URBAN WIND TURBINES

GUIDELINES FOR SMALL WIND TURBINES IN THE BUILT ENVIRONMENT

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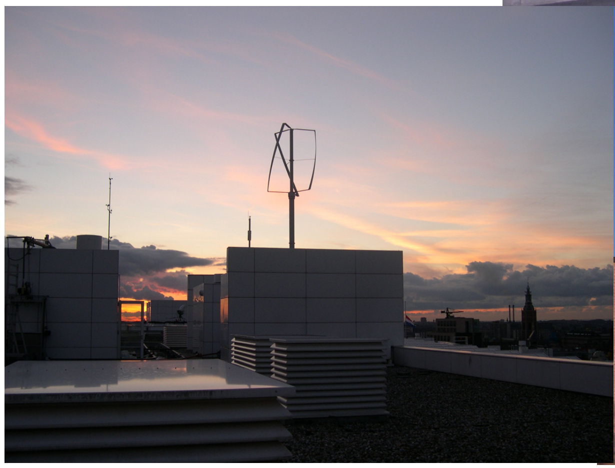

Wind Energy Integration in the Urban Environment

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www.urbanwind.org

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WINEUR was implemented by the following organisations:

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1 Introduction

This document is a deliverable of WINEUR, a project supported by the European Programme "Intelligent Energy Europe". The project is being carried out by five organisations: Axenne and ADEME from France, IT Power from the UK and HORISUN and ARC from The Netherlands. The objective of the project is to determine the deployability of small wind turbines in built environments while identifying the current significant constraints and possible solutions. All the reports produced by WINEUR, including techno-economic, grid connection, planning and standards and socio-economic reports can be found on the project website www.urbanwind.org . The site also includes the datasheets of 58 small wind turbine models in a downloadable small wind turbine catalogue.

There are a lot of developments on the market for small wind turbines at this moment in the UK and in the Netherlands. This is reflected in the large number of manufacturers, suppliers and pilot projects. In France, the situation is different as there are no French manufacturers of small wind turbines and only a few pilot projects have been implemented to date.

This brochure synthesises the research outcomes of WINEUR. It should be noted that the data used in WINEUR regarding the properties and the yield of wind turbines has largely been provided by the suppliers and manufacturers of small wind turbines and has not been independently verified.

The electronic version of these Guidelines can be downloaded from the project website: www.urbanwind.org .

1.1 Purpose of this document

The purpose of this document is to:

- Inform the stakeholders about the state of the development of small wind turbines for the built environment;
- Provide practical guidelines to actors dealing with installation of small wind turbines in urban areas;
- Provide recommendations for future products and for market development.

1.2 Definition

In the context of this document, small wind turbines are defined as turbines that are specially designed for built environment, and can be located on buildings or on the ground next to buildings. This implies that the turbine has been adapted for the wind regime in the built environment and can, in theory at least, resist wind gusts and turbulences and that the shape and size of the turbine have been designed to visually integrate with the surrounding buildings. The capacity of these turbines is generally between 1 and 20 kW. These small wind turbines can also be referred to as "urban wind turbines"; therefore in this report we shall use the acronym UWT.

1.3 Stakeholders

The stakeholders are: national and regional governments and municipalities, research organisations, manufacturers, project developers, architects, building and construction companies, engineering companies, energy agencies, installation companies, energy providers, rental firms/owners of large buildings and infrastructure objects (office buildings, hospitals, sport halls, apartment buildings, motorways, railways) home owners and financial institutions.

Table 1: UWT stakeholders and their roles and involvement

Stakeholders	***Roles / Involvement***
National government	Define national targets, provide legislation (including planning permits and safety aspects)
R&D organizations	Market and other research, support the development of UWTs, solving of identified (technical) problems
Manufacturers	Development and manufacturing of UWTs.
Regional governments	Develop incentives for the achievement of national targets, develop regional policies and plans
Municipalities	Implement national plans, potential developer as an owner of large buildings, provide permits, develop local plans and regulations, develop pilot projects.
Architects and urban developers	Construction, urban design and aesthetic integration
Property developers	Integration of UWTs into new build and renovation projects involving large buildings / tower blocks or large groupings of smaller buildings.
Energy agencies	Initiate, facilitate and support UWT projects
Engineering companies and consultants	Supporting projects by helping other stakeholder to obtain planning permits, carrying out roof construction assessments, project management support, market development, feasibility studies and other support activities
Owners of large objects	Deployment of UWTs, providing the roof space to other interested parties who want to install UWTs
Owners of large free standing houses	Deployment of UWTs
Installation companies	Installing UWTs, providing maintenance services
Energy companies	Purchasing and distribution of the electricity produced by UWTs
Regional grid operator	Connecting UWTs to the public grid, metering, data collection, registration and administration
Metering companies	Meters / measurement equipment for feeding electricity into the grid
Financial institutions	Financial products targeting small-scale energy producers including UWT owners

1.4 European Cities Urban Wind Network

The European Cities Urban Wind Network has been established as a part of the WINEUR project. The goal of the network is to facilitate the exchange of information and ideas concerning UWTs and to support the establishment of a common European approach for the further development of UWTs. The Charter of the network is available at www.urbanwind.org. More than 60 organisations have joined the European Cities Urban Wind Network as of February 2007.

2 Types of turbines

2.1 Horizontal axis wind turbines (HAWTs)

The propeller-type rotor is mounted on a horizontal axis. The rotor needs to be positioned into the wind direction by means of a tail or active yawing by a yaw motor. HAWTs are sensitive to the changes in wind direction and turbulence which have a negative effect on performance due to the required repositioning of the turbine into the wind flow. The best locations for HAWTs are open areas with smooth air flow and few obstacles. Some HAWTs models are shown in Figure 1.

Swift
Eclectic

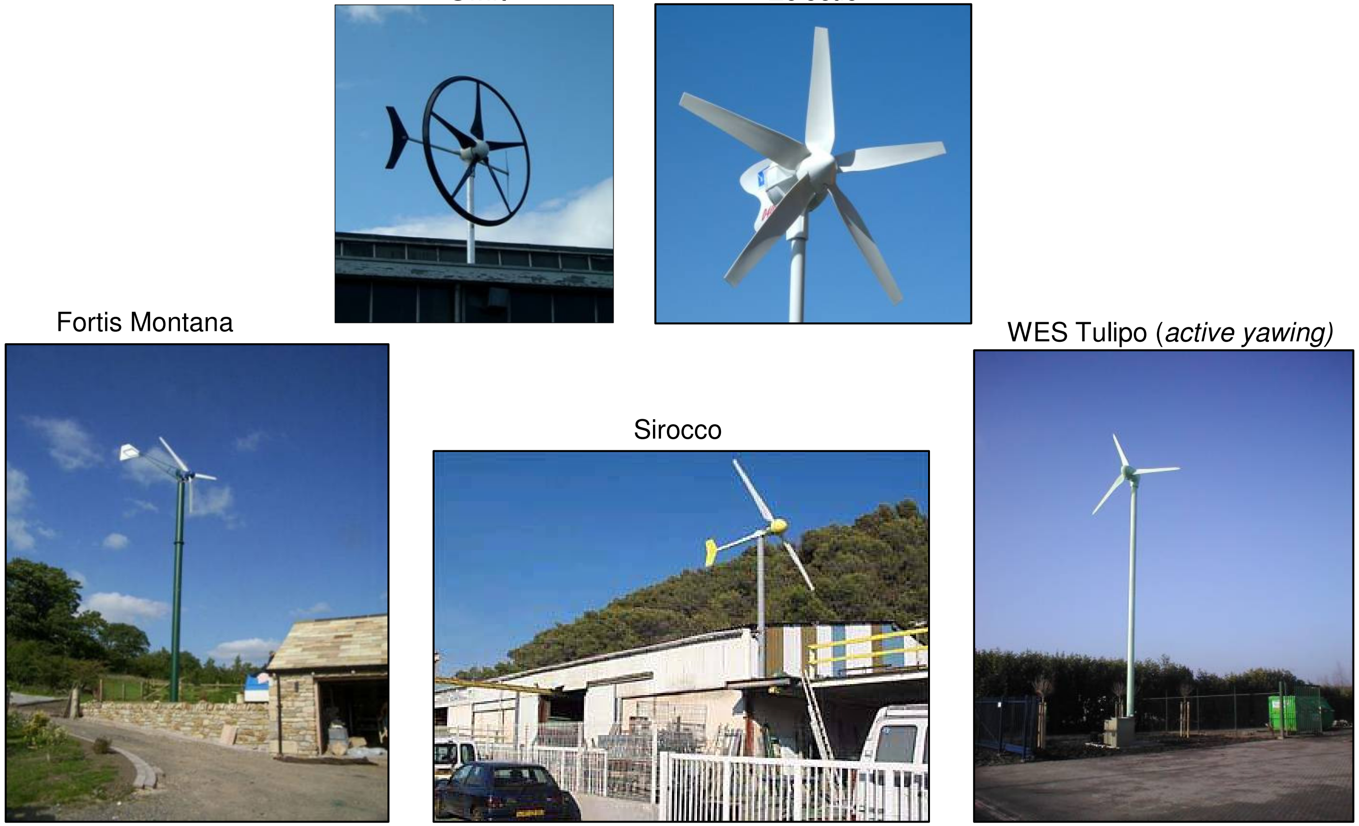

Figure 1: Some examples of HAWT

2.2 Vertical axis wind turbines (VAWTs)

Vertical axis wind turbines VAWTs are typically developed only for the urban deployment. Changes in wind direction have fewer negative effects on this type of turbine because it does not need to be positioned into the wind direction. However, the overall efficiency of these turbines in producing electricity is lower than HAWTs.

