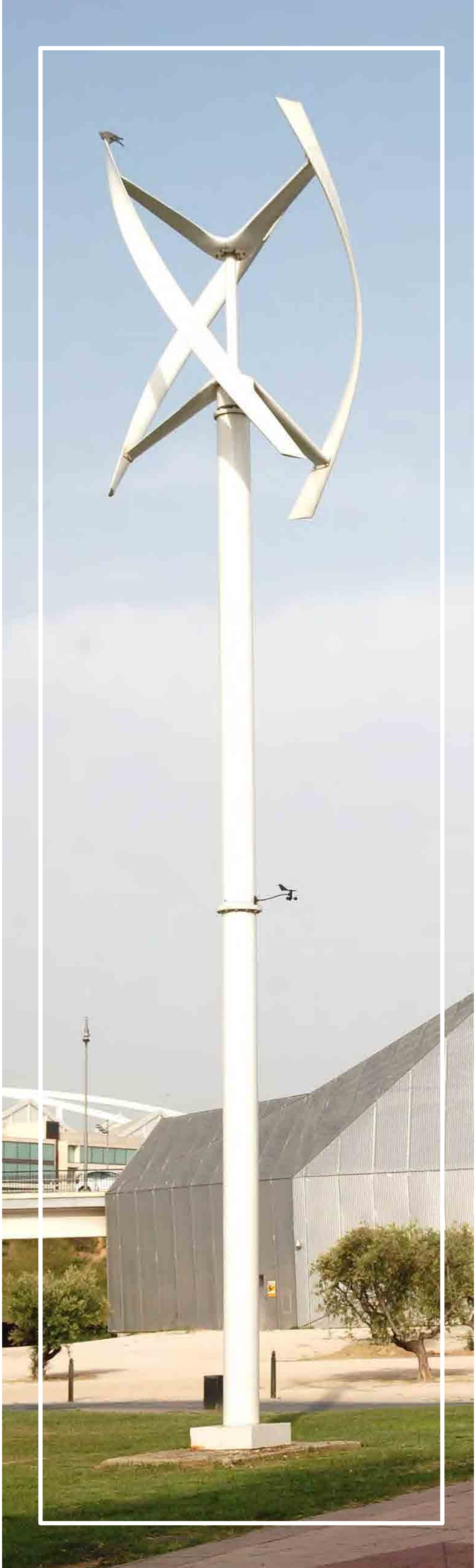

Deliverable 1.1

Benchmarking of small and mediums size wind turbine technologies and legal framework

Date: December, 2013

Location: Gdansk, Poland

Prepared by: Baltic Energy Conservation Agency (BAPE)

SWIP – New innovative solutions, components and tools for the integration of wind energy in urban and peri-urban areas

Grant Agreement: 608554

From October 2013 to May 2017

www.swipproject.eu

"This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 608554"

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Document info sheet

Document Name:	Benchmarking of small and mediums size wind turbine technologies and legal framework
Responsible Partner:	BAPE, Poland
WP:	European framework assessment
Tasks:	Benchmarking of small and mediums size wind turbine technologies; Legal and funding status of the sector
Deliverable nº:	D 1.1
Version:	3rd Final
Version Date:	10/12/2013

Diffusion list

All partners.

Approvals

	Company	Company
Author/s	BAPE	KEMA
	CIRCE	METEODYN
	FORES	TCD
	SOLUTE	
Task Leader	BAPE	
WP Leader	KEMA	

Documents history

Revision	Date	Main modification	Author
1	25/11/2013	Contents	CIRCE, FORES
2	9/12/2013	Text	G!E
3	19/12/2013	Legal aspects	KEMA

Executive Summary

The aim of the benchmarking of small and mediums size wind turbine technologies is to collect, assess and compare the main technologies, both at market and prototype level, concerning small wind turbines.

The impact of the wind turbine design on use of wind kinetic energy is analysed. The extent to which air stream energy is captured and the conversion of mechanical power into electrical power takes place depending on many factors, determined by the design of the wind turbine.

The range of small size wind turbines (SWTs) has been divided into a few sub-ranges, depending on the rated capacity of wind turbines: 1-10, 10-100, 100-300 kW. Benchmarking takes into account types of SWTs and employed technologies. The result of the benchmarking of small WTs in groups is shown in tables in the Appendix. The spreadsheet includes a summary of product data for SWTs and calculated characteristic parameters. Parameters of WTs are divided into mandatory (for each WT included) and non-mandatory additional data, depending on the availability. Additionally to power coefficient and other parameters at the rated (design) conditions, important parameters for potential urban applications like output and productivity at average wind speed 4 m/s are collected and analysed.

Based on previous studies and present benchmark reporting, it can be said that there is lack of reliable data for urban applications of small WTs. Available WTs are characterized by high investment costs with a large spread of costs between models and types of WTs.

Outcomes of the present benchmarking study support planned activities within the project aiming at technological development and setting new practices in use of WTs in urban environments. This includes the modelling of wind conditions at WT locations, design of WTs which are better suited to urban environments, development of technology of WT components in order to reduce costs and make construction robust, and, finally the proper selection of WTs for operation at urban locations characterized by high energy generation, low noise and vibration and low maintenance costs.

There are many regulations, policies and standards that apply to the wind sector. It is clear that none of the SWIP countries did include urban wind in their 2020 targets. Policies and regulations are mainly lacking for urban wind turbines. In most SWIP countries SWT are treated economical equally as large wind turbines making it highly unattractive to invest in SWTs. For now SWTs seem to play only a roll in niche markets. For a high market penetration not only the technical aspects of the SWTs need to improve but also specific policies and regulations for SWT are needed. This seems justified because looking only at the urban wind potential numbers show that it can play a substantial roll in the future electricity market with a total installed capacity of 6,4 GW for the SWIP countries. This installed capacity is calculated assuming a yield of 5MW per km^2 of urban area at 10 m altitude.

Overall the UK seems to have the most favourable market outlook for urban wind with Ireland as runner up.

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1 Introduction

The aim of the benchmarking of small and mediums size wind turbine technologies is to collect, assess and compare the main technologies used around Europe, and also in other countries that are strong in this technology, concerning small and medium wind turbines.

This study shall set a basis from which the project can develop its improvements beyond the state of the art. No less important is the research for current ways to integrate WTs into urban buildings or districts, regarding pros and cons and how to take them into account for further innovative development.

The main objective of this task is to have a general overview of legal, social and economic aspects of SWT and to benchmark the technologies currently available, both at market and prototype level.

2 Benchmarking of small and medium size wind turbines technologies

2.1 Impact of the wind turbine design on use of wind kinetic energy

2.1.1 Theory. Betz equation, performance coefficient Cp [1]

The Betz equation is analogues to the Carnot cycle efficiency in thermodynamics, suggesting that a heat engine cannot extract all the energy from a given source of energy and must reject part of its heat input back to the environment.

Limited efficiency of a wind turbine is caused by slowing the wind from its upstream speed to downstream speed while allowing continuation of a flow regime. The additional losses in efficiency for practical wind turbines are caused by the viscous and pressure drag on rotor blades, the swirl imparted to the air flow by the rotor and the power losses in the transmissions and electrical system.

Considering the ideal model shown in Figure 1, the cross sectional area swept by the turbine blade is designated as S, with the air cross-section upwind from the rotor designated as S_1 and downwind as S_2. The wind speed passing through the turbine rotor is considered uniform as V with values V_1 (upwind) and V_2 (downwind) at the distance from the rotor.

Extraction of mechanical energy by the rotor occurs by reducing the kinetic energy of the air stream from upwind to downwind or simply applying a braking action on the wind.

