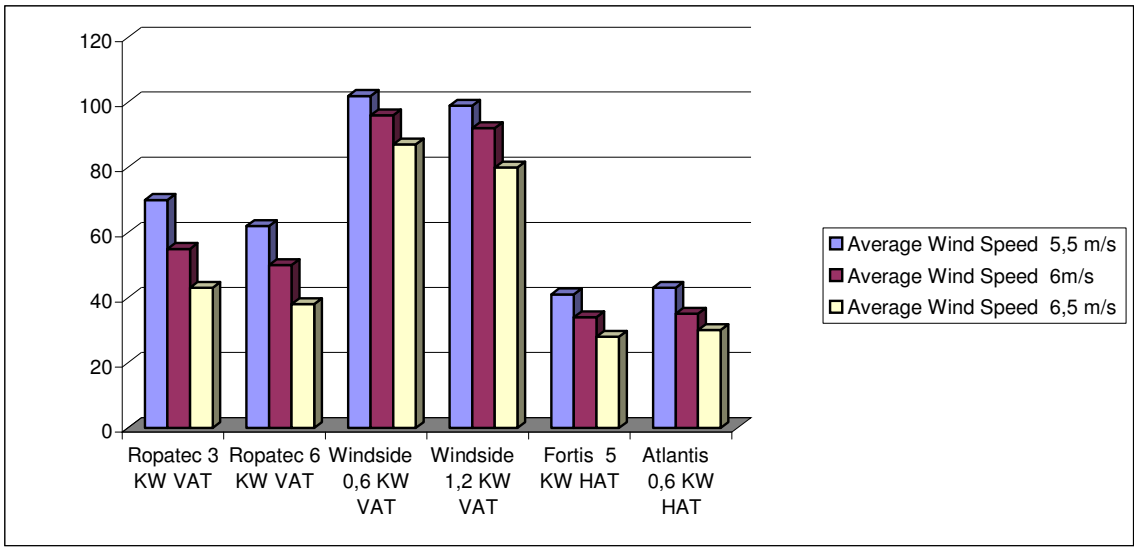

Figure 2. Comparison of the cost per kWh produced, France

2.4 Conclusion

This economic approach shows a large difference in cost between vertical axis wind turbines (VAWT) and horizontal axis wind turbines (HAWT). HAWT appear to be more interesting in economic terms. However, the conditions for integration of this type of turbine include some delicate issues concerning installation in the urban environment, in particular:

- level of noise
- safety problems

These types of very concrete problems do not arise as often with VAWT.

In terms of improving the economics of small wind turbines in France, it appears absolutely necessary in order to promote wind technology in urban environment, and in particular VAWT technology, to consider a specific feed-in tariff for the small wind turbines.

At the moment, the wind power feed-in tariff was defined in 2001, and at this time the prospects for the small wind turbine development was not a topical question. Therefore, the characteristics of this technology were not taken into account.

Since 2001, different feed-in tariffs have been defined for each renewable energy type (photovoltaics, biomass, mini-hydro, etc). However, small wind turbines were never taken into account. It thus becomes absolutely necessary to proceed to a legal definition of a specific feed-in tariff in order to officially consider the small wind turbines on an equal footing with other renewable energy technologies.

This measure is essential, even more so since the law on energy (13th 2005 July) reaffirms the national authorities' willingness to reach 21 % electricity of renewable energy origin by 2010 (against 14 % today).

3 UNITED KINGDOM

3.1 Summary

This chapter examines the cost and economics of small wind turbines in the urban environment in the UK. Information on costs has been collected from manufacturers, installers, the ClearSkies programme and from owners of existing installations of small wind turbines. The resultant data in Table 3 shows the estimated installation cost of the technologies currently available on the market.

Table 3. Wind turbines studied in the United Kingdom

Manufacturer	Model	Rated capacity, kW	Installation type	Cost per kW installed / Euro
Eclectic Energy	D400	0,4	Building mounted	7975 - 9070
Proven	Proven	0,6	Ground installation	8700 - 15000
Windsave	Windsave	1	Building mounted	2175
Renewable Devices	Swift	1,5	Building mounted	4830 - 26100
Proven	Proven	2,5	Ground installation	5220 - 14500
Proven	Proven	2,5	Building mounted	10440 - 12180
Iskra	Iskra	5	Ground installation	3920 - 5080
Proven	Proven	6	Ground installation	4110 - 7730
Proven	Proven	6	Building mounted	6040 - 6280
Proven	Proven	15	Ground installation	3770 - 6200
Gazelle	Gazelle	20	Ground installation	6890 - 7100

An economic analysis on real installations was also carried out to identify the factors which can most influence the cost of energy and payback from small wind turbines. The factors which most greatly affected the economics of the installations examined were:

- Applied Discount Rate
- Grant Funding
- Wind Speed and energy yield
- Ground Conditions
- Maintenance Costs
- ROCs
- Electricity Consumption

3.2 Methodology

3.2.1 Techno-Economic analysis

In order to assess the real costs and economics of small wind turbines, information was collected from four main sources:

1) Manufacturers' and installers' questionnaire

An "economic questionnaire" was developed and sent to manufacturers and installers of small wind turbines. The questionnaire covered the costs of the technology, installation and commissioning, as well as some questions on potential additional costs. A copy of the questionnaire is included in Annex 1. Accessing this information from manufacturers was a time consuming process. Some manufacturers had to be e-mailed and phoned on multiple occasions and while some questionnaires were very accurately filed out, others had to be completed from sources such as the manufacturer's literature, price lists and brochures.

2) Interviews and questionnaires of wind turbine owners

Phone interviews were carried out with and questionnaires were also sent to wind turbine owners, (see below for more detail) who agreed to answer questions about the economic aspects of their turbine. The information gathered included a detailed breakdown of installation, maintenance and electricity tariff costs in order to facilitate an accurate economic study.

3) ClearSkies grants programme

Information was also sought from the ClearSkies programme, which is the government grants programme for small-scale renewables, including wind. ClearSkies provided an anonymous database of technology used and total installation costs. Although there wasn't a detailed breakdown of costs provided, this information was still useful as it provided total costs, annual mean wind speed (AMWS) and generation estimates for over 150 installations and provided a basis for comparison with results from the case study questionnaires.

4) Literature review

Lastly, a thorough literature review, including websearch, was carried out to find any previous analyses that had been done on the economics of small wind turbines.

To carry out the techno-economic analysis spreadsheets were developed to calculate payback period, taking into account a variety of factors, including discount rate, electricity tariffs and annual energy yield. Where necessary, power curves obtained from the turbine manufacturers, with AMWS estimates and a Rayleigh distribution were used to produce generation estimates. To enable analysis of the small wind turbine systems to be meaningful over a larger range of installations than just those identified, a spreadsheet was developed where site factors were altered and the effect on the installations' capital cost, payback and price of energy was assessed.

3.2.2 Case studies

To assess the current state of the small wind turbine industry in the UK a "case studies questionnaire" was sent out to known turbine owners. The questionnaire was designed to build a database of key information about installations. Turbine owners were located mainly through an internet search. Some contacts were available from various other sources, such as manufacturers' and installers' literature.

The questionnaires had a 23% response rate and were enthusiastically received by some, but most required much time consuming investigation to ensure the correct person was contacted. Many organisations needed additional telephone persuasion to ensure the questionnaire was completed. In total 21 questionnaires were received and analysed.