Historically, these turbines are categorised as Savonius or Darrieus types, according to the principle used to capture the wind flow. For the Savonius type, the wind pushes the blades, which implies that the rotation speed is always lower than the wind speed. Contrary to that, the shape of the rotor of the Darrieus type makes it possible for the rotor to spin faster than the wind speed.

Figures 2, 3 and 4 show three VAWT models: Turby, WindSide and Ropatec. The Turby and Ropatec models also utilise the upward wind flows which are present around large buildings.

Figure 2: Turby

Figure 3: WindSide

Figure 4: Ropatec

2.3 Some examples of other types of wind turbines

Figures 5 and 6 show the innovative horizontal axis turbines Energy Ball and WindWall. Energy Ball, also named Venturi, is a horizontal axis turbine with the tail but with an innovative rotor construction: six half-circular blades forming a spherical construction. WindWall is also a horizontal axis turbine, but the axis is fixed to the roof so that it can catch the wind from just one direction. Therefore it is suitable only for locations were the wind from one direction strongly prevails.

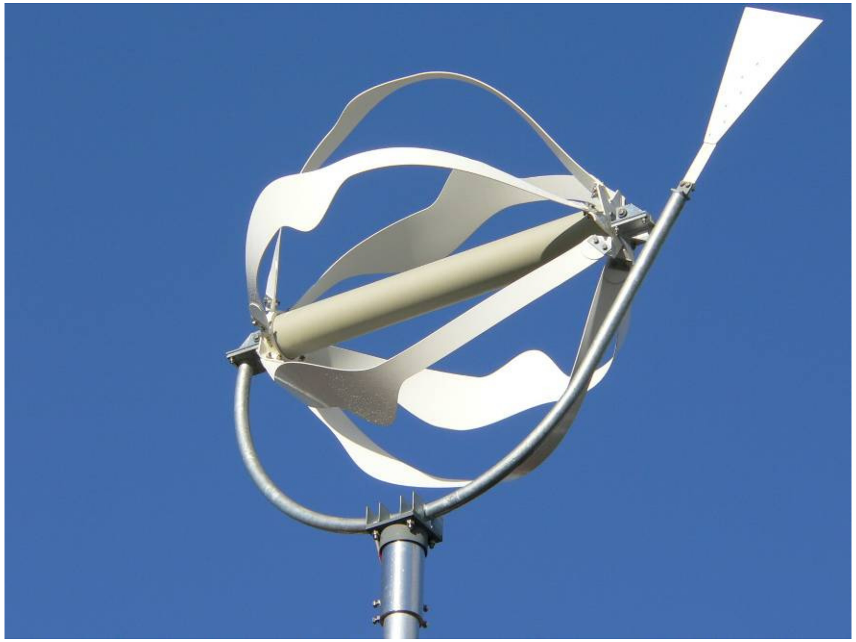

Figure 5: Energy Ball

Figure 6: WindWall

Because UWTs are available in many different shapes and sizes and each type of UWT operates best under different conditions, the choice of UWT model for a potential installation site should be studied carefully. For each type of location there will likely be at least one type of UWT that would best suit the conditions at that particular location.

3 Technical data

Table 2a: Technical data of different turbines available on the Dutch market, as provided by the turbine suppliers

Rated power	Fortis Montana		WES5 Tulipo		Turby		Energy Ball		Ropatec WRE030	
nominal power	2.7	kW	2.5	kW	1.9	kW	0.5	kW	3	kW
nominal wind speed	10	m/s	9	m/s	12	m/s	15	m/s	12	m/s
start wind speed	2.5	m/s	3	m/s	3.5	m/s	2	m/s	2.5	m/s
stop wind speed	n.a.	m/s	20	m/s	14	m/s	n.a.	m/s	n.a.	m/s
maximum wind speed allowed	60	m/s	35	m/s	55	m/s	>40	m/s	60	m/s
DIMENSIONS										
rotor weight	170	kg	200	kg	135	kg	30	kg	430	kg
rotor diameter	5	m	5	m	2	m	1.1	m	3.3	m
rotor surface	19.6	m^2	19.6	m^2	5.3	m^2	1	m^2	7.26	m^2
mast height	variable	m	12	m	variable	m	11	m	variable	m
OTHER DATA										
maximum rotation speed	450	rotations/min	140	rotations/min	420	rotations/min	803	rotations/min.	120	rotations/min
transmission	direct		gear box		direct		direct		direct	
safety	short circuit on generator		electro-magnetic brake, turning away from the wind		electro-magnetic brake		electro-magnetic brake		electro-magnetic or hydraulic brake	
number of blades	3		3		3		6		2	
material blades	glass epoxy		glass epoxy		carbon epoxy		glass polyester		RVS foam filled	
Voltage (AC)	230	V	400	V	230	V	100	V	230	V
minimum operating temperature	-30	°C	-20	°C	-20	°C	-25	-°C	-30	-°C
maximum operating temperature	50	°C	40	°C	40	°C	50	°C	80	°C
noise at 25 m distance with10 m/s	< 60	DB	35	DB	50	DB	none	DB	32	DB
life expectancy	20	Years	15	Years	20	Years	15	Years	20	Years
standards	IEC61400-2, IEC61400-22 NEN 1014, IEC 529		IEC61400-2, IEC61400-22 NEN 1014, IEC 529		IEC61400-2 NEN 1014				IEC61400-2, IEC61400-22 NEN 1014, IEC 525	
auto start	yes		yes		no, but automatic		yes		yes	
positioning	tail		yaw motor		n.a.		tail		n.a.	

Table 2b: Technical data of different turbines available in the United Kingdom, as provided by the turbine manufacturers

Rated power	**Proven WT6000**		**Iskra**		**Gazelle**		**Swift**		**Quiet Revolution**	
nominal power	6	kW	5	kW	20	kW	2.5	kW	6	kW
nominal wind speed	12	m/s	11	m/s	13	m/s	10.5	m/s	12.5	m/s
start wind speed	2.5	m/s	3	m/s	4	m/s	3.5	m/s	4	m/s
stop wind speed	n.a.	m/s	60	m/s	20	m/s	n.a.	m/s	16	m/s
maximum wind speed allowed	70	m/s	60	m/s	unknown	m/s	62	m/s	unknown	m/s
DIMENSIONS										
rotor weight	500	kg	280	kg	1600	kg	50	kg	unknown	kg
rotor diameter	5.5	m	5.4	m	11	m	2	m	3.1	m
rotor surface	23.76	m2	22.9	m2	95	m^2	3.14	m^2	15.5	m^2
mast height	9 or 15	m	12 to 30	m	13 to 20	m	5	m	5-10	m
OTHER DATA										
maximum rotation speed	200	rotations/min	200	rotations/min	106	rotations/min	unknown	rotations/min.	unknown	rotations/min
transmission	direct		direct		direct		direct		direct	
safety	mechanical break		electro-dynamic		unknown		unknown			
number of blades	3		3		3		3		2	
material blades	Glass thermoplastic composite		Composite fibre glass		Carbon fibre epoxy		Moulded carbon fibre		Carbon fibre	
Voltage (AC)	240	V	240	V	400	V	240	V	240	V
minimum operating temperature	-30	°C	-20	°C	unknown	°C	unknown	°C	unknown	-°C
maximum operating temperature	50	°C	50	°C	unknown	°C	unknown	°C	unknown	°C
noise at 25 m distance with 10 m/s	unknown	DB	unknown	DB	unknown	DB	unknown	DB	silent	DB
life expectancy	20-25	Years	20	Years	20-25	Years	20	Years	20	Years
standards	Working towards ISO9001 and IEC61400-2		none		IEC 1400-1 Class III		IEC 61400-2		none	
auto start	yes		yes		yes		yes		yes	
positioning	self-regulating		tail vane		free yaw		wind vane		n.a.	

4 Costs, benefits and efficiency of UWTs

4.1 Costs

Table 3: Costs for some turbine types, as provided by the suppliers (continued on the following page)

Investment	**Fortis Montana**	**WES Tulipo**	**Turby**	**Energy Ball**	**Ropatec WRE030**
	amount (€)	amount (€)	amount (€)	amount (€)	amount (€)
turbine	7,115	14,950	11,466	2,479	10,750
mast	2,660	included	2,000	840	2,490
inverter	3,850	included	included	450	included
other	375	included	600	71	345
transport	separately charged	separately charged	separately charged	separately charged	separately charged
installation, net connection	2,495	2,000	2,700	1,860	2,380
kWh-meter (grid feeding)	separately charged	separately charged	132	separately charged	separately charged
engineering	separately charged	separately charged	240	separately charged	separately charged
lightening safety	none	none	optional	none	optional
grounding	included	included	700	Included	optional
Investment total	16,495	16,950	17,838	5,700	15,965
Operational costs per year					
operational costs	none	none	none	none	none
maintenance	none	175	none	none	none
energy costs	none	none	none	none	none
insurance / year	none	optional	none	none	optional
Replacement costs					
Bearings (per year)	none	none	none	none	none
Inverter (once)	1,300	none	1,300	300	included
Revision after 10 years		1,300			
Warranty	5 years	1 year	2 years	2 years	3 years
Manual	Included	Included	Included	included	included
Remaining value	3,299	3,390	3,568	1,140	5,875
Costs €/kW	**4,887**	**5,424**	**7,511**	**9,120**	**3,363**

Table 3 continued

	Proven WT6000	Iskra
Investment	(€)	(€)
turbine	10,200	10,150
mast	2,800	3,480 to 4,930
inverter	3,000	3,000
other	500	included
transport	separately charged	separately charged
installation, net connection	1,280 to 5,000	5,500
kWh-meter (grid feeding)	270 to 500	270 to 500
engineering	separately charged	separately charged
lightening safety	separately charged	150
grounding	included	150
Total	18,050 to 22,000	22,700 to 24,380
Operational costs per year		
operational costs	none	none
maintenance	250	232
energy costs	none	none
insurance / year	none	none
Replacement costs		
Bearings (per year)	none	none
Inverter (once)	1,500	1,500
Revision after 10 years		
Warranty	2 years (extendable to 5 years on request)	2 years
Manual	included	included
Remaining value	3,610 to 4,400	4,540 to 4,876
Costs €/kW	**2,407 to 2,933**	**3,632 to 3,900**

Remarks on Table 3:

Fortis Windenergy, CFC Ropatec and Proven offer different size models. In order not to overload this table we have presented one turbine per supplier/manufacturer. The Internet sites of all suppliers/manufacturers are listed in Table 6.