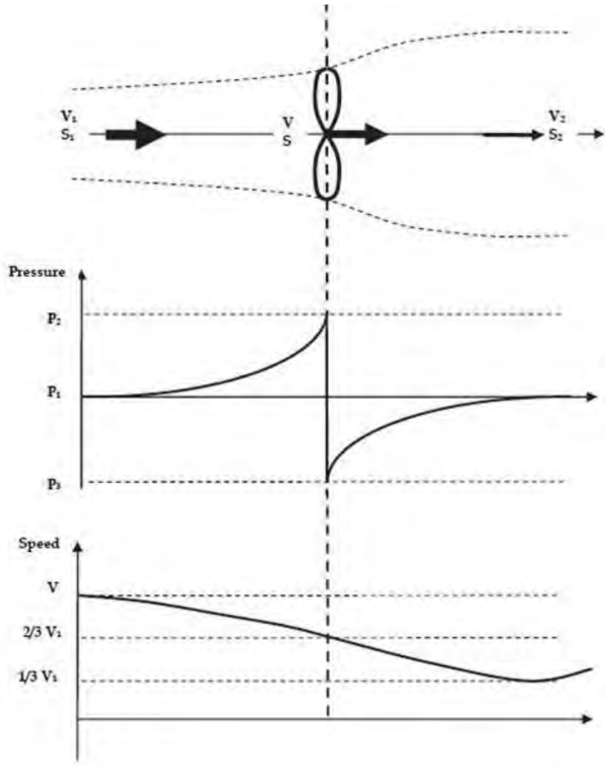


Figure 1 Pressure and speed variation in an ideal model of a wind turbine [1]

Using the continuity equation and other dependences the extractable power P in term of the interference factor b can be expressed as:

$$P=\frac{1}{4}\rho\ S\,V_1^3\,(1\text{-}b^2)\,(1\text{+}b)\ [\text{Watts}] \qquad (1)$$

The kinetic power content of the undistributed upstream wind stream with $V=V_1$ and over a cross sectional area S becomes:

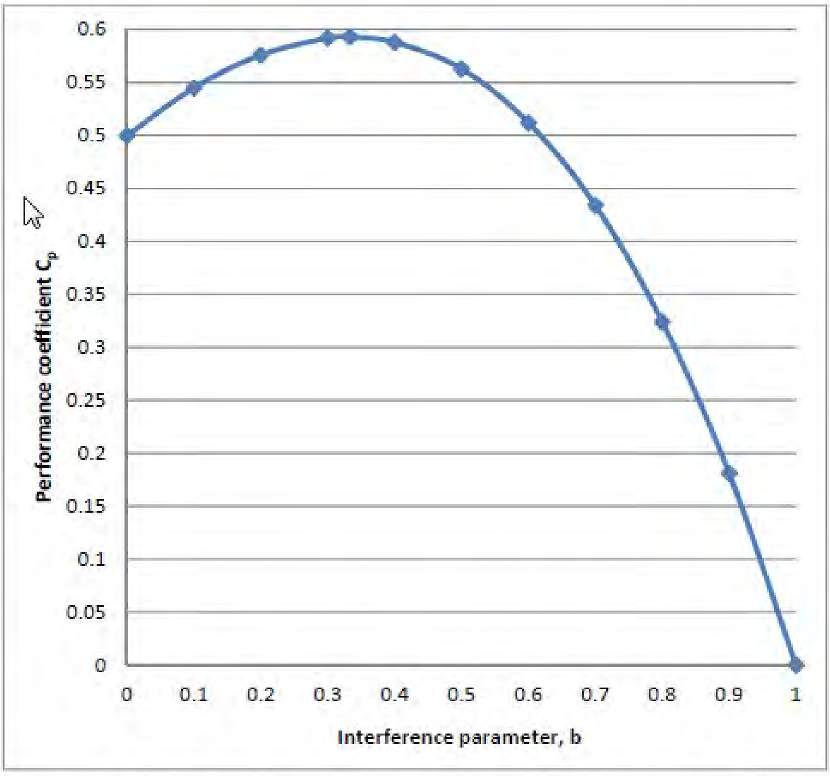
$$W=\frac{1}{2}\rho\ S\,V_1^3\,[\text{Watts}] \qquad (2)$$

The performance coefficient or power coefficient C_p is the dimensionless ratio of the extractable power P to the kinetic power W available in the undistributed stream:

$$C_p=\frac{P}{W}=\frac{1}{2}\ (1\text{-}b^2)\,(1\text{+}b)\ [\text{Watts}] \qquad (3)$$

Where:

$$b=\frac{V2}{V1}$$



b	0.0	0.1	0.2	0.3	1/3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
C_p	0.500	0.545	0.576	0.592	0.593	0.588	0.563	0.512	0.434	0.324	0.181	0.00

Figure 2 The performance coefficient as a function of the interference factor b [1]

When b=1, V_1= V_2 and the wind stream is undisturbed leading to a performance coefficient of zero. When b=0, V_1=0, the turbine stops all the air flow and the performance coefficient is equal to 0,5. It can be noticed from the Figure 2 that the performance coefficient reaches a maximum around b = 1/3.

The maximum value of the performance coefficient C_p becomes:

$$C_{p,max} = \frac{1}{2}\ [1-(\frac{1}{3})^2]\ \ (1+\frac{1}{3}) = \frac{16}{27} = 0{,}59259 \qquad (4)$$

This is referred to as Betz Criterion or Betz Limit.

Modern wind machines operate at slightly lower practical non-ideal performance coefficient.

The Betz Equation results as:

$$P_{max} = \frac{16}{27}\ \frac{\rho}{2}\ V_1^{\ 3}\ \frac{\pi D^2}{4}\ [\text{Watts}] \qquad (5)$$

The most important implication from the Betz Equation is that there must be a wind speed change from the upstream to the downstream in order to extract energy from the wind; in fact a wind turbine must disturb the wind stream in order to operate.

The Betz Criterion reminds us that a wind turbine cannot extract all the kinetic energy from a given stream and must reject part of its input back to the environment.

2.1.2 Rotor optimal Tip Speed Ratio, TSR [1]

Another important concept relating to the power of wind turbines is the optimal tip speed ratio, which is defined as the ratio of the speed of the rotor tip to the free stream wind speed. If a rotor rotates too slowly, it allows too much wind to pass through undisturbed, and thus does not extract as much energy as it could, within the limits of the Betz Criterion, of course.

On the other hand, if the rotor rotates too quickly, it appears to the wind as a large flat disc, which creates a large amount of drag. The rotor Tip Speed Ratio, TSR depends on the blade airfoil profile used, the number of blades and the type of wind turbine. In general, three-bladed wind turbines operate at a TSR of between 6 and 8, with 7 being the most widely reported value.

In addition to the factors mentioned above, other concerns dictate the TSR to which a wind turbine is designed. In general, a high TSR is desirable, since it results in a high shaft rotational speed that allows for efficient operation of an electrical generator. Disadvantages however of a high TSR include:

(a) Blade tips operating at 80 m/s (or greater) are subject to leading edge erosion from dust and sand particles and would require special leading edge treatments like helicopter blades to mitigate such damage,
(b) Noise, both audible and inaudible, is generated,
(c) Vibration, especially in 2 or 1 blade rotors,
(d) Reduced rotor efficiency due to drag and tip losses,
(e) Higher speed rotors require much larger braking systems to prevent the rotor from reaching a runaway condition that can cause disintegration of the turbine rotor blades.

The Tip Speed Ratio (TSR) is dimensionless factor defined in Eqn. 6.

$$TSR= \lambda = \frac{speed\ of\ rotor\ tip}{wind\ speed} = \frac{v}{V} = \frac{\omega\ r}{V} \qquad (6)$$

where:

V	- wind speed [m/sec]
v - ω r	- rotor tip speed [m/sec]
r	- rotor radius [m]
ω - 2 π f	- angular velocity [rad/sec]
f	- rotational frequency [Hz], [sec $^{-1}$]

2.1.3 Power coefficient and tip speed ratio of different wind converters designs

The theoretical maximum efficiency of a wind turbine is given by the Betz Limit and equals to approx. 59 percent. Practically, wind turbines operate below the Betz Limit. For a two-bladed turbine, if it is operated at the optimal tip speed ratio of 6, its power coefficient would be around 0.45. At the cut-in wind speed, the power coefficient is just 0.10, and at the cut-out wind speed it is 0.22. This suggests that for maximum power extraction a wind turbine should be operated around its optimal wind tip ratio.