'We have received similar questionnaires in the past, duplication is annoying for us' and *'no one really has that kind of information'* were amongst the reasons for not responding. The quality of the data collected varied greatly, with some organisations omitting various questions, but most questionnaires were complete and provided very useful data. Some lessons learnt in the process of sending out the questionnaires were:

- Contacting turbine owners after the questionnaire had been returned could have been avoided if the questionnaire had asked them to comment / explain any negative experiences they had whilst installing the turbine and indicate where their stated energy yield figure had come from.

- Sending out a prototype questionnaire to assess the usefulness of the reply would have been beneficial.

These lessons will be borne in mind when designing and sending out questionnaires in the future. All statistical information regarding wind turbine installations are from the case studies questionnaire, unless otherwise stated. The information collected allowed a techno-economic analysis for the following technologies:

Table 4. List of wind turbines studied in the UK

Manufacturer	Model	Rated capacity, kW	Installation type
Eclectic Energy	D400	0,4	Building mounted
Proven	Proven	0,6	Ground installation
Windsave	Windsave	1	Building mounted
Renewable Devices	Swift	1,5	Building mounted
Proven	Proven	2,5	Building or ground
Iskra	Iskra	5	Ground installation
Proven	Proven	6	Building or ground
Proven	Proven	15	Ground installation
Gazelle	Gazelle	20	Ground installation

3.3 Techno-economic analysis

3.3.1 Technology installation costs

Based on the information collected from manufacturers, cases studies and the ClearSkies programme, estimates for installation costs of a variety of small wind turbines are shown in Table 5 below. Figure 3 on the next page is the graphical representation of this data.

Table 5. Installed cost estimates for the technologies studied in the UK

Turbine type	Rated kW	Installed cost, EUR	Approx EUR/kW
D400 (Eclectic Energy)	0,4	3190 - 3625*	7975 - 9070
Proven 0,6 kW	0,6	5220 - 9000[i]	8700 - 15000
Windsave	1	2175*	2175
Swift (now) Swift (in 12-24 months)	1,5 1,5	14500 - 17400[i] 7250 - 10150[i]	9670 - 17400 4830 - 6770
Proven 2,5 kW (ground installation)	2,5	13050 - 25100 [+] 36250 [cs]	5220 - 10040 14500
Proven 2,5 kW (building-mounted)	2,5	26100 [+] - 30450[i]	10440 - 12180
Iskra	5	24650* 19600 - 25400[+]	4930 3920 - 5080
Proven 6 kW (ground installation)	6	24650 - 39150[+] 46400 [cs]	4110 - 6530 7730
Proven 6 kW (building-mounted)	6	36250[+] - 37700[i]	6040 - 6280
Proven 15 kW	15	56500 - 68150[+] 78300 [cs] 92800[i]	3770 - 4540 5220 6200
Gazelle	20	137750[+] - 142100 [cs]	6890 - 7100

Source key:
* Manufacturer's cost estimation
+ ClearSkies programme data
i Wind turbine installer
cs Case study data

ClearSkies estimates that a typical system costs 3625 - 7250 EUR /kW[1]. In Figure 3 below the Clear Skies estimate is that furthest to the left, next to the y-axis.

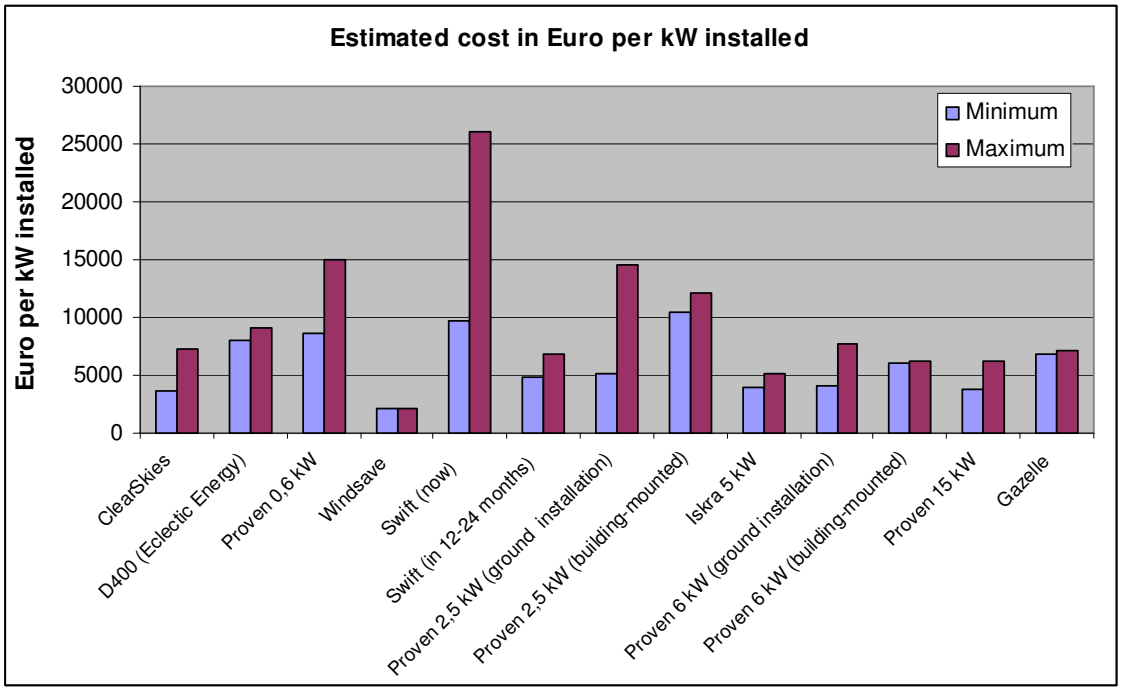

Figure 3. Estimated turbine installed costs for all technologies studied, UK

In Figure 3 the minimum and maximum estimated cost for each kind of installation is shown. The range of cost tends to decrease as the capacity of the turbine increases.

However, this data has some limitations in accuracy. For example, there is more data for some technologies, such as the Proven 2.5 kW (ground-mounted), than others. More data means a greater chance of cost variation making the error bars for this technology particularly broad. This is because the installed cost of a turbine depends a great deal on individual site factors. Some of the other technologies might show the same range of extremes if more data were available.

Building-mounting Proven 2.5 and 6kW turbines does not seem to be significantly more expensive than ground-mounting them. However, there is still limited experience with building mounting these kind of turbines in the UK and therefore, there was limited data on costs.

The source of cost estimates is given to enable the reader to judge the reliability of the cost given, as some turbine costs were only available from manufacturers. For example, the Windsave 1 kW turbine is the cheapest turbine per installed kW, but this is the manufacture's estimate of cost and the turbine is no yet being sold at this price. Very few installations exist, so the price cannot be confirmed and may be subject to change.

[1] ClearSkies programme, 2005

3.3.2 Cost per installed kW

The total installation cost per kW installed for the 21 systems for which case study questionnaires with cost data were received back is shown below in Figure 4. There is a significant variation in the cost of small systems, with both the variation and cost reducing as the installed capacity increases. The logarithmic function explains 56% of the variation in the costs, which statistically is a weak correlation; this signifies that the installations costs are greatly dependant on individual site factors. Site factors have a greater influence on the cost of smaller installations, since they account for a higher percentage of the overall cost. The average cost per installed kW for the systems analysed in the case studies questionnaire was 4870 EUR/kW.