4.1.1 Investment

These costs consist of: complete UWT installation including the engineering, safety measures, monitoring, supporting construction, transport and mounting, proof of operation (commissioning) and the acceptance. Likely additional costs will arise from: feasibility studies, location selection, structural assessments (if mounting the turbine on a building), obtaining permits and project management. In order to at least partially compare the investment costs of the different turbines, the cost per kW installed has been calculated. The figure provided is the result of: (total investment - remaining value after 10 years) / nominal capacity. The remaining value has been estimated as 20% of the investment for all turbines except for Ropatec. This is because the manufacturer of Ropatec guarantees to buy back his turbine after ten years for a fixed price. However, it should be noted that all costs are estimates at the time of publication and could change. Also, all calculations are only indicative, as the separately charged costs cannot be estimated and the performance figures provided by the suppliers and manufacturers have not been verified in practice. Therefore, although these figures provide a rough guide to costs, further investigation on an individual project basis is necessary.

4.1.2 Periodic costs

The periodic costs include maintenance, part replacements, transport costs related to the on-site work, the possible insurance costs (including the third party damage liability), the costs of any equipment replacements and the cost of a complete check of the system after 10 years of operation. Again, these costs have been estimated on the basis of information from suppliers and manufacturers and should be treated as indicative costs only.

4.2 Benefits

4.2.1 Financial incentives

The financial incentives available differ between the Netherlands and the UK.

The Netherlands: E.I.A. – Energy Investment Deduction for profit-making organisations: it is possible to obtain the E.I.A. with a maximum of € 5000 per turbine for turbines with a nominal power < 25 kW.

M.E.P. – Electricity Generation Environmental Quality: applies to the total energy generated by a renewable energy installation. The level of the M.E.P. subsidy per kWh is set by the government and laid out in the Ministerial grant scheme regulation.

UK: A grant can be obtained from the Low Carbon Building Programme (LCBP) in the UK, to cover up to 50% of the installation cost.

Some provinces and municipalities provide additional subsidies as a part of their own renewable energy development programmes. Most commonly these subsidies are a part of local measures against climate change and are usually reconsidered yearly.

4.2.2 Savings through using of the generated electricity

Using the electricity generated at the location means direct savings for the owner through a lower electricity consumption bill. The savings depend on the price paid to the electricity supplier by the consumer for electricity supplied from the grid. For example, the customers of the supplier ENECO in The Netherlands pay approximately 21 €cents/kWh. In the UK, typical cost of electricity for flats and households can range from 11p to 16p/kWh. These prices depend very much on the time during the day (or night) when the electricity is used.

4.2.3 Selling to the grid

If there is a surplus of electricity generated from a small wind turbine, in theory it can be sold and the owner decides to whom. Most commonly it would be sold to an electricity supply company. The price can differ considerably from one electricity company to another, so it is worth investigating several options. For example, in the Netherlands, ENECO pays 4.088 €cents/kWh excluding VAT (2007). The electricity supplier Green Choice gives discount on the supplied electricity to his customers who feed their energy surplus into the grid. Selling electricity to the grid is regulated differently in each country. If the owner of a UWT wants to sell his electricity to the grid, (s)he may need to have a specific type of meter that measures both ways: the electricity sold to the grid and the electricity consumed from the grid. This type of meter is readily available but is not installed as standard and so may need to be installed as part of the wind turbine installation.

4.3 Efficiency of UWTs

The efficiency of wind turbines is most commonly measured in terms of cost-effectiveness, i.e. in cost per kWh of the produced electricity. In a technical context in order to determine the revenue generating potential, the efficiency would be measured as a yield, measured as the number of kilowatt-hours produced per square meter of rotor area per year (kWh/m^2/yr).

At this moment there are insufficient yield figures for UWTs from real projects to draw definitive conclusions on efficiency. This means that the efficiency can only be estimated and that the comparisons between various types of UWTs cannot be done reliably. Nevertheless, an indicative comparison is provided in Tables 4 and 5 by using the “reference yield” from the manufacturer calculated at two specific wind speeds namely:

- 12 m/s: a figure close to the nominal wind speeds of most UWTs
- 5.5 m/s: a good average wind speed for operation of the investigated UWTs

Table 4: Reference figures using a wind speed of 12 m/s

	v wind ref	v wind nom	P nom	P ref	A	P ref spec
	m/s	m/s	kW	kW	m2	kW/m2
Montana	12	10	2,7	4,67	19,60	0,24
WES[5] Tulipo	12	9	2,5	5,93	19,60	0,30
Turby	12	12	1,9	1,90	5,30	0,36
Energy Ball	12	15	0,5	0,26	1,00	0,26
Ropatec	12	12	2,5	2,50	7,26	0,34

Table 5: Reference figures using a wind speed of 5.5 m/s

	v wind ref	v wind nom	P nom	P ref	A	P ref spec
	m/s	m/s	kW	kW	m2	kW/m2
Montana	5,5	10	2,7	0,45	19,60	0,02
WES[5] Tulipo	5,5	9	2,5	0,57	19,60	0,03
Turby	5,5	12	1,9	0,18	5,30	0,03
Energy Ball	5,5	15	0,5	0,02	1,00	0,02
Ropatec	5,5	12	2,5	0,24	7,26	0,03

Explanation:

A = rotor area

V_{nom}, P_{nom} en A have been provided by the vendors (see table 2). P_{ref} is the result of the formula: $P_{ref}=(v_{ref}/v_{nom})^3 \times P_{nom}$

4.3.1 Comparison with large turbines

The initial (capital) investment per kW can vary greatly between different UWTs: according to the information provided by suppliers and manufacturers it can be between 2,400 and 9,100 €/kW. In comparison, the initial investments for large turbines are about 1000 €/kW for land installations and about 2000 €/kW for off-shore (investments in solar photovoltaic (PV) systems are approximately 6,200 €/kWp installed).

The expected yield, assuming there is an average wind speed of 5.5 m/s, would very approximately amount to 150 - 400 kWh/m^2/year. The yield of large turbines varies between 800 and 1200 kWh/m^2/year.

The figures indicate that large turbines clearly outperform UWTs and this is not surprising, as the conditions under which they are implemented are very different. However, UWTs are still in a development phase and although it is unlikely that they will ever reach the yields of large wind turbines (since wind resources are not the same in urban environments) it can be expected that costs will fall and the efficiency of UWTs will be significantly improved. Manufacturers of UWTs in the Netherlands and the UK expect a price reduction of about 40% by a ramped-up production of at least 500 turbines per year.

Finally, UWTs generate electricity that can be directly consumed at the site of generation. This means that the produced electricity is effectively being used against the consumer price which is approximately 5 times higher than the price paid for the electricity produced by large turbines.

Considering the installation capacity, costs and the expected yield, it is better to compare the UWTs with solar PV production of electricity. A detailed comparison between PV installations and UWTs is available on the WINEUR web site: www.urbanwind.org.

5 Suppliers and manufacturers

There are 14 UWT suppliers active in The Netherlands. Eight suppliers are also the manufacturers of their products while the others are importing foreign UWTs. The importation of UWTs is a recent phenomenon on the Dutch market. In the UK there are more than 13 manufacturers and many suppliers of both UK and imported wind turbines. The Dutch suppliers / manufacturers are presented in Table 6a, while a list of the principle manufacturers in the UK is given in Table 6b.

Table 6a: UWT suppliers in The Netherlands

Supplier	Location	Web page	Telephone	E-mail
Turby b.v.	Lochem	www.turby.nl	+31(0)573 256358	ds@turby.nl
WES b.v.	Zijdewind	www.windenergysolutions.nl	+31(0)226 425150	info@windenergysolutions.nl
Fortis Wind Energy	Haren	www.fortiswindenergy.com	+31(0)505 340104	fortis-windenergy@wxs.nl
Venturi Wind Turbines	Deventer	www.venturiwind.com	+31(0)570 510246	info@venturiwind.com
HomeEnergy	Schoondijke	www.homeenergy.nl	+31(0)23 5580022	info@homeenergy.nl
CFC Energy&Environment	Delft	www.cfc-flowcontrol.nl	+31(0)15 2682635	info@cfc-flowcontrol.nl
The Wind Factory International	Amsterdam ZO	www.thewindfactory.com	+31(0)20 3422137	info@thewindfactory.com
SET	Nuenen	www.set.nl	+31(0)492 523008	wim@set.nl
Eco-Energy	Spaarndam	www.eco-energy.nl	+31(0)23 5371470	info@rietpol.nl
Prowin	Nijmegen	www.prowin.nl	+31(0)6 41470070	kees@vhcon.nl
Tulipower	Amsterdam	www.tulipower.nl	+31(0)6 19618369	hd@tulipower.nl
H-energiesystemen b.v.	Swifterbant	www.h-energiesystemen.com	+31(0)32 322599	info@h-energiesystemen.com
PyroSolar Projects	Dodewaard	http://www.pyrosolar.nl	+31(0)488 452496	info@pyrosolar.com
Technisch Centrum Noord Holland	Breezand	http://www.tcnh.nl	+31(0)223 521122	info@tcnh.nl

Note:

Research and development: Ecofys and Haagse Hogeschool are separately developing new types of UWTs. No specific information about the market availability of these models has as yet been announced.