Modern horizontal axis wind turbine rotors consist of two or three thin blades and are designated as low solidity rotors. This implies a low fraction of the area swept by the rotors being solid. Their configuration results in an optimum match to the frequency requirements of modern electricity

generators, and also minimizes the size and weight of the gearbox or transmission required, as whilst increasing efficiency.

Such an arrangement results in a relatively high tip speed ratio in comparison with rotors with a high number of blades such as the highly successful American wind mill used for water pumping in the American West and all over the world. The latter required a high starting torque.

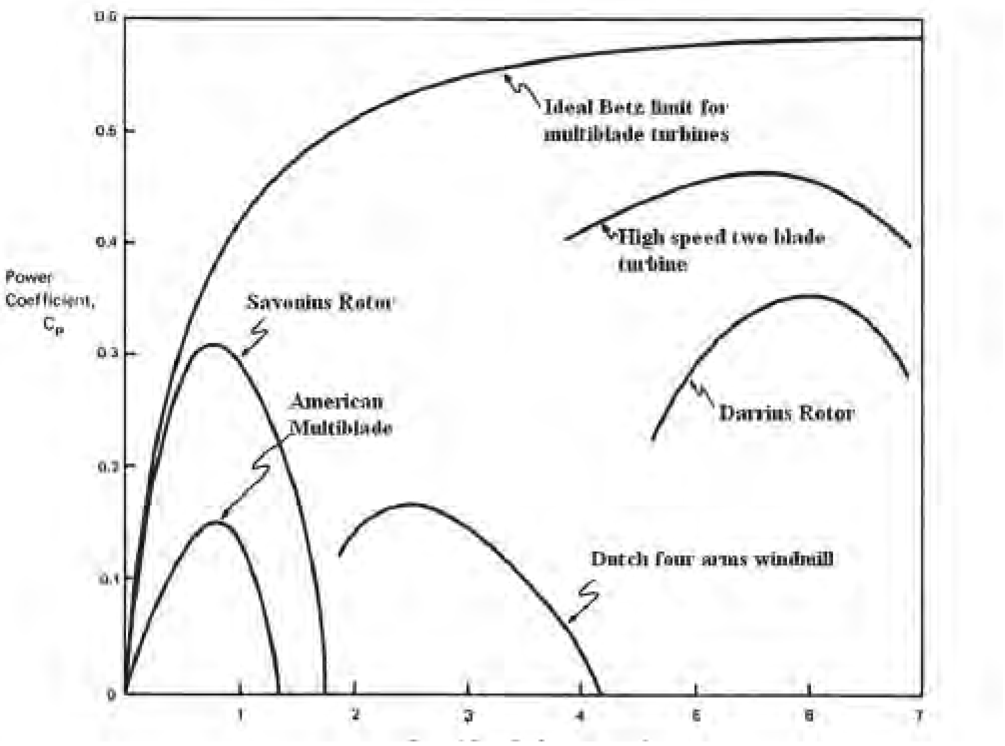


Figure 3 The power coefficient Cp as a function of the tip speed ratio for different wind machines designs [1]

2.1.4 Aerodynamic, mechanical and electrical losses

The power transmitted by the wind engine to the generator is decreased by aerodynamic and mechanical losses resulting, among others, from:

- The fact that the centre of the hub does not capture the energy of the wind
- Air friction on the blades
- Air swirl behind the rotor
- Partial flow of air stream outside the rotor
- Interference effect between blades

- Friction in bearings and gear boxes

$$P_m = \eta_a \bullet \eta_m \bullet P$$

where:

η_a - aerodynamic efficiency

η_m - mechanical efficiency

and the electrical power takes into account the efficiency of the generator, thus:

$$P_{el} = \eta_g \bullet \eta_a \bullet \eta_m \bullet P$$

or:

$$P_{el} = \eta_g \bullet \eta_a \bullet \eta_m \bullet C_p \bullet W$$

And the maximum electrical power which can be extracted:

$$P_{el\ max} = \eta_g \bullet \eta_a \bullet \eta_m \bullet C_{p\ max} \bullet W$$

Experience shows that the total efficiency of the wind engine and the generator ($\eta_G \bullet \eta_a \bullet \eta_m$) amounts to the value of 0,4 to 0,8, and thus if the rotor efficiency was

$$C_{p\ max} = 0.5926$$

then

$$P_{el\ max} = 0.5926\ (0.4 \div 0.8) = 0.237 \div 0.474\ P_a$$

2.1.5 Impact of the structural components of the wind turbine on its operation

Theoretical considerations prove that the extent to which the air stream energy is captured and the conversion of mechanical power into electrical power depends on many factors determined by the design of the wind turbine such as:

- Number of blades
- Shape of blades
- Blade pitch adjustment dependent on the wind speed and rotational speed of the rotor
- Area of the hub
- Rigidity of the blades and their susceptibility to vibrations
- Roughness of the blades and their susceptibility to icing and dust accumulation
- Yaw mechanism
- Gear box structure
- Bearing structure
- Generator structure
- Transmission of power from the mobile elements of wind turbine to the electrical wires
- Operation of the controller
- Operation of the inverter
- Others

2.2 Approach

The range of small size wind turbines (SWTs) has been divided into a few sub-ranges, depending on the rated capacity of wind turbines: 1-10, 10-100, 100-300 kW.

Benchmarking takes types of SWTs and employed technologies into account. Key groups of parameters include:

1. Orientation of axis: horizontal (HA), vertical (VA), hybrids
2. Blades: design, number
3. Masts
4. Efficiency of power generation

5. Feasibility

The main assumptions:

- Parameters are divided into mandatory, for each WT included and non-mandatory, additional data depending on the availability.
- Separate sheets are used for turbines 1-10 kW of horizontal axis (HA) and vertical axis (VA) plus one sheet for WTs > 10 kW to 30 kW and >30-100 kW range.
- The most important for urban areas is the low-velocity wind range of WT operation, with assumed annual average wind speed about 4 m/s.
- For some SWTs of low capacity (range 1-10 kW) there are no power and production curves available. These really do not allow for assessment of these WTs for urban applications.
- For some wind turbines there are problems with collecting and assessing data at the low-velocity wind range; some WTs have cut-in wind speed at 4 m/s or higher.
- Power curves P(v) and production curves kWh(v) are not accurate in low-speed range. Additionally, data for power at low speed do not often correspond to declared annual production of low speed winds.

Result of benchmarking of small WTs in groups is shown in tables in the Appendix. The spreadsheet includes summary of product data for SWTs and calculated characteristic parameters.

2.2.1 Parameters

Parameters used for benchmarking are shown in the table below. Experiences from previous studies on evaluating WTs performance have been used [2], [3].

Table 1. Parameters of WTs

	Parameter	Unit	Remarks
	Mandatory data		
1	Producer		Producer of the WT
2	Model name		The name of specific WT
3	Orientation		The orientation of the rotor axis against wind direction and tower; six possibilities from a dropdown pre-defined menu: vertical axis, horizontal upwind, horizontal downwind, horizontal crosswind, hybrid, ducted.
4	Blades		Number and type of blades (if relevant)
5	Rotor diameter	m	Rotor diameter
6	Rotor height	m	Rotor height of vertical axis (VA) WT
7	Swept area	m2	The area of wind stream swept by a WT rotor: area of circle defined by rotor diameter for horizontal axis (HA) WT; area set by diameter, height and geometry for VA WT
8	Rated output	kW	Power generated at design conditions
9	Rated wind speed	m/s	Wind speed at which a wind turbine produces its rated power
10	Cut-in	m/s	Wind speed at which a wind turbine begins to produce power
	Non-mandatory data		
11	Contact	-	Contact data to WT producer
12	Country	-	Country of origin
13	Peak output	kW	Maximum power output of WT
14	Cut-out	m/s	Wind speed at which a wind turbine is stopped from producing

	Parameter	Unit	Remarks
			electricity
15	Noise level	dB (A)	At design conditions
16	Head weight	kg	The weight of WT head including rotor, gear box, generator, and other rotary components connected to a tower.
17	Recommended tower height	m	Recommended tower height in order for the WT to achieve rated capacity
18	Price	EUR	Price of complete WT
19	Power curve	-	Availability of power curve of a WT (Yes/No)
20	Power at 4m/s	kW	Power generated at speed 4 m/s
21	Annual production at 4m/s	kWh	Annual production at 4m/s declared by producer (in form of graph or table)
22	Rated power coefficient C_p	-	Rated output per swept area divided by the potential of WT = 0.625 V^3
23	Productivity at 4m/s	kWh/kW	Estimated annual production at 4m/s against rated output
24	Unit price	EUR/kW	Cost parameter for installed capacity
25	DGC	EUR/kWh	Discounted, estimated costs of generation for 15 years of operation

Where:

- Rated power coefficient C_p

rated power per swept area divided by power of wind (½ ρV^3)

$$C_p = P / (½ \rho S V^3) < 16/27$$

With numerical application:

$$C_p = P / (0,625 S V^3) < 0.593$$

Where:

P - rated power [kW]
ρ = 1.25 kg/m^3
S – swept area [m^2]
V – rated wind speed [m/s]

The result, less than 1, will be also less than Betz limit (0.593).