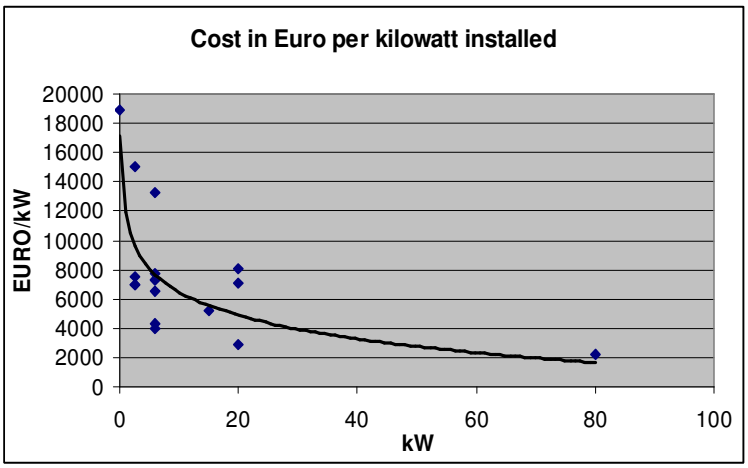

Figure 4. Cost per installed kW – Case study data, UK

Comparing the results from the case studies with the data from the ClearSkies programme, we can see that there is a good correlation. The ClearSkies data logarithmic function explains 42% of the variation in the costs, which again emphasises the importance of individual site factors. This trend line also shows that cost reduces significantly as the installed capacity increases. The average cost per installed kW for the ClearSkies data was 5440 EUR/kW.

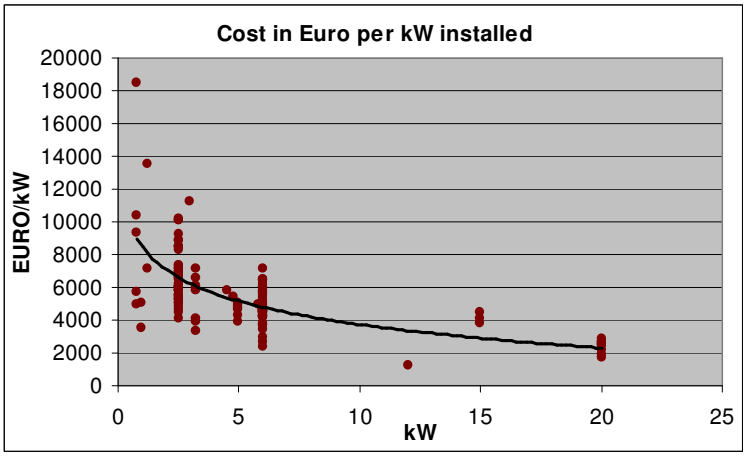

Figure 5. Cost per kW installed - ClearSkies data, UK

3.3.3 Factors affecting the economics of small wind turbines

Two case study projects were examined in detail to assess what factors have the greatest effect on the cost of energy and payback period.

The first site is a primary school in Scotland which has a 2.5 kW turbine, and is the most expensive in terms of £/kW installed of all the studied installations. The average annual wind speed is 5.1m/s. The school has a net metering tariff and the value of their electricity is 6.3p/kWh for imports and exports. The cost of their generated electricity based on a 25 year payback period would be 15.6p/kWh, and based on their current electricity tariff; the installation will never pay back financially.

The second site is a country park with a 6 kW turbine, which paid an average price in terms of £/kW installed. Their average annual wind speed is 5.3m/s. The park has a Good Energy tariff where they get paid 4.5p/kWh for energy they produce and pay 7.67p/kWh for imports and a standing charge of 10.1p/day, giving financial payback in 19 years. The cost of their generated electricity based on a 25 year payback period would be 8.5p/kWh.

From a sensitivity analysis of differing site factors the effect on the price/kWh of electricity produced from the two sites were analysed, with the influential site factors shown below in Figure 6 . A 25 year payback at a 3% interest rate was used.

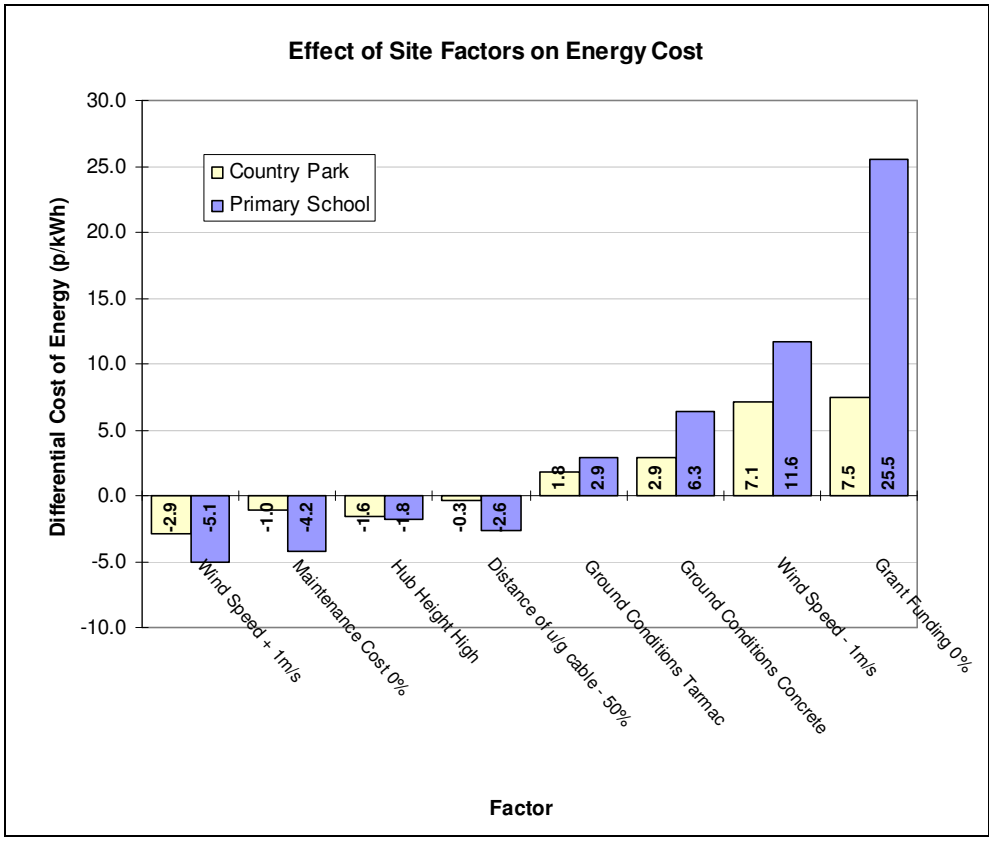

Figure 6. Effect of varying site factors, UK

The factors which most greatly affected the economics of both installations were:

- Applied Discount Rate
- Grant Funding
- Wind Speed and energy yield
- Ground Conditions

In an overall analysis of costs, the other main factors effecting economics of installations are:

- Maintenance Costs
- ROCs
- Electricity Consumption

This section will now briefly examine each one of these factors.

3.3.3.1 Applied discount rate

The interest rate at which you choose to discount your investment has an underlying effect on its economics. Large wind farms will discount at around 10%, as they must survive as a business and make a profit; whilst many published payback calculations for smaller turbines are done at a 0% interest rate, and often neglect to take into account running costs. Due to the barriers facing small urban wind turbines none of the studied installations would ever payback at a 10% discount rate. Since only 4% of the installations were for financial reasons it would be incorrect to discount them as a business investment. The economics in this study are therefore calculated using a 3% discount rate to represent inflation.

3.3.3.2 Grants

At present there are several funding streams available in the UK that project developers can use. The most common grant source is the Clear Skies programme, for England and Wales or the Scottish Community and Household Renewables Initiative (SCHRI) for Scotland. Other grant sources are energy suppliers (e.g. Scottish Power, EDF or Northern Ireland Electricity), local renewable energy agencies (e.g. TV Energy or ALIENERGY) and local authorities. These are the sources of major grant funding available, however this is not an exhaustive list and there may be other sources of small levels of grant funding. For example, funding for small wind projects has also been obtained from the Carbon Trust (for innovative projects) and the Government of Northern Ireland (DETI).