Table 6b: UWT manufacturers in the UK

Manufacturer	Location	Web page	Telephone	E-mail
Ampair	Ringwood	www.ampair.com	+44 (0) 1425 480 780	info@ampair.com
Eclectic Energy	Edwinstowe	www.eclectic-energy.co.uk	+44 (0) 162 382 15 35	sales@duogen.co.uk
Eurowind	Newhaven	www.eurowind-uk.net	+44 (0) 12 73 61 23 83	info@eurowind-uk.net
Gazelle	Ryton	www.mkw.co.uk	+44 (0) 191 413 00 12	KChaplin-Gazelle@mkw.co.uk
Iskra	Nottingham	www.iskrawind.com	+44 (0) 115 841 32 83	enquiries@iskrawind.com
Marlec	Corby	www.marlec.co.uk	+44 (0) 1536 201 588	sales@marlec.co.uk
Proven	Stewarton	www.provenenergy.com	+44 (0) 1560 485 570	info@provenenergy.com
Renewable Devices Swift	Edinburg	www.renewabledevices.com	+44 (0) 131 535 33 01	enquiries@renewabledevices.com
Rugged Renewables	Gateshead	-	+44 (0) 191 478 51 11	-
Samrey	-	www.samrey.co.uk	-	info@samrey.co.uk
Winddam	Truro	-	+44 (0) 180 387 39 56	winddam@btinternet.com
Windsave	Glasgow	www.windsave.com	+44 (0) 141 353 68 41	info@windsave.com
XCO2	London	www.quietrevolution.co.uk	+44 (0) 207 700 1000	info@quietrevolution.co.uk

6 Projects

6.1 Installed turbines

At the moment of the writing of this report, the WINEUR project has counted 56 UWTs installed in the Netherlands and an estimated 120 UWTs have been installed in the UK. The majority of these have been single turbine installations. France has very few UWTs in operation but recently 3 feasibility studies with wind measurements were conducted in Lyon, Grenoble and Lille. Figure 7 shows the monitoring site in Grenoble.

Table 7: UWT locations per supplier in The Netherlands

Turby	
Customer	***Place***
Imkerij Poppendamme	Grijpskerke
Stadhuis	Den Haag
TUD	Delft
Bos en Lommer	Amsterdam
Milieudienst	Groningen
Duits Engineering	Zutphen
Stadhuis	Hoofddorp
Stadhuis	Almelo
Saxion College	Enschede
Bachflat	Tilburg
Wonen Breburg	Breda
Provinciehuis	Zwolle
Wintershall	IJmuiden
Flevohuis, Zeeburg*	Amsterdam
Stadhuis	Leeuwarden
Gasunie Research	Groningen
Boerenbedrijf Attema	Ferwoude
Flevoland rotonde	Lelystad
Promenade kantoren	Almere
Saltoschool	Eindhoven

Energy ball	
Customer	***Place***
Piushaven	Tilburg
Provincie Groningen	Strobos

Fortis Windenergy	
Customer	***Place***
Peter Broekmeulen	Dieren
Pilkes Verlichting BV	Stompetoren
Henk Berends	Sebaldeburen
J.Brak	Petten
W.H.van de Heuvel	Hoogland
Slendebroek	Hoogkerk
Animal Science, WUR	Raalte
Wiertsema en Partners	Tolbert
P.Itserda	Wapserveen
Camping "De Noorman"	Cadzand
MEA	Dronrijp
Minicmamping 't Sluisje	Hoek
GreenPeace	Amsterdam
Minicamping Het Peelvenneke	Zeeland
Gemeente Assen	Assen
De With	Lutjegast
v Veen Transport	Assen

WindSide	
Customer	***Place***
Eolus	Sexbierum
woonboot	Amsterdam

Provane	Zuidwolde
Turbojet	Zweeloo
H-energysystemen	Wirdum

WES[5] Tulipo	
Customer	***Place***
Mainwind B.V.	Zevenbergen
Renema	Gaastmeer
Huisman Elektrotechniek	Elst
Gemeentewerf	Waddinxveen

WindWall	
Customer	***Place***
Deltion College	Zwolle
AMC Erasmus	Rotterdam
HTM	Den Haag
Siemens	Den Haag
kantoorgebouw	Scheveningen
Hotel Het hoge duin	Wijk aan Zee
Stadsdeelwerf	Amsterdam O-Watergraafsmeer

CFC Ropatec	
Customer	***Place***
AEH	Kesseleik
Energy Point gebouw*	Rotterdam
Altran*	Zeeland
Indusriegebied*	Geleen
Now&Wow*	Rotterdam

*waiting for a building permit

6.2 On-going projects

6.2.1 Project 'Voor de wind gaan'

In 2004 the three northern provinces of the Netherlands: Groningen, Friesland en Drenthe initiated the 'Voor de wind gaan' project to investigate in practice the future viability of different types of UWTs. The project was subsidized by the national DEN-programme of SenterNovem (Dutch Governmental Agency of the Ministry of Economic Affairs charged with implementation of technology policy measures). The research organisations KNN Milieu and 'Van Hall Instituut' are monitoring the progress.

The mission of the project is summarised as: "Where and under which circumstances one should expect the optimal performance of the investigated turbines in respect to: return-on-investment, applicability, safety and aesthetic impact?" A special attention is given to governance and legal aspects in relation to the participating municipalities.

The intention has been to place 22 turbines from 6 different manufacturers in three types of environment: countryside, industrial areas and residential areas. Due to long processes to obtain permits, the deployment has taken longer than planned. In order to ensure enough time for research and analysis it has been decided to end the deployments in January 2007. The adjusted planning assumes the installation of 15 turbines. Despite this reduction in installations, the project is considered very important for the UWT market in the Netherlands as it will provide verifiable results regarding the actual performance of UWTs available on the Dutch market.

Table 8: Turbines installed within the project 'Voor de wind gaan' by September 2006

	Customer	Location	Place	Turbine type
1	J. Slendebroek	Aduarderdiepsterweg	Hoogkerk	Fortis Montana
2	Milieudienst Groningen	Duinkerkenstraat	Groningen	Turby
3	Gasunie	Energieweg	Groningen	Turby
4	Wiertsema&Partners	Fietspark	Tolbert	Fortis Montana
5	Venhuizen	Eekerdermeedenweg	Wirdum	H-energiesystemen ES 800
6	MEA adviesbureau	De Alde Mar	Dronrijp	Fortis Alyze
7	Gemeente Leeuwarden	Oldehoofsterkerkhof	Leeuwarden	Turby
8	W. Attema	Doniabuorren	Ferwoude	Turby
9	Aeolus Vaartjes	Hearewei	Sexbierum	WindSide
10	Gemeente Assen	Mileiudienst	Assen	Fortis Montana
11	Gemeente Coevorden	Gemeentewerf	Zweeloo	Turbojet
12	Gemeente de Wolden	Hoofdstraat	Zuidwolde	Provane
13	Van Veen Transport	Wenkebachstraat	Assen	Fortis Montana

The contacts for the project 'Voor de wind gaan' are: Werna Udding, w.udding@provinciegroningen.nl and Desmond de Vries, ddeveries@provinciegroningen.nl .

6.2.2 Pilot project Duurzaame Driehoek, Brabant

The project “Duurzame Driehoek” (“Sustainable Triangle”) is a joint effort of 11 municipalities situated in a triangle between the cities Den Bosch, Tilburg and Eindhoven in the province of Brabant, Netherlands. As a part of the project, the municipalities Den Bosch, Tilburg, Eindhoven and Boxtel have signed an agreement to place seven (7) small wind turbines on different buildings. The objective is to gain insight in practical aspects of deploying UWTs and produce a fact-based list of pro’s and con’s of UWTs. Initially, the project had decided to place WindWall turbines on 5 (out of 7) locations. After the manufacturer was declared bankrupt in 2006, the project suffered substantial postponements. More delays were caused by needed changes regarding the building heights in the destination plans. Only two turbines were placed by the end of 2006. The contact person for this project is Ruud van Rijn: ruud@boschenvanrijn.nl.

6.2.3 Local authority projects in the UK

In the UK many local authorities and city councils are showing a strong interest in UWTs. Of these, some have completed or are planning pilot UWT projects. For example, Kirklees Metropolitan Council in Yorkshire has installed two 6 kW Proven wind turbines on the flat roof of one of its office buildings, Civic Centre 3, situated in Huddersfield city centre. Figure 8 shows the wind turbines on the roof of Civic Centre 3. Kirklees Council have also installed a 15kW Proven turbine in the ground at the Deighton Centre, also in Huddersfield. Some other local authorities which are planning UWT projects in the near future are Sheffield City Council, Harrogate City Council and Basingstoke and Deane Borough Council.

Figure 7: UWT installation at Equihen-Plage

Figure 8: Wind turbines installed on the roof of Civic Centre 3 in Huddersfield

6.3 Projects in preparation

6.3.1 Technical monitoring, Province Zeeland

In the Netherlands, the utility energy company DELTA together with the province of Zeeland, the Wind Corporation Zeeuwind and the municipality of Sluis have initiated a pilot project with the objective of comparing the yield and the noise production of UWTs. Eleven (11) different UWTs will be installed in the industrial area of Technopark Zeeland in Schoondijke, Netherlands. The deployed turbines will be monitored for two years.