- DGC – Dynamic Generation Cost; calculated for 1500 h/year, 15 years, 5% discount rate

$$DGC = p_{EE} = \frac{\sum_{t=0}^{t=n} \frac{KI_t + KE_t}{(1+i)^t}}{\sum_{t=0}^{t=n} \frac{EE_t}{(1+i)^t}}.$$

Table 2. Calculation of DGC

	Discount factor	Investment	Generation	Discounted costs (KI)	Discounted generation (EE)	DGC
		KI	EE			
Year		EUR	kWh	EUR	kWh	EUR/kWh
0	1	6 700		6 700.0	0.0	
1	0.952		1 752	0.0	1 668.6	
2	0.907		1 752	0.0	1 589.1	
3	0.864		1 752	0.0	1 513.4	
4	0.823		1 752	0.0	1 441.4	
5	0.784		1 752	0.0	1 372.7	
6	0.746		1 752	0.0	1 307.4	
7	0.711		1 752	0.0	1 245.1	
8	0.677		1 752	0.0	1 185.8	
9	0.645		1 752	0.0	1 129.4	
10	0.614		1 752	0.0	1 075.6	
11	0.585		1 752	0.0	1 024.4	
12	0.557		1 752	0.0	975.6	
13	0.530		1 752	0.0	929.1	
14	0.505		1 752	0.0	884.9	
15	0.481		1 752	0.0	842.7	
				6 700.0	**18 185.2**	**0.368**

2.3 Results of benchmarking of SWTs

2.3.1 Results of comparison of parameters

Totally parameters for **199** SWTs are compared. Previous reports on WTs benchmarking have been included [4], [5] as well as producers' data [10].

Types of analysed WTs:

- vertical axis (VA)
- horizontal axis (HA) upwind
- horizontal axis (HA) downwind
- horizontal axis (HA) crosswind
- hybrid
- ducted

in groups set by power output: 1-10 kW HA, 1-10 kW VA, >10-30 kW and >30-100 kW.

Parameters of benchmarked WTs in groups are summarised in the table below.

Table 3. Summary of parameters of WTs in groups

Parameter		Unit	1-10 kW HA	1-10 kW VA	>10-30 kW	>30-100 kW
Number of WTs		-	108	33	28	30
Rated power coefficient C_p	Maximum	-	0,546	0,585	0,538	0,549
	Average		0,275	0,316	0,286	0,294
Productivity at 4m/s	Maximum	kWh/kW	3 077	1 000	2 134	1 360
	Average	EUR/kW	1 111	854	842	847
Unit price	Minimum	EUR/kWh	985	3 500	2 080	1 248
	Average	EUR/kW	3 623	5 854	3 519	2 286
DGC	Minimum	EUR/kWh	0,088	0,506	0,288	
	Average	EUR/kW	0,383	0,668	0,531	0,469

Parameters of WTs are based on data provided by WT manufacturers and have not been verified during the present study. Characteristic values can be summarised as follows:

- Average values of rated power coefficient C_p for SWTs are from 0.27 to 0.32 for all WTs. Maximum values of C_p are in the range from 0.54 to 0.58.
- Average values of productivity at 4 m/s are in the range from 840 kWh/kW to 1100 kWh/kW. Maximum values of productivity at 4 m/s are in the range from 1000 kWh/kW for vertical axis WTs in the range 1-10 kW to 2000-3000 kWh/kW for some WTs.
- Minimum unit price of installed capacity is in the range from 990 EUR/kW to 3500 EUR/kW depending on the type of a WT with average price in groups from 2300 EUR/kW to 5900 EUR/kW. For bigger WTs prices are available only on request. Typically, vertical axis WTs are more expensive than horizontal axis WTs.
- Minimum values of Dynamic Generation Cost DGC for operation in low-speed conditions range from 0.09 to 0.67 EUR/kWh depending on the type of WT.

2.3.2 Other parameters

There are other, often qualitative, parameters that shall be considered when comparing and selecting a wind turbine for the specific location and application.

They include:

- Environmental costs
- Purchase and other costs
- Standing of manufacturer of the WT

2.3.2.1 Environmental costs of the wind energy use

- The Life Cycle Assessment of the wind turbine should take into account the environmental impacts associated with all the stages of the product's life from-cradle-to-grave. It should include the amount of energy consumed and gas emitted during the manufacture of the wind turbine components (including the mass and types of raw materials), their transportation to the site, and assembly. It is also significant that the frequency of the required repair and maintenance, the availability of the service, the supply of spare parts and other elements are comprised in the LCA.
- Special consideration is required for the operation of the wind turbine, noise generated and the aesthetics of the plant.

- The location of the wind turbine site and the method of its installation should allow for necessary periodical maintenance and failure repair works.
- The productivity of the wind turbine is to a larger extent determined by the location of its site rather than by its technological excellence. A wind turbine installed in the wrong site in the urban area can generate only 150 kWh/a because the air stream is blocked from the windward side by the surrounding buildings, or it can produce 3000 kWh/a when it is well exposed to the wind. In the first case the manufacture and installation of the wind turbine will result in the increase of the CO_2 emissions due to the consumption of the input energy in the production process which will not be released in its long-term operation cycle. In the second case the input energy will returned in a few months.

2.3.2.2 Purchase costs, installation cost and maintenance costs of a specific wind turbine

These costs must warrant the return on investment in the specific site conditions at the latest within the lifespan of the wind turbine.

Calculations should take into account:

- Productivity of the wind turbine in a specific site
- Price of electricity for internal use of the wind farm and for sale
- Stability of electricity prices
- Legal regulations supporting the use of RES
- Economic and political stability of the state

2.3.2.3 Standing of the manufacturer

Standing of the manufacturer is determined by:

- Volume of production (number of items produced)
- Economic standing in the market (revenue, profit, EBITDA)
- Opinion on the product expressed by users
- Organization of sale and distribution
- Organization of maintenance services
- Length of the market presence
- Certificates obtained (quality assurance, environmental and energy control systems)

2.4 Integration of WTs into urban buildings and districts

2.4.1 Conclusions from previous projects

Wind profile in urban areas is shifted upwards by a distance known as the displacement height. This requires higher mounting of WTs in comparison with rural sites. Additionally, obstacles such as buildings and trees in the path of the wind cause it to flow around or over the obstacles, often with turbulent (disturbed, relatively slow moving) air in its wake.

Some reports of studies on integration of WTs into urban buildings or districts are available.

1) Report 'UK Small Wind Survey: Installed Capacity & Annual Generation' [6]

The report shows large uncertainty of measurements and lower productivity of WTs in comparison with rural locations. For example, values of capacity factor for micro and small WTs are shown in the table below.

Table 4. Reported capacity factor for WT in urban locations [6]

Siting Scenario	0 – 1.5 kW	1.5 kW – 10 kW	10 – 20 kW	20 – 50 kW	50 kW – 100 kW
Excellent	0.11	0.13	0.15	0.17	0.19
Average	0.06	0.07	0.08	0.09	0.1
Poor	0.01	0.02	0.03	0.04	0.05

2) Report 'Small-scale wind energy. Policy insights and practical guidance' [2]

Report on small-scale WTs giving basic guidelines on location of a WT in urban environment and estimation of expected generation of a WT.