However, some project may be ineligible for grants (e.g. businesses are not eligible for ClearSkies) and grant programme come to an end, sometimes without any replacement. The ClearSkies programme is due to end in March 2006, and it is not clear if the replacement funding stream, called the "Low Carbon Buildings Programme" will offer the same kind of capital grants to small wind projects, as ClearSkies did.

3.3.3.3 Wind speed

The wind speed at an urban site has the greatest influence on its economic viability; therefore it is the most important consideration when siting a turbine. Unfortunately wind speed is an unknown factor at most installation sites since the process of obtaining wind speed measurements prior to installation is time-consuming and expensive. In fact, carrying out wind speed measurements at a specific site could cost as much as a wind turbine

installation itself. Therefore measurements are rarely carried out for installations of single turbines.

As Figure 6 shows, a 1 m/s difference in the predicted wind speed can make a very big difference to the economics of an installation. For the school in Figure 6, a decrease in wind speed of 1 m/s would increase the cost of the school's electricity by 11.6p/kWh, whereas 1 m/s high wind speed would decrease the cost by 5.1p/kWh. This is a net swing of 16.7p / kWh.

Therefore the extra investment required to increase the hub height of the turbine and place it in a position to receive a higher average wind speed should be considered for most installations. Although it would increase capital expense, it could be worthwhile due to increased wind capture and energy yield.

3.3.3.4 Energy yield

The owners of the urban turbines who responded to the questionnaire tended to be disappointed with the energy yield of their wind turbine. This is because installers estimate the energy capture based on the annual mean wind speed in the Noabl database, which is the result of a mass wind flow model across the UK with corrections made for land/sea interfaces. The model does not take into account roughness changes, such as trees and houses, in urban areas and it is likely that predictions of the wind speed in areas of complex terrain are inaccurate.

Table 6 below shows the mean wind speed from three case study sites calculated from their stated annual electricity production in the questionnaire, compared to the wind speed for the same location from the Noabl database. These calculations assume 85% availability and 97% electrical efficiency of the system and a Rayleigh distribution of wind speeds. The results showed the calculated mean wind speed to be significantly lower, especially when the hub height of the turbine was comparatively low.

Table 6. Calculated wind speeds at urban sites in the UK

Site	Hub Height (m)	Calculated Wind Speed (m/s)	Noabl Wind Speed (m/s)
Sports-centre, Scotland	9	2.7	4.3
Primary School, Buckinghamshire	9	3.8	6.3
Eco-Centre, Teesside	30	5.2	6.1

3.3.3.5 Capacity factor

The impact of the lower wind regime and availability of the studied systems are reflected in their low capacity factors. The capacity factors for turbines from the cases studies ranged from 1.6% to 13.6% with the average being 6.4%. This is significantly lower than capacity factors for big wind, which range between 20% to 35%. Figure 7 below shows that the capacity factor distribution is positively skewed. This may reflect the low urban wind regimes interacting with the cut in speed of the wind turbines, or could simply be a product of the low sample size.

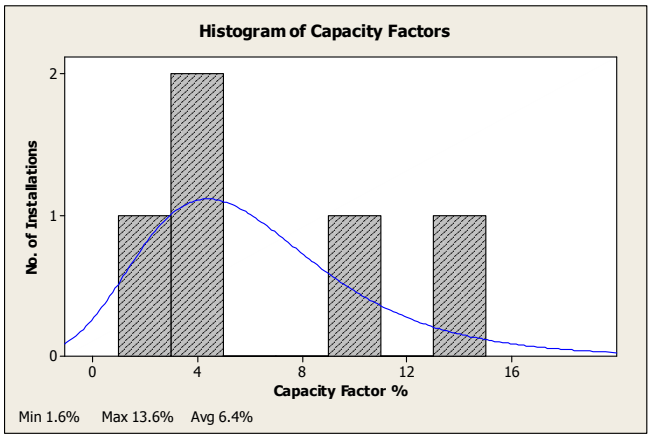

Figure 7. Distribution of capacity factors of turbines in urban areas in the UK

3.3.3.6 Ground conditions

It is best practise to distance a wind turbine from habitation to reduce the risk of noise nuisance and increase the distance from tall buildings, which could disrupt airflow. However, this requires cabling over a greater distance, and since the cable is laid underground, the ground conditions can have an effect on costs. For example, cable laying for the school's 2.5 kW turbine through mainly rough ground for a distance of 260 metres accounted for 46% of the total installation cost. The cost of cabling underground increases if the cable has to go under tarmac or concrete, compared to a lawn or a field.

3.3.3.7 Maintenance costs

Yearly maintenance typically involves inspection and re-greasing. The costly aspect of the service is paying for an installer to travel to site and lower the turbine to working level. Due to the relatively less demanding wind regime of an urban area, there may be scope for reducing the maintenance intervals. Another option is to have the service done by on-site staff, therefore avoiding the cost of an installer.

3.3.3.8 Renewable Obligation Certificates

Claiming Renewable Obligations Certificates (ROCs) on produced electricity adds a value of 4.6p/kWh. Due to complicated registration procedure and a minimum generation requirement, many small generators do not claim ROCs. The analysis showed that claiming ROCs did improve the payback period of an installation, although by itself it did not have a big impact, especially on installations under 5 kW.

3.3.3.9 Electricity Consumption

The best way to ensure a good price for generated electricity is to offset the need to purchase from the supplier. This is because most often this electricity is charged at a higher rate than electricity bought back (unless net metering is used).

For example, in the case of the country park where the turbine electricity supplies a gift shop, visitor centre and café, it has been estimated that for 80% of the time the electricity demanded from the building will exceed the amount of electricity generated from the turbine. Hence the value of their renewable electricity is 12.2p/kW (4.5p + 7.67p), with the remaining 20% of the time being 4.5p/kWh.

3.3.4 Building integrated turbines

Tall buildings and tower blocks seem to offer an opportunity to capture higher wind speeds, therefore making installations in cities more economically viable. Some installations on tower blocks are under way in the UK. To put small wind potential into context, Sustainable Energy Action estimate that there are approximately 4000 tower blocks in the UK. A 10 kW installation on each tower block would give a capacity of 40MW, the equivalent of about 20 large wind turbines.

Many of the issues facing the economics of today's small scale turbines will not be so significant in the building mounted sector. Building mounted turbines should be closer to the distribution board, will not need underground cabling, will be mounted higher above ground level, and some systems also claim to be maintenance free. However new issues which will affect the economics of the installation will start to emerge, such as:

- planning permission
- health and safety issues
- structural surveys
- noise (both for building users and surrounding environment)
- flicker from the blades
- building strengthening costs and
- Possible electromagnetic interference with nearby electrical equipment

With regards to wind data, there is clearly a need for more research on airflows and wind speeds in urban surroundings, particularly looking at airflows around buildings and other obstacles. More data must be collected, and computer models must be developed that can make predictions tailored to urban areas. Project developers should not have to rely on NOABL in the urban environment as it does not take into account local topography, and will very likely overestimate the wind speed.

There are currently too few building mounted installations currently in the UK to be able to draw definitive conclusions about costs or success of the installations. However, the building mounted sector is growing and in the future there will be more data to draw upon for conclusions.

3.4 Conclusion

The UK urban wind industry has much potential; its biggest asset is currently the overwhelming interest from both public and private sector actors and the positive attitude these actors have towards the technology.

However, it is important at this stage that the industry is realistic about its capabilities. It is evident that wind turbines in urban surroundings receive lower wind speeds and have lower capacity factors. This reduces energy production significantly, thus reducing economic feasibility.