The required permits were obtained in November 2006. The negotiations with the turbine suppliers are ongoing. The costs are entirely covered by the four project partners. The suppliers have to provide the turbine for free but will be fully compensated for all installation and de-commissioning costs. The suppliers will also be paid for the electricity produced during the project. The contact person for this project is Sjaak Vogel: JVogel@delta.nl .

6.3.2 Warwick Microwind trial project

This is an open-access project to provide independent and objective data on the performance of rooftop wind turbines on real sites in the UK. During 2006-2008 the project aims to evaluate the contribution rooftop-mounted wind turbines may make to improve the energy performance of existing homes in the UK. This project has been initiated and is led by Encraft and is funded by the Pilkington Energy Efficiency Trust, Warwick District Council, and participating homeowners. The project is also supported by the Department of Trade and Industry of the UK (DTI), the British Wind Energy Association (BWEA), Warwickshire County Council, Action 21 and the Micropower Council.

This project will monitor 10 rooftop wind installations on a variety of urban and rural sites over 12 months, starting in early 2007. In addition, public opinion surveys will be conducted before and after the project to establish whether the installations have any impact on attitudes to energy efficiency and climate change. The aim is to collect and publish objective data on performance when the systems are used by real families and homeowners. We will also explore how easy it is to get systems installed on houses and what the barriers and real costs are. Most importantly, we aim to discover what impact installing these systems has on awareness of energy efficiency in the households with the systems and amongst members of the local community.

An interim report on the project's progress will be published in early 2007, largely covering the experiences of securing supplies of the systems, working through planning, and getting installations completed. This report will also contain detailed analysis of the initial feedback and results of the first public opinion survey. The final report, published in early 2008, will contain technical data from the monitoring trials, including energy generated and actual wind speed data for the monitored sites. Further information and the published reports are available at http://www.warwickwindtrials.org.uk/index.html .

6.3.3 Installation of 30-50 UWTs in the city of The Hague

The city of The Hague has initiated the placement of 30 to 50 UWTs in the city in cooperation with other actors. The city has reserved € 200.000 for the year 2007 for this purpose. The municipal councillor in charge of environmental issues has stated that the UWTs are "attractively designed and appropriate for siting in prominent places in the city like roundabouts, road junctions and tall buildings".

This initiative is part of the climate change policy of the city. The current plans are that The Hague will fully contribute to the country-wide Kyoto obligation of reducing CO_2 emissions by at least 6% by the year 2010. In addition, the city council decided that the municipal services would become CO_2 neutral in 2020. More information is available at: www.denhaag.nl/smartsite.html?id=50477 .

6.4 Some research activities

A number of high schools and universities in the Netherlands have conducted research activities concerning UWTs. The ongoing research of TU Delft focuses on technical issues like: wind potential in urban areas, wind flows around buildings, efficiency and the optimisation of UWTs.

In the UK, Loughborough and Reading University have carried out research on small wind turbines. Bath University has on-going PhD research on UWTs and Nottingham and Durham Universities have been involved in testing small wind turbine models.

In the Spanish research centre CIEMAT (Energy, Environment and Technology Research Centre), European research on UWTs has been taking place since 2005. The research is conducted on all aspects of UWTs such as: safety, durability, yield and noise. The certification issue is also being addressed. The provisional conclusions of CIEMAT's work, as presented in February 2006 at the European Wind Energy Conference in Athens are:

- There are identified markets for UWTs as much in urban areas as in remote locations;
- The technology is underdeveloped (high costs and low efficiency); and
- Political and financial support is necessary.

The leading Dutch technical university TU Delft is also involved in this research; more information is available via Gerard van Bussel: J.W.vanBussel@TUDelft.nl

6.4.1 Some available reports in the Netherlands

A number of reports have been published on UWT projects in the Netherlands:

- The PhD research of Sander Mertens at TU Delft looks at the energy production of small turbines in urban areas through the effect of buildings on wind flows. The results are published in the report: 'Wind energy in the built environment', 2006, ISBN 0906522 358. More information available via the author at: sander.mertens@dhv.nl .
- As a part of the WINEUR project, Energiebureau ARC from Amsterdam have completed a study on problems with deploying UWTs, based on five projects in Amsterdam. The study was conducted by Anne Elsen Mileuadvies and describes the preparation phase of the projects: the approach, problems and possible solutions. The recommendations of the study include simplification of the permit process, the inclusion of the UWTs in the urban design plans and the development of incentive policies. The study report is freely available via the author: anne@elsenmilieuadvies.nl .
- During the preparation phase of the project 'Voor de wind gaan', a study concerning the permit processes was conducted by Marcel Logtenberg (graduation report at "Hoge School Windesheim"). This research involved about ten locations in different municipalities and focused on the questions:
  1. What are the biggest problems regarding the procedure for obtaining a permit to install a UWT?
  2. What can be done to speed up the process?

  The most important recommendation from this research is to deploy the UWTs preferably in industrial zones and to remove the permit procedure for these locations altogether. This would be possible within the existing legislation by characterising the UWTs as a 'permit free and light building permit objects'. The report has been published by the research organization "KNN Milieu". More information with C. Kamminga, KNN Milieu: k.j.kamminga@knnmilieu.nl.

- The Master thesis of Kristel Meijers “Mini turbines in beweging” (“Mini turbines in movement”) in 2005 brings together all significant factors that influence the government policies towards UWTs.
- In order to avert the potential problems expected with the pilot project regarding installation of 11 UWTs, the Province of Zeeland has developed the necessary strategic policies (published as a report with the name ‘De beleidsvisie kleine windturbines’). Different aspects regarding the deployment of wind turbines are elaborated and new permit procedures regarding the UWTs have been formulated. More information via DELTA: JVogel@delta.nl.
- The University of The Hague, “Haagse Hoogeschool”, has prototyped equipment to measure the wind speed on the top of roofs. This equipment is currently being tested. More information with Elze de Vries: vre@thrijswijk.nl .
- The city of Haarlem investigated the legal possibilities of permit-free placement of wind turbines with a rotor diameter smaller than 2 meters. This initiative has was found to conflict with the existing legislation and was therefore abandoned. More information is available via T.G. Elfrink (tgelfrink@haarlem.nl).

6.4.2 Identified bottlenecks

Different studies and ongoing projects have identified a number of bottlenecks regarding the development and installation of UWTs. In this paragraph, the bottlenecks have been clustered around a few important aspects, namely: turbine technologies, projects, costs, attitudes and permits.

Turbine technologies

- The innovative turbine models designed for the urban environment are still maturing: based on practical experience the turbines are being improved aiming at better efficiency, less noise and improved safety.
- Some turbines are of inferior quality (inferior materials used, poor welding).
- There is very little independent information about UWTs. The majority of information comes from the suppliers/manufacturers and has not been verified.
- There are no norms and standards for the technical quality of UWT and especially VAWT.

Projects

- UWTs are too often placed at unsuitable locations (too low and/or behind an obstacle).
- National governments are not doing enough to support the installation of UWTs. This makes further development of the UWT market fragmented and uncoordinated and there is little common ground for exchange of “lessons learned”. The absence of the government support also increases project risks.
- It is quite complex to determine the optimal location for UWTs. A simple tool to assist developers needs to be created.
- The electricity yield shows large variation depending on location and turbine model.
- There have been negative experiences: noise, vibration, unexpected faults, and damage by stormy weather (broken blades). In one case a turbine had to be stopped over night due to noise levels and also during sunny days because of flicker.
- UWT projects are typically progressing slower than planned; every new location has specific needs and requires customised implementation.

Costs

- The investment costs are too high, especially compared to the benefits.
- The administrative expenses regarding permits are high and out of proportion compared to the investment for equipment and installation. The administrative costs are sometimes responsible for as much as the half of the total investment.
- The indirect costs such as the cost of feasibility studies, structural surveys and site surveys have a significant share within the project costs.

Permits

- Obtaining permits for UWTs is complex, takes too long and is different in each municipality or local authority. Because UWTs are not standardised or certified, each permit request needs to be separately assessed and sometimes external experts have to be used, which is expensive and costs time.
- The requests for permits are often incomplete due to lack of information or good communication channels.
- There are no guidelines for the structural or architectural integration of UWTs.

Attitudes

- The noise specifications provided by the suppliers / manufacturers are sometimes too optimistic and need to be independently verified as noise is a very sensitive issue for neighbours.
- Practically all suppliers / manufacturers are too optimistic when specifying the expected electricity yield, if this continues it will lead to more and more disappointed consumers and an unsustainable market.
- In urban environments there is a reluctance to accept UWTs due to fears about sun reflection and shadows from blades (flicker), noise, safety concerns related to possible incidents (broken blades) and deterioration of property value in the neighbourhood.
- The communication among the different parties involved appears difficult: the views on UWTs and the knowledge levels differ strongly.

Figure 9: H-energy turbine

7 Why UWTs in urban areas?

UWTs are suitable for small scale energy generation at locations where there is no space for large turbines. Therefore UWTs should not be seen as alternative to large turbines but as a complementary technology. The generated electricity can be used at the site of installation and the owner of the building can use this as publicity for a 'green image'. In the Netherlands and the UK, UWTs are also being seen as complementing solar PV energy as wind is commonly associated with cloudy weather and less sun.