3) The Catalogue and Technology review developed within WINEUR [8]

The Intelligent Energy Europe WINEUR Project 'Wind Energy Integration in the Urban Environment' was run in the period 2005-07. The major objective of the project was to identify the conditions that need to be established for the integration of small wind turbines into the urban environment (www.urbanwind.net).

The Catalogue comprising data on 57 WTs has been compiled within the project. Based on the Catalogue, technological review of WTs and their suitability to urban areas is available.

The following parameters are presented as crucial for urban use of WTs:

- Horizontal (HA) versus vertical axis (VA) wind turbines
- Rated power and rated wind speed
- Cut-in and cut-out wind speed
- Noise
- Life time
- Maintenance

The study has revealed that parameters of a large share of WTs make them unsuitable for use in urban locations. These include high cut-in and rated wind speed.

Another limitation is that typical parameters provided by WT manufacturers are not sufficient for assessing WT applicability for urban locations. These parameters include power, energy generation and noise level at low wind speeds.

4) The Guidelines for small wind turbines in the built environment developed within WINEUR [7]

The Guidelines developed within WINEUR after discussing WT potential address potential use of WTs in urban areas. This subject is discussed in the following areas:

(a) Projects.

At the moment of preparation of the report, the number of WTs installed in urban areas was estimated at about 200, mostly in the UK and in the Netherlands. Results from on-going and

planned projects are discussed in the report. The main identified barriers include the following aspects: turbine technologies, projects, costs, attitudes and permits:

- Turbine technologies - innovative turbine models designed for the urban environment are not ready, there are quality issues, lack of technical information and norms and standards
- Projects – WT location is often unsuitable, projects do not have government support, designers are lacking support tools, and there have been negative experiences: noise, vibration, unexpected faults and even damage, meaning projects progress slower than planned
- Costs - investment and other indirect costs are too high
- Permits - obtaining permits for urban WTs is complex, takes too long and is different in each municipality or local authority, and developers miss guidelines
- Attitudes – data provided by producers and suppliers are too optimistic, later incomes are lower and noise is higher than expected, there is a reluctance to accept urban WTs 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.

(b) Case study

A study of the urban WT market in the Netherlands was conducted. Depending on the scenario, potential electricity generation of WTs in urban areas varies from 128 to 1194 GWh/year, reaching 0.17% of total energy demand in the Netherlands.
The study analyses the status of certification criteria for small turbines. A certificate proves that the turbine is safe and that the quality and durability guarantees are in place. However certification of urban WTs shall be solved at the European level.

(c) Remarks on deployment of WTs in built environments

The list of issues to be considered includes the role of urban planning, location (for the Netherlands the minimum recommended average wind speed at a WT location is 5.5 m/s) and specific rules regarding location and implementation of a successful urban WT project, especially flow structure at the planned WT location.
Other aspects to be considered include maintenance issues, location of equipment and connection to grid.

2.4.2 Conclusions from the present study

The aim of the study is to analyze current ways of how to integrate WTs into urban locations, regarding pros and cons and how to take them into account for further innovative development.

Both previous reports, as well as the present benchmarking study, demonstrate the development of WTs in all their aspects on one hand, but few examples of successful urban applications, on the other.

The main conclusions from the benchmarking study are as follows:

- Available data provided by WTs producers differ very much and parameters of WTs have different reliabilities.
- There is lack of parameters describing small WTs for urban conditions, characterized by low wind speed, turbulence and variable flow conditions.

- There is lack of noise data, especially for low-speed wind conditions.
- Available WTs are characterized by high investment costs with a large spread of costs between models and types of WTs.
- Problems with control of WT operation and connection to internal network and external grid are not solved.

2.5 Conclusions

2.5.1 General remarks

Benchmarking of small-scale wind turbines has involved collection of basic data on the technical parameters (not always comparable) available to the general public. The data has been compiled from the information and materials published on the websites of wind turbine manufacturers.

The data does not make it possible to compare the produced wind machines in order to choose a wind turbine which is best in a given category. This data allows for designating the devices and technological solutions which should be subject to thorough benchmarking analysis that includes other parameters such as:

- Complete energy characteristics allowing for the determination of the wind energy in the full range of wind speed
- Noise emission
- Vibrations transmission
- Materials of the components
- Environmental impact (LCA)
- Production costs
- Stability of production
- Organization of sale, distribution and maintenance
- Recycling and disposal of parts
- Product durability
- Siting – location of the WT (field, roof), mast and neighbouring objects (buildings, construction, trees)
- Utilization of generated energy - important issues:
    - Island mode operation: size optimization, inverter type, batteries, connection to local network
    - Grid-connection mode: inverter type, metering, possibility of covering local (LV) needs and delivery of surplus to the grid.

2.5.2 Suggestions for further development

The aim of this study is to set a basis from which the project can develop its improvements beyond the state of the art. Outcome of the present benchmarking study supports the planned activities within the project aiming at technological development and setting new practices in use of WTs in urban environment. This implies continuation of activities within the project:

(a) Modelling of wind conditions at WT location in order to optimise WT selection and location, including integration in buildings and districts
(b) Design of WTs better suited to urban environment

(c) Development of technology of WT components (rotor, gearbox, generator, inverter, control system), in order to reduce costs and make construction robust
(d) Proper selection of WTs for operation at urban locations characterized by high energy generation, low noise and vibration and low maintenance costs.

3 Legal and funding status of the sector

3.1 Europe and methodology

The EU is committed to reducing greenhouse gas emissions to 80–95 % below 1990 levels by 2050 in the context of necessary reductions by developed countries as a group. The Energy Roadmap 2050 of the European commission distinguishes various future scenarios, where wind power takes a large part of the target values. By 2050 wind power provides more electricity than any other technology in the *High Renewables scenario* (EU roadmap 2050). Driven by emission reduction mandates of the EU, many EU countries extended support in the form feed-in tariffs for wind power. Feed-in tariffs for urban wind are not differentiated from large scale wind productions. Urban wind enlarges the total wind potential, with 5MW/km^2 rated capacity, in the urban environment.

This chapter describes the legal and funding status for SWT's within the various European SWIP-countries. These factsheets on the following pages address to the following issues:

- **Status**: describing the current status of wind energy in general, and if available data is provide on SWT's. Data is provide on the target values for wind energy in 2020, installed capacity and number of turbines installed.
- **Legal**: Describes the permitting procedures for SWT, and legal aspects for applying SWT for the production of sustainable electricity. Applying of SWT's in the urban environment is bounded to environmental and construction legislations. Buildings and construction licences need to be aligned with the relevant legislations, which requires measures towards health and safety. Vibration, shadow and noise limitations are often addressed to by national legislations. Also standardisation is applied for several countries; e.g. IEC 64100-2 for 10 m noise analysis.
- **SWT-potential (Pi-chart):** graphical plot, providing data on the Urban Area of the targeted country, and the potential for small wind turbines in MW. Below, more background on these calculations is given.
- **Economical**: economical instruments used for feed in tariffs or other ways to stimulate the usage of small scale wind turbines are addressed here.
- **Wind speed map**: wind speed maps indicate the average wind speeds on low altitude heights (e.g. 10 meter).

Methodology: An estimation of the future wind energy potential in the urban environment cannot easily be given. There is limited experience with the large scale use of SWT's, which prohibits historical data to use. Also the diversity of wind turbines is quite large, which differ in characteristics as P-curves. The lack of a good definition on "build environment" makes it not always clear which differences are being addressed in building types, building functions and ownership-constructions. For this reason the calculation therefore only estimates the total potential of SWT rated capacity.