There is scope for improvement in these areas as the reliability of the systems will improve as the technologies mature. Installers can also improve capacity factors by responding more rapidly to problems and advising customers correctly on the suitability of their location for a turbine. As the available quantity of historical wind data grows energy predictions will

become more accurate and experience with siting wind turbines will improve, thus placing them in locations most likely to maximise wind capture.

The installations studied in this report showed that at the moment small scale wind can not be justified as a financial investment. However, a turbine owner can improve the financial results by reducing their overheads such as maintenance costs and by achieving a good price for the electricity produced. The best way to do this is to consume a maximum of the electricity produced on site, thus offsetting the need to purchase high cost electricity from a supplier.

Another way to improve the financial aspects is to claim the ROCs, although this may only be realistic for larger producers. To this end the system for small generators claiming ROCs need to be simplified by the government and indeed a review process is currently underway that should enable micro-generators easier access to ROCs.

In conclusion, it may be true that small wind turbines are not economic today, but it is also currently true that economic factors are not the primary reason for individuals and organisations installing wind turbines. So although improving the economics of the installations is necessary and feasible, in the meantime the industry can rely on other incentives such as improving environmental and educational awareness to stimulate the market.

4 THE NETHERLANDS

4.1 Summary

This report provides an overview of techno-economic aspects of urban turbines based on analysis of four types of turbines. These are: WES5 Tulipo, Fortis Montana, Turby and Windwall.

4.2 Methodology

The analysis has been mainly based on the information we collected from the manufacturers via the Economic Questionnaire. In addition to that, we met each manufacturer separately and consulted them about their expectations regarding costs development and about their practical experiences regarding the implementation of urban turbines. At the same meetings we also verified the answers to the Economic Questionnaire, this in order to learn more about the motivation behind the answers.

The first section is the summary of the economic survey on four urban turbines. In the second section we provide an overview of these four turbines. The responses to the Economic Questionnaire are included in the overview table in Annex 2.

4.3 Techno-economic analysis

In this survey the economic aspects of four different urban turbines are analysed. All of these turbines comply with the specialised requirements of urban surroundings: they are visually attractive, can stand strong wind gusts and turbulences, are safe and have a low sound level.

One of the turbines, Montana, has been on the market for nearly 20 years. Originally it was developed for stand-alone electricity generation in developing countries. In the last few years, the turbine was functionally and visually adapted to fit the requirements of urban surroundings.

The other three turbines, Tulipo, Turby and WindWall, were recently developed, especially for de-centralized electricity generation in urban surroundings. The Tulipo has the visual appearance of classic 3 blade wind turbines, but the functionality of an urban turbine. Turby and WindWall are innovative wind turbines with an unusual visual appearance. They have been specially developed for mounting on the roofs of high buildings.

The marketing, sales, production and installation of urban turbines are being done directly by the manufacturers of turbines. There are still no dedicated advisors, representatives and servicing parties which we can find in developed markets as for example central heating installations.

4.3.1 Costs

The investment costs of urban turbines are:

- € 3,02 per W for Montana
- € 5,67 per W for WindWall

- € 6,77 per W for Turby and
- € 6,88 per W for Tulipo.

None of the turbines uses rectifiers. Two of the turbines, Montana and Turby have no special control equipment regarding temperature, vibrations and or bearings. Two of the turbines, Tulipo and Montana are supplied with an operational manual. Turby has no manual because the producer believes that nothing can go wrong and WindWall has a warranty for 10 years and the manufacturer guarantees an uninterrupted operation during that period.

Tulipo and Montana are placed on ground next to buildings, Turby and WindWall are mounted on the top of buildings. WindWall has no tower. Also it can not turn around towards wind. Therefore this turbine must be placed in the optimal direction, were the most wind comes from.

4.3.2 Lifetime and warranties

All producers agree on the 20 years as overall life time for their turbines. Tulipo needs a general check-up and change of bearings after 10 years. All producers except Fortis believe that inverters would have to be replaced after 10 years.

Different producers give very different warranties. Tulipo has 1 year warranty, Montana 5 years, Turby 2 years and WindWall 10 years. There are no charges for material replacement and failures during the warranty period.

4.3.3 Electricity yield and electricity price

The electricity yield varies per turbine. It is:

- 1429 kWh/kW for Montana
- 1579 kWh/kW for WindWall
- 2000 kWh/kW for Turby and
- 4000 kWh/kW for Tulipo.

As mentioned earlier, these data are provided by the manufacturers and will be verified in practice in the next two years.

According to the calculations of the producers, the cost of generated electricity by urban turbines are as follows:

- 15 €ct/kWh for Tulipo and Turby
- 18 €ct/kWh for Montana and
- 20 €ct/kWh for WindWall.

Please notice that the manufacturers have calculated these values in different ways (with or without incentives and subsidies).

The pay-back time for all turbines is 10 years.

4.3.4 Life Cycle Costs

Life cycle costs are calculated to € 14.310 for Montana, € 15.014 for Turby, € 16.697 for Tulipo and € 17.356 for WindWall. The table below gives the total overview of the calculations.

lifetime (N)	20	years
investment rate (D)	6%	
inflation rate (i)	3%	
X =(1+i/1+D)	0,972	

$P=A(1-X^N)/(X^{-1}-1)$

$P = FX^N$

LCC = C + M + E + R - S

	Tulipo		Montana		Turby		WindWall	
	initial costs (€)	present worth (€)	initial costs (€)	present worth (€)	initial costs (€)	present worth (€)	initial costs (€)	present worth (€)
capital costs (C)								
turbine	14950	14950	7115	7115	10920	10920	12.238	12238
mast	included		2660	2660	2000	2000	no	
inverter	included		3850	3850	included		2.670	2670
electrical items	included		375	375	600	600	1.113	1112,5
foundation	2000	2000	2495	2495	2700	2700	1.335	1335
lightening, grounding	included		included		700	700	223	222,5
maintenance (M)								
operational costs	175	1.499	No		No		no	
maintenance			No		No		1.758	1.758
energy (E)	-	-	-	-	-	-	-	-
replacement (R)								
bearings	100	857	No		no			
inverter	1300	1300	3850	2.168	no			
salvage (S)								
20% of original equipment costs	3390	1.909	3299	1.858	3384	1.906	3.516	1.980
LCC		**16.697**		**14.310**		**15.014**		**17.356**

4.3.5 Production volume in relation to the price development

The price of an urban turbine currently depends on technological state of advancement, material prices and production volume. If the turbine is not technologically finalized, there still can be some major changes in design and materials. All turbines from this survey have undergone several changes regarding the construction and materials.

Commonly used materials are: stainless steel, zinc doped steel, aluminium, copper, concrete and carbon epoxy composite. The price of steel will be of main influence regarding the material prices because the greatest part of the weight of the turbines is made of this material. At this moment the prices are high, due to the booming expansion of Chinese industry. However, as long as turbines are produced in very small series, the material prices will remain of minor effect to the final price of urban turbines.

The biggest price cutting effect must come from the large production volumes. All producers agree on estimation that a production volume up to 100 pieces can cut the prices for about 20%, while the series of 1000 pieces can reduce the price with further 30% - 50%.

4.3.6 Experiences with mechanical and electrical installation

There were no problems regarding the electrical installation of urban turbines so far, in the first place because the turbines are connected to the internal installation of the customer, behind the kWh-meter. Except for some vibration problems with Turby, there were no major mechanical problems.

All producers agree that permit procedures and the lack of dedicated safety standards and directives for visual integration in urban surroundings are the biggest obstacles for the introduction of urban turbines.