Figure 10: Tulipo, Hannover Messe

The following is a brief summary of motivations for installing UWTs:

- CO_2 savings;
- Green electricity generation;
- Meeting the requirements regarding energy saving and renewable energy appliances (EPC, EPBD);
- Preventing energy transport losses from large power plants to the consumer;
- Stimulate change of attitude: individual energy producers are typically more energy efficiency aware;
- Saving of fossil fuel resources;
- A visible "green" image for marketing purposes and emphasis on socially involved entrepreneurship;
- Role model function: a government organisation leads by example to encourage businesses;
- Savings on energy costs;
- Less concerns regarding rising energy prices;
- Less dependency on energy utility companies;
- Development of export product.

8 Case Study: State of the UWT market in The Netherlands

The Dutch UWT market started with the article "Wind in de wijk" ("Wind in a city district") in the magazine "Duurzame Energie" ("Sustainable Energy") and at the World Expo in 2000 (Hanover Messe) where the Tulipo, a small turbine from Lagerweij, was exhibited on the roof of the Dutch pavilion. The tremendous interest in UWTs inspired several innovators to start the development of new, conceptually different wind turbines targeting built environments. Turby, Energy Ball and WindWall are the examples of these efforts.

The design and technology of the majority of urban wind turbines is not yet mature and has not been proven in practice. The implemented projects with Turby and WindWall have shown that there is a lot of room for technical improvements. The current efforts by Turby are focused on performance improvement. Energy Ball has undergone a complete redesign targeting performance improvements and industrial production. WindWall was declared bankrupt in 2006 due to a variety of different problems, not all of them technical.

In the past years, the Ropatec turbine has been used under various conditions and on different locations and can be considered mature.

A number of small three-blade horizontal axis wind turbines have been manufactured in The Netherlands for over 20 years and the technology is considered mature. Yet there are significant quality differences between the products. The project 'Voor de wind gaan' has provided insights into these facts.

8.1 Position of the Dutch government

National strategies and policies supporting UWTs have not yet been developed; therefore there is neither a target to achieve nor are there incentives in place. This is a consequence of the following views held by the government at present:

- The energy potential of UWTs is of no significance to the national renewable energy and CO_2 emissions targets;
- UWTs are too expensive and there are no indications that these turbines could compete with fossil fuels without being substantially supported;
- Certification is the responsibility of the manufacturers.

8.2 Position of market actors

The suppliers and manufacturers of UWTs disagree with this position of the government. Their point of view can be summarised as follows:

- UWTs have the potential to contribute to electricity generation in built environments. Therefore it is of importance to pursue the development of new solutions and initiate demonstration and pilot projects, in order to verify the claims of the emerging UWT technologies. To achieve a level playing field in relation to other renewable energy sources, it is necessary that the government initiates and financially supports the needed development programmes;
- Commercially competitive prices are possible, on the condition that sound and simplified regulations are implemented and industrial production starts to take place;
- Whatever the perceived overall energy potential of UWTs, the government should still provide the needed laws and guidelines and support the development of related norms and certification standards;
- In terms of location, energy yield and the costs, UWTs are comparable with solar electricity generation (PV). This similarity should be respected when defining the incentives for renewable energy sources, i.e. incentives given for solar PV should also be available for UWTs;
- The government has the responsibility to simplify the process of obtaining installation permits and to exempt the UWTs from disproportional administrative costs or simply the administration so the cost is more reasonable.

8.3 Potential

The UWT projects undertaken so far show that local authorities, owners of offices and residential buildings, energy suppliers, public institutions, commercial firms and house owners are showing considerable interest in UWTs. For all these actors a primary condition for installation of UWTs are the highest safety and reliability requirements, while most of the potential buyers are willing to accept a return of investment within 10 years.

Calculating the energy potential is apparently a very complex endeavour and the results vary significantly, depending on the method used. Since 2000, different studies have been conducted to estimate the energy potential of UWTs for The Netherlands. The estimates for 2020 vary between 60 MW (source: Has Koning, a Dutch independent consultancy firm) and 517 MW (source: NGUp, a rotor blades manufacturer from The Netherlands). The research report of Mark Koehorst conducted for Ecofys as a graduation study at TU Delft concluded that there are approximately 40,000 roof mounting locations in The Netherlands. The research of TU Delft (S. Mertens, ‘Wind energy in the built environment’, 2006) theoretically implies a significant energy potential in built environments.

A study of the potential of UWT was also conducted as part of the WINEUR project. Calculations were based on an 'average' UWT with a rotor area of 10 m^2 and a nominal power of 2.5 kW. The study resulted in an expected market potential between 116 en 1,161 MW in 2040. Different levels of penetration for UWTs for different environments in both coastal regions and inland were considered in the calculations. The results are summarised in Table 9 below. To realise this potential the government must support research and development as well as pilot projects and market development for a period of approximately 12 years.

The complete study can be found on: www.urbanwind.org.

Table 9: Market potential for UWT in the Netherlands

Market potential for UWT in the Netherlands	***Coastal region***		***Inland***		***Total***	
	low	high	low	high	low	high
Rotor area (m^2)	231.929	1.990.936	231.446	2.653.023	463.375	4.643.959
Amount of UWTs	23.193	199.094	23.145	265.302	46.338	464.396
Electric power (MW)**	58	498	58	663	116	1.161
Electricity generation* (GWh/year)	93	796	35	398	128	1.194
Share in the total energy demand in the Netherlands*** (%)	0,013	0,115	0,005	0,057	0,018	0,172

*1 GWh = 1 million kWh
**based on 2.5 kW per UWT
*** the total energy demand is estimated as 2500 PJ/year

8.4 Certification

Small wind turbines are placed on and near to buildings. This implies high safety risks if the turbine gets damaged for whatever reason. These risks can be avoided only if the turbine complies with specific safety and quality requirements. A certification scheme is needed to ensure that the requirements have been matched. The certification scheme should include durability tests and quality verification. Throughout the durability test all significant parameters of the turbine operation should be tested under field conditions.

A complete certification may only be conducted by accredited institutions and is expensive. The most well known certification authorities are the Danish DNV (Det Noorske Veritas) and the German GL (Germanischer Lloyd). The Dutch institute ECN has been involved in the certification process of large turbines in the past. The certification criteria for large turbines with its protocols and standards have been agreed upon internationally. However, the same process has not yet been fully developed for small wind turbines, largely due to the cost involved.

The current status of certification criteria for small turbines are as follows:

- In 2006 the technical quality norm for HAWT was introduced: IEC 61400-2;
- The norms for the technical quality of VAWT and other turbines are lacking;
- There are some technical norms regarding the construction integration (Dutch national group of norms NEN6700). These norms contradict the HAWT norm IEC 61400-2 on essential points, such as dynamic load;
- There are no specific UWT norms for the noise production, power quality and certification (safety and dynamic behaviour).

A certificate proves that the turbine is safe and that the quality and durability guarantees are in place. The installation permits for certified turbines could be granted much more easily if a certification system for both the products and the installers was in place, as the certificates limit accountability and simplify safety controls.

The physical integration of UWTs onto buildings is a complex undertaking, very much dependent on various local conditions. It would be opportune, given the interest in building-mounted wind turbines to produce specific guidelines for safe installation of UWTs on building rooftops. These would have their basis in existing structural assessments and construction norms and guidelines. When UWTs complied with these building-integration guidelines, granting of the permit could be reduced to a minimum, simplifying the process and saving time and money.

The agreements concerning norms and certification should be made at the international (IEC) level, although at first a start can also be made at the national level as this will be faster. It takes approximately 5 years to agree on an IEC norm. At the national level, safety criteria regarding UWTs will differ by country. This has to do with the environment of the deployment. In the United States UWTs are most commonly deployed in rural areas. The requirements in Europe are different and the deployment varies per country, but urban deployments are a far bigger issue. Therefore it would be a welcome initiative to define a European set of norms for UWTs.

9 Deployment of UWTs in built environments

9.1 Issues to consider

9.1.1 Urban planning

The following points should be considered when planning an UWT project:

- Turbines should be preferably placed on large buildings with a flat roof.
- Investigate which turbine type and model is the best for the chosen building or location.
- Deploy multiple turbines at the same location if possible.
- Investigate if the building and the surroundings are suitable for UWT deployment.
- Investigate the visual impact: the blade movements may bring a certain dynamic appearance to the area, however flicker or general visual disturbances are also possible.
- Concentrate the deployment in certain targeted areas.
- Ensure that the turbines are recognised in the spatial development plan and that the deployment plans respect the vision other stakeholders have about the location.
- Give enough attention to the aesthetic aspects of the integration. The turbine needs to visually integrate well with the building and the area.

9.1.2 Location

The turbine model and the local wind regime are the most important factors determining energy yield. The energy available from wind increases with the cube of the wind speed, therefore modest differences in the wind regime may have substantial effects on the electricity yield. The minimum recommended average wind speed at an UWT location is 5.5 m/s.

The highest wind speeds in The Netherlands are in the costal regions as shown in Figure 11. As an example, Figure 12 shows the distribution of the wind speeds and wind directions at the Schiphol airport. Note that wind in the speed range of 3.0 – 5.9 m/s can come from any direction but that wind speeds of 6.0 – 8.9 m/s most often come from the directions west and south-west, while winds with speeds higher than 9.0 m/s are almost always from the west.