For the calculation of the SWT-potentials for the various SWIP countries the following equation has been used:

$$SWT\ potential\ [MW] = [1]energy\ density * [2]\ high\ building\ share * [3]Urban\ area$$

- ***[1] Energy density for SWT's per square meter roof:*** The energy density per m^2 roof is estimated at 5 W/m^2.
  This value is based on a Dutch study from 2002 "*on wind energy in the build environment"* [11], and comprehends two main assumptions; s*pacing between SWT's on the roof*: four times the rotor diameter, and the *Installed capacity*: 175 W/m^2 (SWT's vary for 100 W/m^2 and 250 W/m^2 (W/rotor surface).
- ***[2] Share of high buildings in the urban environment****:* A detailed GIS analysis was carried out, based on the dataset 'Basisregistraties Adressen en Gebouwen' (BAG). This dataset consists of different layers with different types of information. Two GIS layers were relevant:
  - The *panden*-layer shows the boundaries of the building and
  - The *verblijfsobject oppervlakte* layer points the location of buildings and gives additional information on these objects, as total floor surface area.

  The height of the various buildings was estimated by combining these layers. By calculating the numbers of floors, the building heights were estimated using an average floor-height of 3,5 meter. The results from the data analysis are shown in Table 5. The analysis data of "Rotterdam City"was held to be representative for the urban environment. The area percentage of buildings higher than 10 meter was calculated on 0,490 %. Also industrial areas are suitable for SWT, the value used for the calculations was based on 2 times 0,490% ≈ 1%.
- ***[3] Urban Area per country***: The share of urban land cover is multiplied by the total land surface of each SWIP country. The share of urban land cover is based on Eurostat data [12], and given in Figure 4. The total surface per SWIP country is based on the size of each country.

Table 5. Buildings in build environment: Rotterdam City and Rotterdam incl. industrial area

Buildings in the build environment: Rotterdam City			
			
Class	**Number of buildings**	**Area (ha)**	**Area percentage**
All Buildings	162037	1801.61	13.81
Buildings with height	103106	1562.98	12.00
Building above 10m	1527	54.63	0.490
Building above 20m	164	9.58	0.073
Building above 30m	80	2.07	0.016
*Area percentage based on outline of the city (13 047.74 ha)			

Buildings in the environment: Rotterdam including industrial area			
			
Class	**Number of buildings**	**Area (ha)**	**Area percentage**
All Buildings	203545	2420.59	7.430
Buildings with height	125399	1888.68	5.797
Building above 10m	1654	57.06	0.175
Building above 20m	196	10.34	0.031
Building above 30m	102	2.54	0.007
*Area percentage based on outline of the city including industrial area (32 579.40 ha)			

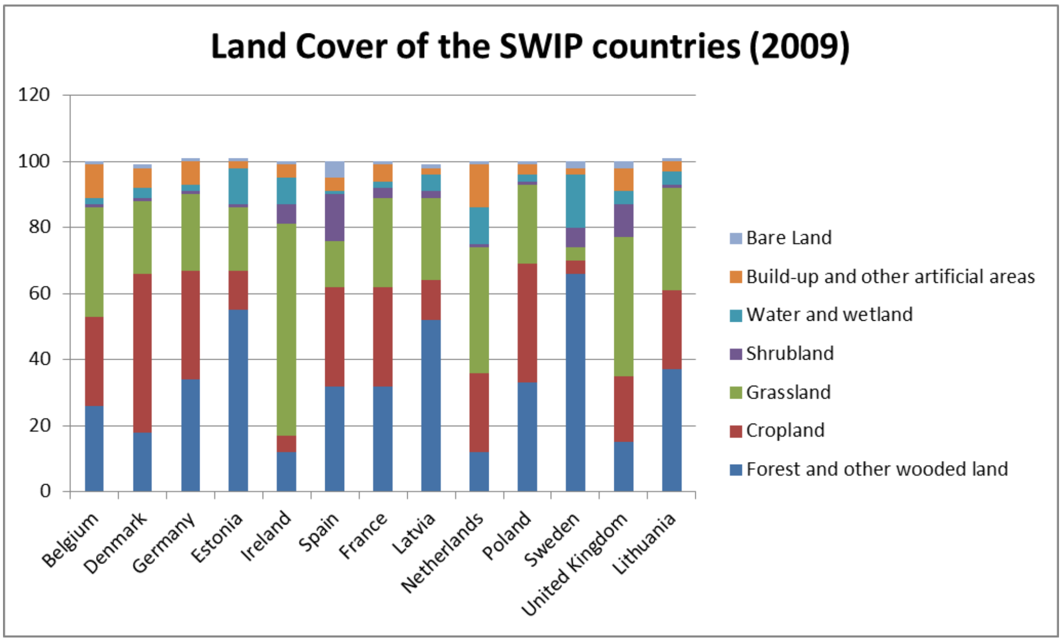


Figure 4 Land cover of the SWIP countries (2009)

Rough estimation on the wind potential per SWIP country, calculated according to Equation 1, is given in Figure 5. The total urban wind potential for the SWIP countries is 6,4 GW installed capacity.

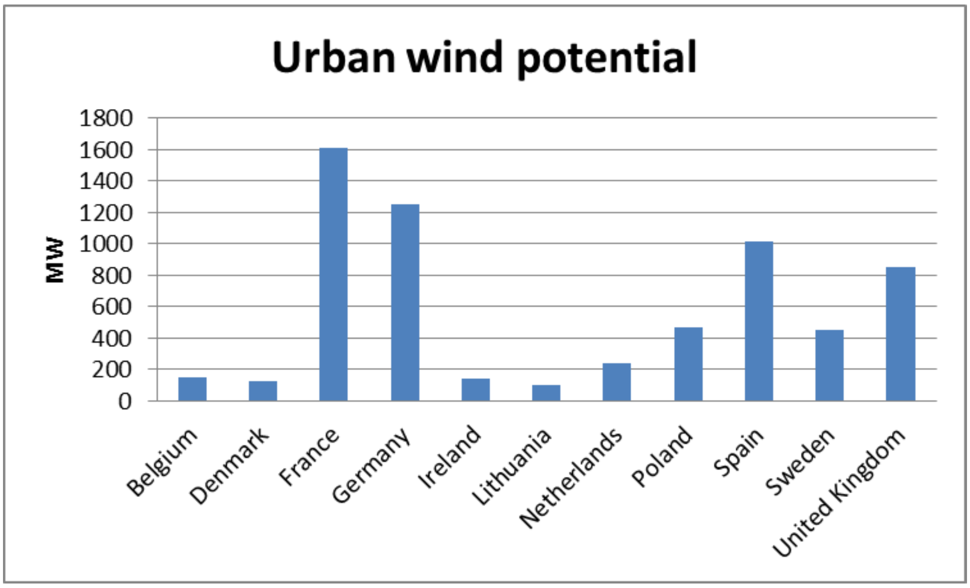


Figure 5 SWT potential in MW, for the various SWIP countries

3.2 Factsheets per SWIP

Wind power is one of the main renewable energy sources in Belgium. However, only about 10% of the available wind energy potential is used, mainly by through large wind turbines. Belgium recognizes that a possible addition to the large wind turbines can be found in micro wind turbines (<3 kW) and small wind turbines (<100 kW). These are (much) smaller and therefore cheaper. There are however not many users, although there are different models available on the market. This is mainly due to the lack of reliable data on the wind speed at low altitude, and the difficulties in obtaining planning permission. Also many individuals and small businesses aren't simply aware of the existence of small wind turbines.

Status: The Belgium Government does not take urban turbines into account for their targets of 3900MW onshore wind. EWEA calculated that the potential of wind power for Belgium is 23% of its electricity usage in 2030.