4.3.7 Technical standards

Tulipo and Montana comply with the international safety standards IEC 61400-2 and IEC 61400-22 which were developed for large wind turbines. WindWall complies with the Dutch standard NEN6702. It has been also officially tested by the Dutch Energy Centre ECN. Turby does not comply with any recognised safety standards.

4.4 Conclusion

The majority of urban turbines were developed between 2000 and 2002. The technical and economic data in this report were provided by the manufacturers and will be verified in practice in the next two years.

According to the manufacturers, all turbines comply with the high requirements of urban surroundings: they are visually attractive, can stand strong wind gusts and turbulence, are safe and have a low sound level.

The marketing, sales and installation of urban turbines are being done directly by the manufacturers of turbines. A market focused on urban turbines has not yet formed. The manufacturers cannot rely on services of other firms like specialised advisors, constructors specialised in building integration, providers of building permits and the like. This gap between the manufacturers and the customers is an obstacle that needs to be recognised as such.

The capacity of urban turbines from this survey lies between 2,5 and 5 kW. The investment costs of urban turbines vary from € 3,02 to € 6,88 per W installed power. The life time is expected to be 20 years. Different manufacturers give very diversified warranties for the periods of 1, 2, 5 and 10 years.

The electricity yield varies between 1429 kWh/kW and 4000 kWh/kW. According to the calculations of the manufacturers, the electricity costs lie between 15 €ct/kWh and 20 €ct/kWh. The pay-back time is 10 years and life cycle costs are between € 14.310 and € 17.356.

The prices of urban turbines depend on the maturity of the used technology, prices of the materials and the production volume. Because we are dealing with newly developed turbines, it is likely that some more minor adaptations will be necessary in the coming years.

Commonly used materials are: stainless steel, zinc doped steel, aluminium, copper, concrete and carbon epoxy composite. The price of steel will be of main influence regarding the material prices because the greatest part of the weight of the turbines is made of this material. However, the biggest price cutting effect on short term must come from the larger production volumes. All producers agree on the estimate that the production volume of approximately 100 units per series can cut the prices for about 20%, while the series of 1000 units would reduce the price by 30% - 50%.

There were no problems regarding the electrical installation of urban turbines, in the first place because the urban turbines are connected to the internal installation of the customer, behind the kWh-meter.

No significant problems regarding the mechanical integration of urban turbines were reported.

All producers agree that permit procedures and the lack of dedicated safety standards and directives for visual integration in urban surroundings are the biggest obstacles for the introduction of urban turbines.

5 REFERENCES

1. Merton Unitary Development Plan, http://www.merton.gov.uk/udp.pdf, p.86
2. Case studies analysis available from IT Power
3. Statement based on report ERU 15: Assessment of the Accuracy of the DTI's Database of UK Wind Speeds found at http://www.eru.rl.ac.uk/broch94/eru15.html
4. Extract from statement by north east government office, http://www.go-ne.gov.uk/gone/news/windfarms/
5. PPS 22 Companion text, http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_033489.pdf, p.167
6. Proven and Swift planning information, www.provenenergy.co.uk, www.renewabledevices.com, and conversations with local planning authorities.
7. Avg ROC auction prices from, http://www.nfpa.co.uk/ , click "ROC auction prices"
8. Engineering Recommendation G83/1, p.6
9. Threshold for claiming ROCs on an annual basis, DTI Micro-generation consultation document June 2005, http://www.dti.gov.uk/energy/consultations/microgen.pdf p.24
10. DNO questionnaires available from IT Power
11. Murray Thomson, Loughborough University, M.Thomson@lboro.ac.uk
12. Bradford West City Tower Blocks, Wind Energy Feasibility Study, ESD, December 2003
13. Sustainable Energy Action, http://www.sustainable-energy.org.uk
14. Small Wind turbines for the Urban Environment: State of the Art, case Studies and Economic Analysis, Peter Robinson, Reading University, 2005
15. Investigation into the Installation of Small Wind Turbines in an Urban Environment, Stephen P Carroll, Loughborough University, 2005

6 ANNEX 1: ECONOMIC VARIABLES

6.1 Variables included in the economic analysis

Type of turbine	The power curves and details of wind turbines being manufactured and aimed at the urban market are available from www.urbanwind.org
AMWS	Access to measured data, and NOABL
Discount rate	0% is favourable. 10% unfavourable
ROC value	£45/MWh is the highest. £0/MWh is the lowest. ROCs are rounded to the nearest MWh, where 0.5MWh = 1 ROC, and 0.49MWh = 0 ROCs.
Grants	From 0-100% of total project costs. There are many potential grant sources.
Tariffs	A typical tariff for an organisation might be £0.06/kWh, for a house £0.07/kWh. Normally, less is paid for electricity sold to suppliers.
% of imports offset	As less is paid for electricity sold, the economics are better if the electricity is used to offset imports
Electricity price evolution	Electricity prices are projected to increase, but it is uncertain by how much. A range from 0-4% is used.
Maintenance & other ongoing costs	The costs for some turbines are available, for others it is less certain partly because they have been on the market for shorter periods of time

There is more information on these variables and how they affect the economics below. One variable that has not been included is repair and maintenance time, which reduces the turbines' availability.

6.2 AMWSs

NOABL, although useful to make an estimate, doesn't take account of local topography and circumstances. It only takes into account the effects of topography in a resolution equal to and greater than 1 km. It doesn't take account of small hills, trees, individual buildings or groups of buildings, etc. Neither does it take account of local thermally-driven winds (e.g. sea breezes). (BWEA, 2005b)

There are other programs that one may use, such as WAsP, to model wind speeds whilst taking into account the effects of local topography on AMWS. Obviously, compared to NOABL, in an urban environment this produces lower estimates of AMWSs. In a feasibility report by CSE for urban wind in Ealing, the NOABL estimate was 5.6 m/s and the WAsP estimate was 4.4 m/s. (Clear Skies, 2003) If we compare the measured figure for the

centre of Reading (2.8m/s) with the NOABL estimate (4.8m/s) it gives weight to assuming that revised estimates lower than NOABL data are more accurate.

Where the height of the turbine will be at a height that the NOABL model doesn't predict, (e.g. if the turbines are on a tall building), then we can extrapolate using the logarithmic model of wind shear equation shown below:

$$V = V_0 \left[\frac{\ln\left(\frac{H}{z_0}\right)}{\ln\left(\frac{H_0}{z_0}\right)} \right]$$

Where H is height the wind turbine will be at, z_0 is an estimate of the roughness coefficient, H_0 is the height at which the wind speed is estimated, and V_0 is an estimate of the wind speed[2].

The roughness coefficients, z_0, can be estimated as so:

Terrain	**Surface roughness length, z_0**
Snow on flat ground	0.0001
Coast with onshore winds	0.001
Cut grass	0.007
Airport runway areas	0.01
Hedges	0.085
Scattered trees & hedges	0.15
Trees, hedges, a few buildings / shelter belts	0.3
Suburbs	0.4-0.5
City	1

(Gipe 2004 & CSE 2003)

[2] Gipe, 2004

6.3 ROC prices

ROC prices have varied since being implemented. The table below shows their historical average auction levels.