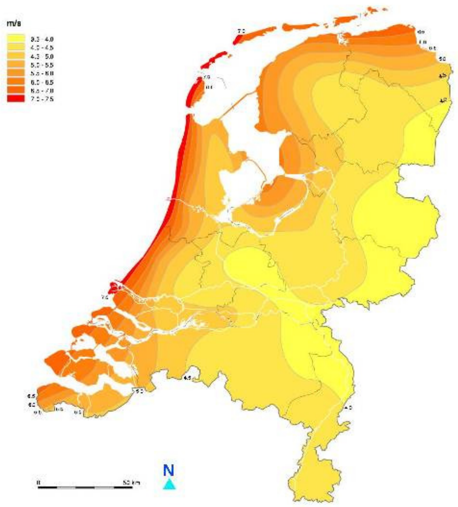

Figure 11: Yearly average wind speeds

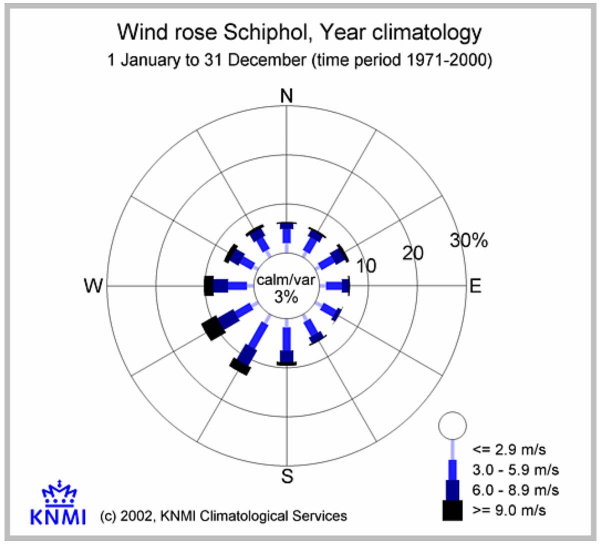

Figure 12: Wind distribution Schiphol airport

Buildings, trees, noise barriers and other obstacles influence the wind flow and create local, “micro” wind regimes with more turbulence and gusts. The average wind speed is also lower than on similar locations without obstacles. A sloped building or a roof on the side of the prevailing wind direction can have a positive effect on the energy yield of urban turbines (see Figure 13).

Due to influence of the surrounding buildings, it is important to place the turbine on the highest building in the area and to ensure that there is enough distance from other buildings. The yield can be as much as a factor of two higher or lower, depending only on a few meters distance from the obstacles or a few meters difference in height (see Figures 14 and 15). In general, the higher the turbine is placed, the better.

9.2 Rules of thumb regarding the choice of location

The following rules of thumb regarding location choice can help to achieve a successful UWT project:

- The annual mean wind speed at the location should be at least 5.5 m/s;
- The mast or building roof should be approximately 50% taller than the surrounding objects;
- The turbines should be positioned near the centre of the roof;
- The turbine should be positioned on the side of the most common wind direction;
- The lowest position of the rotor has to be above the roof by at least 30% of the building height (see Figure 14);
- If possible, ensure building orientation is towards the most common wind directions at the location as given on the local wind rose;
- If possible, introduce a sloped side to the building to increase the wind speed;
- Ensure that the roof can withstand the static and dynamic forces produced by the wind turbines;
- Place multiple turbines oat the same location or on the same building if possible to increase energy yield;
- Ensure that the quantity of the generated energy is in proportion with the energy needs on location;
- Ensure that energy saving measures are in place before deploying UWTs;
- Take measures against flicker, noise and vibrations;
- Ensure acceptance of the turbines in the neighbourhood.

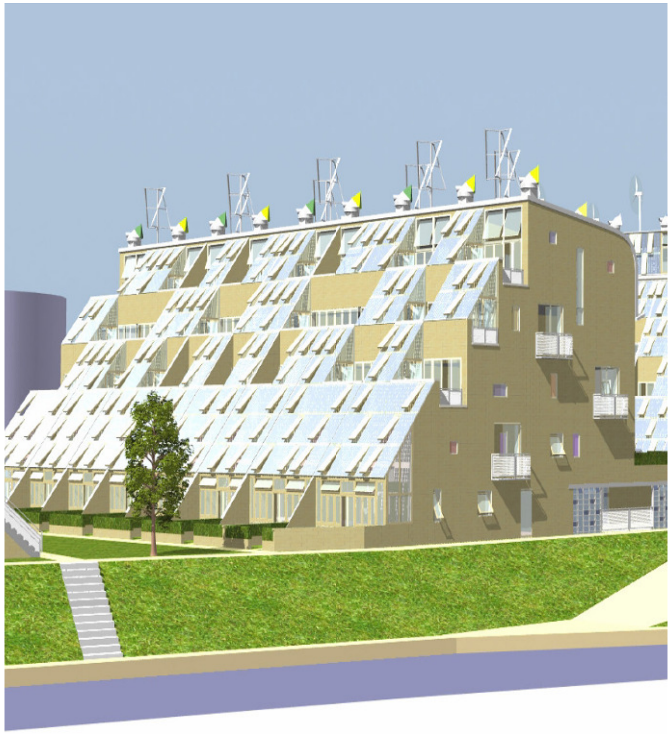

Figure 13: Urban turbines, source: Bill Dunster Architects

As the wind passes buildings and other obstacles in built surroundings, the flow gets distorted and produces turbulences. These flow disturbances are shown in Figures 14 and 15 (source: TU Delft). Both figures show the wind flows above a building. In Figure 14, the top of the building is shown from the side. The intensity of the wind is conveyed through the size of the arrows. Short arrows and the blue colour represent weak wind flow. The longer the arrows, the greater the velocity. The area with the yellow arrows has the strongest wind with a mostly constant direction. Figures 14 and 15 show that UWTs should be placed approximately in the middle of the roof where the wind is the strongest and the turbine is outside of the areas of turbulence.

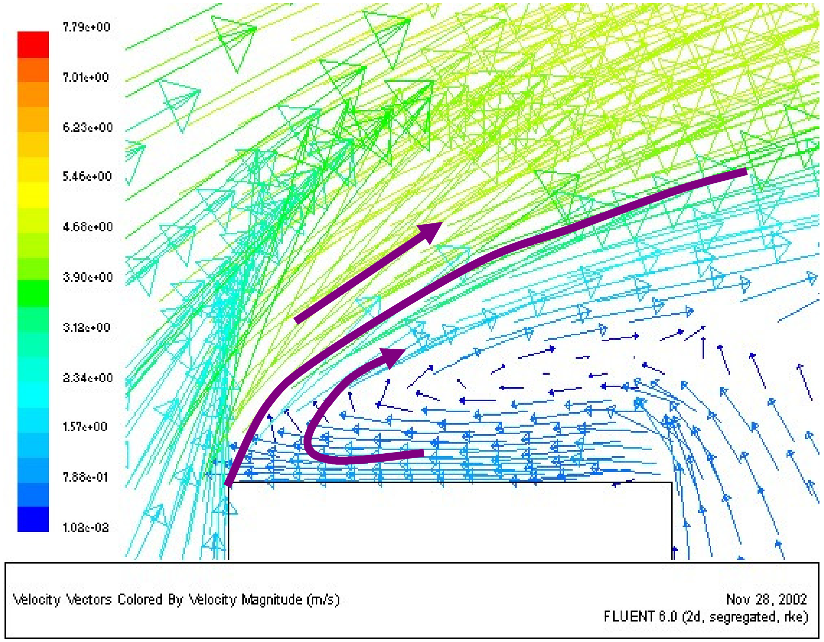

Figure 14: Wind flow around a building

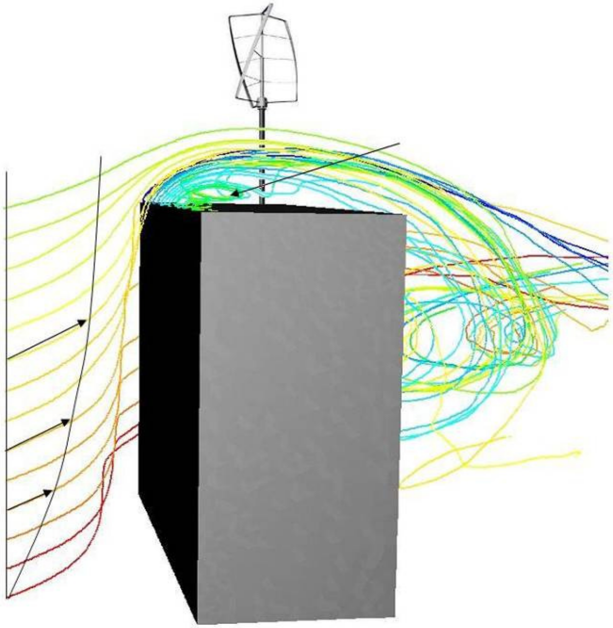

Figure 15: Placing of a turbine on the roof

9.2.1 Other issues to consider regarding the location of UWTs

In addition to the issues related to the energy yield of the turbines, there are some other aspects requiring attention:

- Maintenance access to the turbine;
- The passage for the cable between the turbine and the main switchboard;
- Room for additional equipment such as inverters, monitoring devices and the like;
- Connection to the public grid. The prerequisite for connecting to the public grid is to comply with the conditions of the regional grid operator. It is recommended to contact the regional grid operator at an early stage during project development.

9.3 Communication

UWTs, like other renewable energy technologies, require an effective communication plan to assist market development. Table 10 summarises the communication plan for The Netherlands, focusing mainly on dissemination of information.