Status & targets	*Total wind*	*Urban*
Target 2020	*3,9 [GW]*	*-*
Installed	*1.375 [GW]*	*n.a.*
Number of turbines	*385 **	*n.a.*

*2012

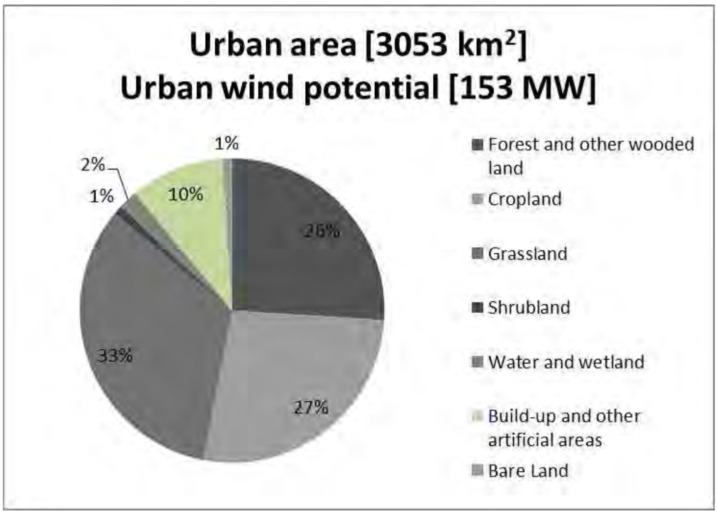
Legal: The permitting procedure depends on the size of the small scale wind turbines. Small wind turbines are defined as max 15m height, mid-scale turbines >15 m with a maximum of 300 kW. Fot both catgeories a building permit is required:

- Safety according to IEC 61400-2 (HAT) or certification test by accredited organization (VAT)
- Integration of the small scale turbine with its surrounding
- Noise limits: max 39 dB(A) in urban area; 59 dB(A) in industrial area during the night
- Shadow: no residents within 2 times tip height; <30 hrs/yr

Other remarks

University of Brussels (ODE Flanders) runs several research projects on urban turbines. University of Genth has a SWT field lab, in collaboration with University College West Flanders.

windspeed at 10 m height



Economical

In Belgium, electricity of renewables is mainly supported through a quota system, based on a certificate trading system. Electricity suppliers are obliged to present green certificates to prove that a certain proportion (quota) of the electricity supplied was generated from renewable sources. This quota may differ according to the regions Brussels, Flanders and Wallonia.

Economical	
Brussels; quota system	3.5% in 2013, 3.8% in 2014 (for 5 years), annual average certificate price EUR 81-92/MWh
Flanders; quota system	15 years, average certificate market price EUR 95.23/MWh (1,287 kWh)
Wallonia	Minimum price EUR 65 (10 years)

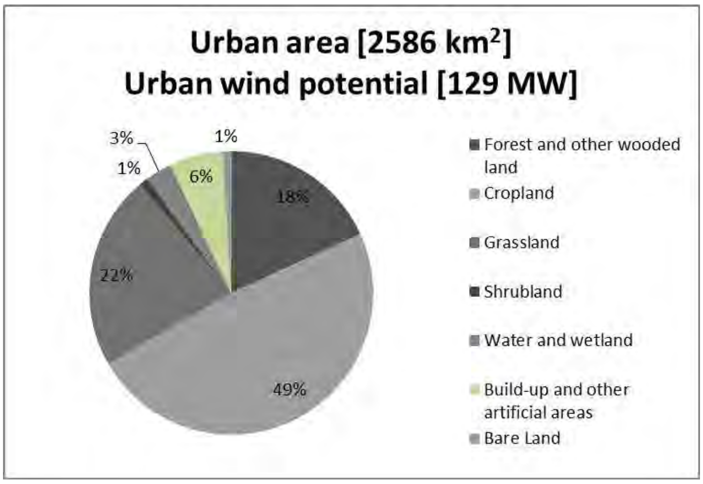
Subsidies for renewable energy investments do not include small scale wind turbines.

Denmark has by far the largest share of wind power of any country in the world. By the end of 2012, wind covered more than 30% of Denmark's electricity consumption. The target is 50% of wind energy in 2020 and the long term strategy is to achieve a 100% renewable energy target in the electricity and heat sector in 2035. To meet the 50% target in 2020 already 2 GW of new wind energy installations is planned. Due to the very effective offshore tendering system the electricity prices are considerable lower than in most other markets in Europe. Denmark has some leading wind turbine producing companies including urban wind.

Status: The Danish Government does not take urban turbines into account for their targets of 50% wind in 2020.

Status & targets	*Total wind*	*Urban*
Target 2020	*6,2[GW]*	-
Installed	*4,2[GW]*	*n.a.*
Number of turbines	*5479*	*n.a.*

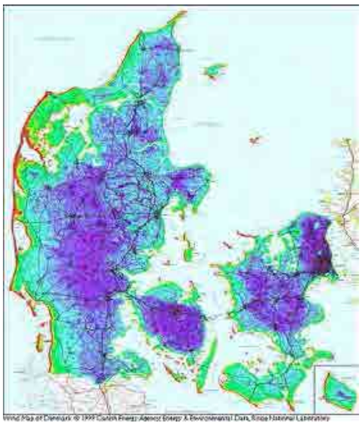
Legal: Municipalities must approve plans for erecting single as well as groups of wind turbines. The construction of a turbine must be registered in advanced with the municipality. The minimum distance to a neighboring home is four times the turbines total height.



Part of the documentation is the noise regulations.

- For dwellings; 39 dB (8 m/s) and 37 dB (6 m/s)
- For dwellings in open country; 44 dB (8 m/s) and 42 dB (6 m/s)

For both categories the limit for low frequency noise is 20 dB. The limit applies to the calculated indoor noise level at both 6 and 8 m/s wind speed.



Red is 8 m/s, dark blue is 5 m/s

Other remarks

Denmark houses the largest R&D wind turbine test facilities in the world. They can test even the world's largest blades of 75 meter

Economical

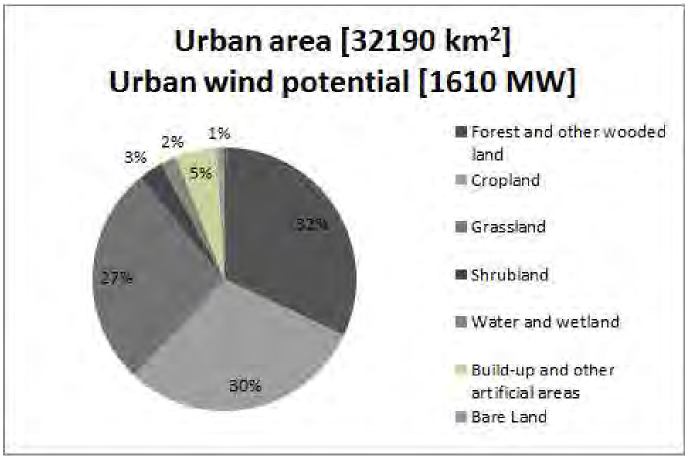
Funding for expanding the renewable energy supply to the electricity grids will be financed through a Pub lic Service Obligation (PSO) scheme via the Energy Bill (DEA 2012)

Economical	
Onshore wind bonus	3c/kWh for first 22.000 kWh
Ceiling with 1:1 subsidy deduction above prices of 8 c/kWh	1 January 2014
Offshore tariff, tendering system	Lowest bid for the first 50.000 full load hours per MW installed capacity

The French government's 'Grenelle Environnement' round table is France's roadmap to a more environmentally-friendly, sustainable land-managed and economically developed society. Two of its core objectives are increased production of renewable energy and more green building construction. Consequently, France has set an ambitious goal of increasing its energy from renewable sources to 36 million tons of oil equivalent (MTOE), raising its energy from renewable sources to 23 percent of the country's total energy mix by 2020.

On 10 February 2000, the Electricity Law (Loi relative à la modernisation du service public de l'électricité) was published including amongst other principles a fixed tariff for electricity generators and a purchase obligation of power for projects up to 12 MW. France has very few installations but has conducted 3 main feasibility studies with wind measurement in Lyon, Grenoble and Lille. The WINEUR project targets on France, but was carried out in 2007.

Status & targets	*Total wind*	*Urban*
Target 2020	*25 [GW]*	*-*
Installed	*7.5[GW]*	*n.a.*
Number of turbines	*5157*	*n.a.*



Legal

Installation of a wind turbine with a height of maximum 12m does not need a construction permit. An impact notice and declaration of the work is required. For small wind turbines with a height of >12m a construction permit is required and an impact study is needed (without public hearing). The French government has very strict noise regulation. Wind turines have to be limited to 3dB(A) above the ambient noise at night and 5 dB(A) daytime.