20 July 2005	£ 45.75 / MWh
27 April 2005	£ 46.07 / MWh
20 January 2005	£ 47.18 / MWh
26 October 2004	£ 46.12 / MWh
21 July 2004	£ 52.07 / MWh
20 April 2004	£ 49.11 / MWh
20 January 2004	£ 47.46 / MWh
21 October 2003	£ 45.93 / MWh
16 July 2003	£ 48.21 / MWh
15 April 2003	£ 46.76 / MWh
16 January 2003	£ 47.46 / MWh
17 October 2002	£ 47.13 / MWh

(Non-Fossil Purchasing Agency, 2005)

Notwithstanding any chance that there might be for ROCs being abolished without any replacement scheme, the paperwork involved in trying to claim as a "small generating station" (≤ 50 kWe) is so long & complicated that it could put off many people. In addition to ROCs, a small generator can also claim for LECs (Levy Exemption Certificates) and REGOs (Renewable Energy Guarantees of Origin). The administration procedure notes are 51 pages long, the application form is 24 pages long, the guidance notes for the application form are 13 pages long (and refer to much more additional Ofgem reading that an applicant should do), followed by 7 pages on the instructions for submitting ROC and LEC data[3].

That said though, there are companies one can contact, such as TradeLink Solutions or Utility Link, who will assist people with the paperwork, and then act as the agent in selling the ROCs.

[3] Ofgem, 2002

6.4 Energy price evolution

Electricity & gas prices in the UK are rising, which is likely due to the depletion of North Sea gas. Although recent increases from some energy suppliers have been large – in the region of 7.5% for electricity and almost 12% for gas from NPower for domestic consumers – it seems unlikely that prices will keep increasing at that rate. It is extremely difficult to predict energy prices, so it is assumed that the average increases over the next 25 years might be around 0% - 4% (where 0% is very pessimistic).

6.5 Percentage of imports offset

The price one receives for exporting electricity is almost always less than the price one pays for importing it. Therefore, the most optimistic economic appraisal one that assumes that 100% of the electricity generated has been used to offset imports.

7 ANNEX 2: ECONOMIC QUESTIONNAIRES FROM THE NETHERLANDS

Costs of urban Turbines

	Cost of the installation (€)	WES5TULIPO (2,5 kW)	Fortis Montana (5,6 kW)	Turby (2,5 kW)	WindWall (3,6 kW)
1	Wind turbine	14,950	7,115	10,920	12,238
2	Mast (if required)	Included in price	2660	2000	no mast
3	Inverter	Included in price	3850	Included in price	2670
4	Rectifier	no	no	no	no
5	Other control equipment (vibration auto brake, bearing temperature sensor, etc. - list as required)	Included in price	none	none	445
6	Electrical items (AC isolators, additional distribution board, etc.)	Included in price	375	none	667.5
7	Energy display board e.g. showing current production, total production, etc.	not included	included	600	web-site
8	Handover pack / Operation manual	yes, Included in price	yes, Included in price	no manual	no manual
9	Delivery of all items to site	depends on distance	200	depends on distance	1335
10	Foundation & erection of wind turbine (installation)	2,000	2,495	1,400	1,335
11	Electrical integration and commissioning	Included in 10	Included in 10	Included in 10	667.5

	Other costs (€)	WES5TULIPO (2,5 kW)	Fortis Montana (5,6 kW)	Turby (2,5 kW)	WindWall (3,6 kW)
12	Design work (technical drawings, wind measurements, site assessment, calculations, etc.)	Depends on project	Depends on project	Depends on project	no
13	Application for grid connection (where applicable)	250	200	45	no
14	Installation of an export meter	500	500	no export meter	no
15	Lightening protection / grounding	no lightening, grounding included	no lightening, grounding included	700	222.5
16	Other? (insurance, etc.)	no	no	no	no

	Operation and Maintenance costs (€)	WES5TULIPO (2,5 kW)	Fortis Montana (5,6 kW)	Turby (2,5 kW)	WindWall (3,6 kW)
17	Are there any operational costs?	optional	no	no	no
18	How much does yearly maintenance cost?	optional	no	no	10% included

	De-commissioning costs (€)	WES5TULIPO (2,5 kW)	Fortis Montana (5,6 kW)	Turby (2,5 kW)	WindWall (3,6 kW)
19	Please estimate costs of taking down turbine	500	500	500	2225

Other aspects

	How often do major parts need to be changed?	WES5TULIPO (2,5 kW)	Fortis Montana (5,6 kW)	Turby (2,5 kW)	WindWall (3,6 kW)
	Major parts	Lifetime (years)	Lifetime (years)	Lifetime (years)	Lifetime (years)
	bearings	10 year	no	20 years	no
	mast /frame	20 years	20 years	20 years	30 years
	blades	20 years	20 years	20 years	20 years
	generator	20 years	20 years	20 years	20 years
	electronics including inverter	10 years	no	10 years	10 years

	Varranty, safety and electricity price (€)	WES5TULIPO (2,5 kW)	Fortis Montana (5,6 kW)	Turby (2,5 kW)	WindWall (3,6 kW)
A	How many years is the turbine warranty valid for? Is there an extra cost to have a warranty?	1 year, no extra costs	5 years, no extra costs	materials 2 year	10 years, costs included
B	What is the average price of the electricity produced in EURO / kWh?	0,15 €/kWh at 6,5 m/s	0,18 €/kWh at 6,5 m/s	depends on the site	0,20 €/kWh
C	What is the average electricity yield in kWh/year?	10.000 kWh/year	8.000 kWh/year	5000 kWh/year	6000 kWh/year
D	Have you encountered any particular problems / constraints when connecting your wind turbines to the grid? If so, please describe	No problems so far	No problems so far	No problems so far	No problems so far
	Technical problems:	No problems so far	no	mechanical resonance	no

8 ANNEX 3: PROFILE OF FOUR URBAN TURBINES

8.1.1 WES[5] Tulipo

Tulipo in Zevenbergen, Netherlands

Description

WES[5] Tulipo is a horizontal axes turbine (HAT) with three blades and a capacity of 2,5 kW. The tower is 12 m high and the rotor diameter of 5 m. The tower is placed on the standard foundation of concrete block with an anchor.

WES does not supply lightening protection for the Tulipo. The turbine is provided by a grounding protection system, and complies with the international safety standards IEC 61400 which were developed for large wind turbines.

The turbine is produced by the Dutch company Wind Energy Solutions b.v. (WES) from Zijdewind, Netherlands. The company produces three different kinds of wind turbines in the range of 2,5 kW, 80 kW and 250 kW.

Tulipo was developed specifically for appliances in built surroundings by the Dutch wind turbine developer Lagerweij and introduced to the market during the Hannover Messe in the year 2000. After Lagerweij went bankrupt, WES has taken over the technology for the production of Tulipo. This is the only turbine in the Netherlands that has been certified by an official international certifying institution, in this case NREL in the US.

Up to now, Tulipo has been placed on two locations in the Netherlands, in Elst and in Zevenbergen. On both locations, the turbine was placed on the ground next to buildings. The manufacturer believes that this is the optimal way of mounting this turbine. In the coming months 5 Tulipos will be installed on different locations in England.

Costs

The total costs, including transport inside Netherlands, mechanical and electrical connection and the operation manual are € 17.200 exc. VAT.

A display for the presentation of energy production is available as an additional feature. In order to insure smooth operation of Tulipo, it is necessary to change the lubricating oil and grease the rotating parts once in two years. The instructions for these maintenance activities are provided in the Operation Manual and the maintenance can be completed by the owners as it does not require special tools or qualifications. Wes also offers this maintenance service for € 175 per year. Once in ten years the Tulipo must undergo the complete check up. The costs of check up are about € 1.000, and can be paid in advance by € 100 per year.

Tulipo has a warranty for one year and the expected lifetime of 20 years.

According to the manufacturer, Tulipo generates 10.000 kWh/year at 6,5 m/s. Taking 15 years as write-off period with no subsidies or fiscal incentives, WES calculates the electricity costs to 15 €ct/kWh. This yield data have not been verified by an independent party or in practice.