Table 10: Communication plan UWTs

Initiators	Target group	Information	Medium
Suppliers	Potential buyers (1)	Product specifications, including also safety guarantees, yield, location requirements, environmental effects, installation guidelines and checklists (2)	Website, flyers, product booklet
Suppliers	All stakeholders	Product development, project information, news	Website, Internet newsletters and feeds, newspapers, press releases, TV/radio
Suppliers	R&D institutions	Unresolved issues, problem areas	Direct communication
Suppliers	Permit issuing authorities	Product specifications, standards, certificates, location requirements including roof construction requirements, environmental effects	Product manuals (3), seminars
Suppliers	Consultants	Product specifications, standards, certificates, location requirements including roof construction requirements, environmental effects, costs and benefits, incentives	Website, Direct communication, product booklets
Suppliers	Buyers	Operation and maintenance	Hand books
Suppliers	Financial institutions	Product description, environmental effects, costs and benefits, incentives	Public meetings, flyers, seminars, direct communication
Suppliers	Construction sector	Product description, location requirements including roof construction requirements, environmental effects, costs and benefits, incentives	Public meetings, symposia and conferences, flyers (4), seminars
Suppliers	Installation companies	Technical requirements regarding placement and electrical connection	Public meetings, symposia and conferences, flyers, booklets
Suppliers, buyers	Energy suppliers, metering companies, network companies	Electricity production: quantity, distribution in time, other technical details	Website, symposia, test and evaluation reports, direct communication
Suppliers	Energy consultants	Product specifications, including also safety guarantees, yield, location requirements, environmental effects	Websites, Guidelines, public meetings, symposia and conferences, test and evaluation reports
Suppliers, R&D institutions, municipalities, consultants	Government	Product description, environmental effects, costs and benefits, issues to consider, importance of UWTs, description of steps from idea to UWT implementation	Websites, Guidelines, public meetings, symposia and conferences
Government	All stakeholders	International and national targets and importance of meeting them, legal framework, R&D programs, financial measures and incentives	Guidelines, public meetings, symposia and conferences, catalogues, TV/radio, webpages
Government	All stakeholders	Specific current developments and decisions	Press releases, Internet news letters and feeds, webpages
Various industry associations: construction, installation, financing	Association members	General information on UWTs, specific branch-connected information (roof integration, electrical installation), product and project information	Internet news letters and feeds, web pages , association magazines,

Initiators	*Target group*	*Information*	*Medium*
Renewable energy associations and trusts, environmental organisations	All stakeholders	General information about UWTs, product information and financial incentives	Internet newsletters and feeds, public meetings, conferences, association magazines
Energy consultants	Municipalities, businesses, building owners, neighbourhood	General project and product information	Public meetings, symposia, catalogues, magazines, radio/TV, Internet newsletters and feeds, public meetings, webpages
Municipality, city planners	Actors involved in the development of projects	Information concerning locations, local plans, urbanisation plans, general requirements regarding spatial quality, etc.	"Ruimtelijke kwaliteitsplan" (Spatial quality plan), website
Project initiators	Neighbourhood	General project information, possible disturbance in the neighbourhood during construction activities on location	Information binders, Internet newsletters and feeds, public meetings, webpages, flyers
R&D institutions	Buyers, project initiators, government	Issues to consider, problems, solutions, testing and monitoring results	Research reports, presentations at conferences and symposia, website
Vereniging Nederlandse Gemeenten (Association of Dutch Municipalities)	Association members	General information, UWT product information, incentives, , description of steps from idea to UWT implementation	Booklets, catalogues, magazines, web pages

1 Owners of large buildings like office buildings, hospitals, sports halls, apartment flats, and industrial warehouses. Owners of industrial grounds, organisations managing motorways, waterways, railways etc. Owners of free-standing houses.

2 Steps that have to be taken before installation can proceed and the turbine can be commissioned (acquiring permits, verifying roof construction, deciding on the location of switches, meters and other equipment, agreeing with the grid operator, contract with energy supplier etc.)

3 Suppliers to issue own booklets

4 Suppliers could produce a joint flyer.

9.4 Environmental effects

Electricity generated by UWTs results in a reduction in the emission of greenhouse (and acid) gases by the following quantities per kWh:

- CO_2 : 0.566 kg / kWh
- NO_x : 0.15 g / kWh
- SO_2 : 0.42 g / kWh

Source: Senter/Novem, 'Cijfers en Tabellen 2006' (Yearly handbook of the Dutch government on the possibilities for energy saving)

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10 Conclusions

At the time of writing 14 UWT suppliers are active in the Dutch market; eight of those are also developing and manufacturing turbines in the Netherlands. A distinctive feature of the Dutch market is that the technical solutions are generally more diverse and innovative in comparison to other countries. In the UK there are also at least 13 UWT manufacturers. This activity is relative to the considerable market potential in the two countries. In total, there were 56 UWTs installed in the Netherlands by December 2006, most of those on roofs of office and apartment buildings. In the UK, more than 150 turbines had been installed in urban areas by the end of 2006.

The diversity of technical solutions means that different types of turbine perform optimally under different conditions and that a solution can be found for most locations and specific wind regimes. However, some UWTs are not yet fully developed, mature technologies. The electricity yield is still too low and the costs are out of proportion to the benefits of installing a wind turbine. The information that is generally available regarding UWTs is insufficient. The technical data has almost never been verified by independent institutions and information available on existing installations is very limited.

There are no standards regarding the safety, size, longevity and noise production, and there is no certification in place. Because there are no incentives that stimulate research and development, the developments in the UWT field are slow and knowledge remains fragmented among a variety of actors. This fragmentation constitutes a significant risk for all projects. One of the conclusions of the WINEUR project is that governments should do more to create the conditions needed for faster UWT product and market development.

Universities and research institutions dedicate a lot of attention to UWTs. In The Netherlands, the leading technical university, TU Delft, established a broad research programme with a special focus on wind in urban areas including wind flow around buildings, performance of UWTs placed on buildings and the associated optimisation. Several years of research have also been carried out at CIEMAT, the Spanish Public Research Agency for excellence in energy and environment. The main aspects being investigated are safety, noise production and reliability and durability of UWTs. The research activities of TU Delft and CIEMAT show that UWTs have significant potential. One of the studies carried out under the WINEUR project resulted in an expected market potential between 116 and 1,161 MW in the Netherlands.

Placing of UWTs requires a building permit. Because UWTs are not represented in laws and regulations, obtaining the necessary building permits is associated with long delays, disproportional administrative costs and project cancellations. The Dutch survey “Voor de wind gaan” (“Choice for the wind” see paragraph 6.2.1) advises that the UWTs should be mainly placed in industrial zones and that building permits should not be required for these locations.

UWTs offer an additional opportunity for renewable energy generation “on the other side of the meter”. They could be placed on many large buildings with a flat roof, but also at many locations in industrial zones and next to free standing houses in less densely populated areas. Relatively strong and smooth wind flows make locations along the seashore the most suitable. Selecting the optimal location for UWTs is a complex process. Changing the position of a turbine by a few meters may result in significant yield changes. Spatial and visual integration is also important. Expert advice may be needed to achieve a functional and aesthetic optimum.

Local authorities, owners of office and residential buildings, energy suppliers, public institutions, diverse commercial firms and house owners all show considerable interest in UWTs. All actors consider the installation of UWT conditional on the achievement of high safety and reliability requirements. In order to stimulate further development of UWTs, the WINEUR project has organised an association of interested parties under the name ‘European Cities Urban Wind Network’. The mission of this network is to facilitate information exchange regarding UWTs and to stimulate a joint approach in technology and market development. The network has been organised on two levels: international and national. Approximately 60 organisations from the Netherlands have joined this network, 20 from the UK and 10 from France. To conclude, the answer to one of the central questions posed by the WINEUR project, whether or not UWTs could significantly contribute to the energy generation in the built environment is as follows:

> UWTs have the potential to contribute to energy generation in the built environment. The fulfilment of that potential depends on the commitment of the stakeholders. The governments should play the enabling role by creating the preconditions for innovation and further technology development and by stimulating demonstration and pilot projects to verify the progress being claimed by manufacturers.

The concrete recommendations of WINEUR are presented in Table 11 and are actions addressing problems identified throughout the duration of the project.

Table 11: Recommendations follow-up activities

action	***Government***	***Suppliers***	***R&D institutions***	***Consultants***	***Certifying bodies***	***Building owners***	***Building sector***
Investigate and compare the efficiency of different UWT types	□	***x***	***x***	***x***		***x***	
Perform LCA (Life Cycle Assessment) of UWTs and the long term price development per type and model	□	***x***	***x***	***x***			
Carry out a study to estimate the overall energy potential of UWTs	□	***x***	***x***	***x***			
Develop a R&D programme for UWTs	□	***x***	***x***	***x***	***x***	***x***	***x***
Introduce financial incentives similar to those for PV	□	***x***	***x***	***x***		***x***	***x***
Develop safety norms for VAWT	***x***	***x***	***x***	***x***	□		
Develop noise norms UWTs	***x***	***x***	***x***	***x***	□		
Develop a set of guidelines for the construction integration of UWTs	***x***	***x***	***x***	□	***x***	***x***	***x***
Develop a certifying protocol for UWTs		□	***x***	□	***x***		
Certify UWTs		□	***x***		***x***		
Include UWTs in the building regulations (building permit, local plan, etc)	□	***x***		***x***			***x***
Harmonise laws and regulations on national, European and international level	□						
Grant exemptions from the administrative costs	□						
Exempt UWTs from the building permit regulations in industrial zones	□			***x***		***x***	***x***
Develop a simplified method for identifying optimal installation sites		***x***	□	***x***		***x***	***x***
Initiate demonstration and pilot projects	***x***	***x***	***x***	□		***x***	***x***
Develop an objective information package	***x***	***x***	***x***	□			

<u>*Legend*</u> The table shows which stakeholders are being directly involved:

□ denotes the party responsible for the initiative.

x denotes direct involvement.

The first two recommended actions are intended to identify the most promising options. Subsequently, these options would be the base for the estimate of the overall energy potential of UWTs. If the estimate exceeded a previously agreed and specified threshold (the minimum energy potential) the rest of the actions would be conducted. Please note that it has been assumed that national governments would support this type of plan.

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