The de-commissioning costs are estimated to € 500.

The Life Cycle Costs of Tulipo are 16.697.

8.1.2 Fortis Montana

Figure 2: Montana at Badger Wells Cottage

Sabden Clitheroe, UK

Description

Montana is a HAT turbine with three blades, rotor diameter of 5 m and the capacity of 5,6 kW. The turbine is can be supplied with a tower of 12, 18 or 24 m height. This turbine has a very simple and compact design, which makes it possible for users all over the world to order it as do-it-yourself package and assemble it themselves, simply by following the instructions from the Handbook.

The turbine is provided by grounding protection and complies with the international safety standards IEC 61400 for large wind turbines.

This turbine has been developed 20 years ago. Since then, this product underwent many modifications which improved the product quality, increased the efficiency and lowered the costs. The best place for Montana is on the ground, next to buildings. The turbine can be supplied for grid connected or for stand alone operation.

The manufacturer of Montana, Fortis Wind Energy, is located in Haren, Netherlands. This company has a long tradition of producing small wind turbines in the range from 200 W up to 30 kW. Between 1997 and 2005, more than 40 Montana wind turbines have been placed all over the world. In the Netherlands, ten Montana's have been placed in Zwolle, Stompetoren, Sebaldeburen, Hoogland, Groningen, Raalte, Tolbert, Wapserveen, Cadzand and Assen.

Three more will be placed this year within the project 'Voor de wind gaan' in the three Northern provinces Friesland, Groningen and Drente. Within this project 22 urban turbines from six different manufacturers will be placed. The main goal of the project is to gather information on issues associated with the implementation of small wind turbines in urban and rural areas and on industrial sites. The project duration is from March 2004 till June 2007.

Costs

The total costs, including transport inside Netherlands, mechanical and electrical connection, energy display and operation manual are € 16.895 exc VAT.

There are a few different options for the tower and the foundation. These have to do with the aesthetic requirements of the location and the type of the ground. The costs as mentioned are calculated for the standard option: a steel tube tower with one central anchor and four side anchors. Contrary to the Tulipo, one can buy Montana turbine without a tower, foundation, inverter and/or grid connecting items. The prices of all major parts are separately specified.

Due to compact construction, all sensitive parts of the turbine are air tight protected and lubricated. Therefore there are no operational and maintenance costs. Montana has a warranty for 5 years and the expected lifetime of 20 years. The owner will be charged no extra costs in case of faults of malfunctions during the warranty period.

According to the manufacturer, Montana generates 8.000 kWh/year at 6,5 m/s. Taking 10 years as write-off period, the manufacturer calculates the electricity costs of 18 €ct/kWh. Fiscal incentives of 14% of the investments costs were taken into account.

The de-commissioning costs are estimated to € 500.

The Life Cycle Costs of Montana are € 14.310.

8.1.3 Turby

Figure 3: Turby on the roof of the apartment building in Tilburg, Netherlands

Description

Turby is a wind turbine with vertical axes (VAT), Darrieus rotor and an electrical capacity of 2,5 kW. With his very light construction, Turby is specially constructed for placing on flat roofs. The turbine is developed in 2001 by the Dutch company Turby b.v. from Lochem, Netherlands. This turbine was an answer to the huge market interest which started after the first presentation of the Tulipo at the Hannover Messe. The shape of the rotor has been changed few times in order to increase the efficiency. Furthermore, the manufacturer was confronted with some unexpected vibration problems in the two first pilot projects, which were solved last year. Turby is equipped with lightening protection and grounding system. The turbine does not comply with the international safety standards for the large wind turbines.

Up to December 2005, Turby was placed on 10 different locations in the Netherlands: Amsterdam, Enschede, Tilburg, Breda, Hague (2), Zutphen, Velschen, Leeuwarden and Delft. Four more Turbys will be placed this year within the project 'Voor de wind gaan'. There is a lot of interest for this turbine in Canada, Australia, Ireland and France.

Costs

The total costs, including transport inside Netherlands, mechanical and electrical connection and an energy display are € 16.920 exc VAT.

There are a few different options for the mast. The choice depends on the height of the building and costs the investor is prepared to make. The costs as specified are calculated for the standard option: a 6 m high steel pipe tower with one central anchor and four side anchors.

Due to compact construction, all sensitive parts of the turbine are air tight protected and lubricated. This means that there are no operational and maintenance costs.

Turby has a warranty for 2 years and the expected lifetime of 20 years.

According to the manufacturer, this turbine generates 5.400 kWh at 5,3 m/s and 4.200 kWh/year at 5,1 m/s. Taking 4 years as write-off period, the manufacturer calculates the electricity costs of 15 €ct/kWh. The calculations take into account that the 14% of the costs will be covered by fiscal incentives. Furthermore, the national feed-in tariff (MEP) of 7,7 €ct/kWh is taken into account. The yield data have not been verified in practice.

The de-commissioning costs are estimated to € 500.

The Life Cycle Costs Turby are 15.014.

8.1.4 WindWall

WindWall in Oost Watergraafsmeer, Amsterdam

Description

WindWall (WW) as shown on the picture is a wind turbine with vertical axes mounted horizontally. It has a Darrieus rotor and an electrical capacity of 3,6 kW. WW turbine has no tower. It is mounted on a steel construction with concrete ballast of 4.900 kg, without anchoring.

WW is equipped with lightening protection and grounding system. The turbine complies with the Dutch safety standards NEN 6702. It is officially tested by the Dutch research institute ECN.

The aluminium blades are shaped like airplane wings. All components are transported separately and assembled at the location. The rotor can be produced with a diameter from 2 to 5,6 m. The length per module is 5 m for the 2m diameter and 10 m for the 5,6 m diameter. The electrical power for the modules with the diameter of 2 m is 1,9 kW per module. The large modules with 5,6 m diameter have an electrical power of about 8 kW. The size of the installation can vary from one to four modules.

The turbine is developed in 2001 by the Dutch company NGUp b.v. (Never Give Up) from Delden, Netherlands. The company has more than 20 years experience in the production of blades for wind turbines in the range of 0,75 MW to 2,5 MW. The working principle of the WW turbine has changed drastically after the first two pilot projects. The changes were made due to safety and efficiency reasons. The results from the newest projects are very satisfactory.

Up to December 2005, WW was placed on 7 different locations in the Netherlands: Zwolle, Hague (2), Rotterdam, Amsterdam, Wijk aan Zee and Schiedam. Four more WW will be placed this year within the project 'Voor de wind gaan'. This year several WW's will be supplied to customers in France and UK.

Costs

The total costs, including transport inside Netherlands, mechanical and electrical connection and energy display via internet are € 21.530 exc VAT.

There are different options for the support construction. The choice depends on the size of the turbine and the building construction. The costs as mentioned are calculated for the installation consisting of 2 modules with 2 m diameter. Due to compact construction, all sensitive parts of the turbine are air tight protected and lubricated. Therefore there are no operational costs. The maintenance costs, 10% of the total investment costs, are included.

WW has a warranty for 10 years and the expected lifetime of 20 years. Because the maintenance costs are included, there will be no extra costs for the owner. All repairs in the warranty period will be paid by the manufacturer. According to the manufacturer, this turbine generates 5.019 kWh at 5,56 m/s. This calculation was made for the location in Amsterdam. Taking 10 years as write-off period, the manufacturer calculates the electricity costs of 20 €ct/kWh. No fiscal incentives were taken into account and feed-in tariff was put to 4,9 €ct/kWh. The de-commissioning costs are estimated to € 2225.The Life Cycle Costs of WW are 17.356.