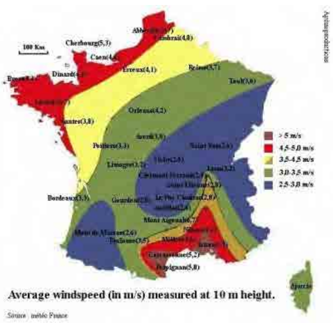
Economical

Electricity from renewables is supported by a Feed-in Tariff (FIT) scheme. The tariffs are guaranteed minimum payments and depend on the investment and O&M costs. Besides the FIT, renewables may receive a premium, depending on the amount of electricity exported.

Economical	
Feed in tariff (2013)	EUR 0.082 per kWh for 10 years and then EUR 0.028-0.082 per kWh for the next 5 years
Tax incentive (Crédit d'Impôt).	Depends on region/province

Other remarks

France is the third largest European market for wind power, annual investments one billion euros. Approx. 888 MW were installed in 2007, for a total wind power capacity of 2455 MW.



Ref : WINEUR; EU ; Wind energy integration in the urban environment

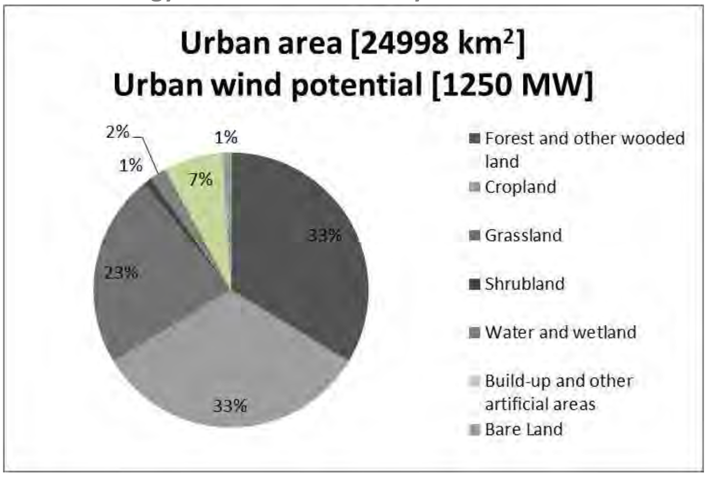
Ref: FRANCE: Renewable Energy Market Overview



Germany

Compared to the climate goals of the EU, which aim at reducing emissions in the same period by 30%, the German climate goals are even more ambitious. A pivotal measure to reach the climate goals is the extensive support of renewable energy sources (RES). In particular, this includes the stepwise increase of the share of RES in primary energy generation to 35%. In the year 2011, this share was already at about 20% (AfEE, 2011). Despite increasing shares of RES, technical, economic, environmental as well as social acceptance problems are more and more slowing down the energy transition in Germany.

Status & targets	*Total wind*	*Urban*
Target 2020	*49-52 [GW]*	-
Installed	*31.3 [GW]*	*n.a.*
Number of turbines	*23572*	*n.a.*



Legal

The small-wind market is growing worldwide. Germany has a very high demand, but due to federal differences in permission, the market is blocked.

Building permission in Germany:

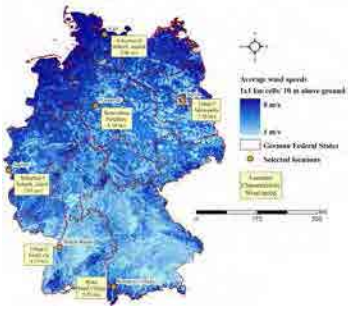
• Partly permission-free up to 10m height (almost everything can be constructed)

• >10m from simple statics and noise-analysis to IEC 64100-2 Certificate (Costs for IEC up to 200 000€ per turbine)

• >30m obligations increase – partly not permittable and economic

• >50m extremely high obligations – not economic

With the following certifications, one can be relatively sure that the turbine is of good quality: IEC 64400-2, AWEA, MCS1



Windspeed 10 m height

Status

Germany was for many years at the top of the international league table for wind power generating capacity. In 2008, however, Germany was pushed into second position by the USA and in 2010 into third position by China. Since 2000 Germany's total wind capacity has gone from 8.8 GW to 31.3 GW, an annual average growth of 1.9 GW.

Economical

In the case that the plant's yield falls short of a plant-specific reference level, the payment period of the increased tariff can be extended. In order to decrease the costs of the plant operators, SWT are assumed to reach only 60% of the reference level, so that, in total, the increased tariff can be paid for 16 years and 8 months.

Economical	
Feed in tariff	8,93c/kWh for first 5 years 4,83c/kWh after 5 years
Bonus payment if you meet the technical requirements of SDL WindV	0,48 c/kWh

1R. Schneider, Small wind turbines: Electricity for self-consumption.2Grieser et al., FCN Working Paper ; 1/2013. 3 Wind Energy Report Germany 2011

Ireland

Ireland is a comparative newcomer to urban wind energy though it has long adapted to rural and offshore wind. The total energy load requirement target for renewables is an estimated 6,000 MW (40% of the total energy generation requirement by 2020, of which wind will satisfy 92%). Approximately 1,500 Mw had been established by 2010 which has been estimated to displace over 1.3 million tonnes of CO2 emissions. Ireland at present is 85.2% dependent on imported energy supplies. There are 2 major manufacturers of medium and micro wind turbines which hold 80% of the market share of installed devices. These comprise almost exclusively conventional horizontal axis configurations with low penetration into urban settings. Two experimental medium size research machines are in operation

Status

The total energy load requirement target for wind generation is an estimated 6,000 MW (40% of the total energy generation requirement). Ireland at present has 15% renewables in its energy mix..

Status & targets	*Total wind*	*Urban*
Target 2020	*6 [GW]*	-
Installed	*1,7 [GW]**	*2 [MW]***
Number of turbines	*1178*	*300-400*

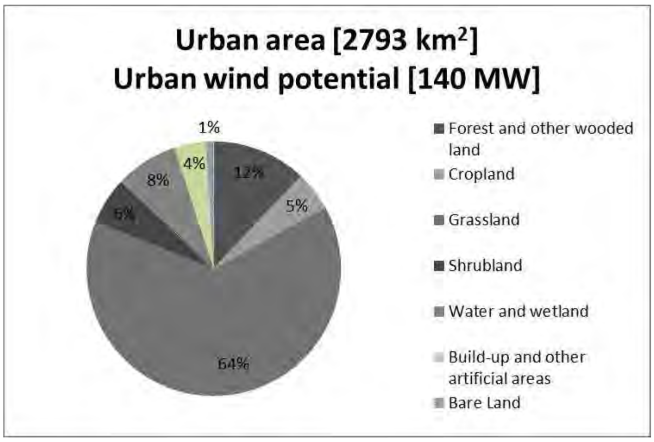
*2012, **2010

By the end of 2010 of the order of 2MW of micro wind has been installed at about 300-400 predominantly rural sites. Micro wind has about a 92% share of the micro-generation market and site location is strongly influenced by the presence of a local manufacturer. With a few notable exceptions there is almost no wind energy presence in urban or peri urban areas in Ireland

Other remarks

The Irish Electricity Networks classify turbines of less than 6kW as microgenerators and will facilitate grid connection by providing metering and expertise and favourable pricing for exported energy

Windspeed at 50 m height



Economical

Ireland does not support installation costs or pay for avoided generation (ie own consumption upstream of the meter) .

Economical	
Feed in tariff for microgeneration	19c/kWh for first 5 years 10c/kWh after 5 years
Limit to	3000 kWh per year

Legal

Subject to certain conditions domestic wind turbines may be exempt from planning requirements up to a maximum hub height of 10m and total (tip) height of 13m. Commercial installations (and the agricultural sector) 2008 saw an increase in the exemption up to the maximum (blade tip) height of 20m

The Standard EN 61400-11:2003.is used to regulate noise and vibration impact with 43dB(A) (or 5dB(A) above background noise) being the maximum permitted at generation or nearest neighbour's premises (whichever is closer). The interface with the grid must be of EN 50438 type compliant. ESB Networks maintains a list of 'type tests' for EN50438

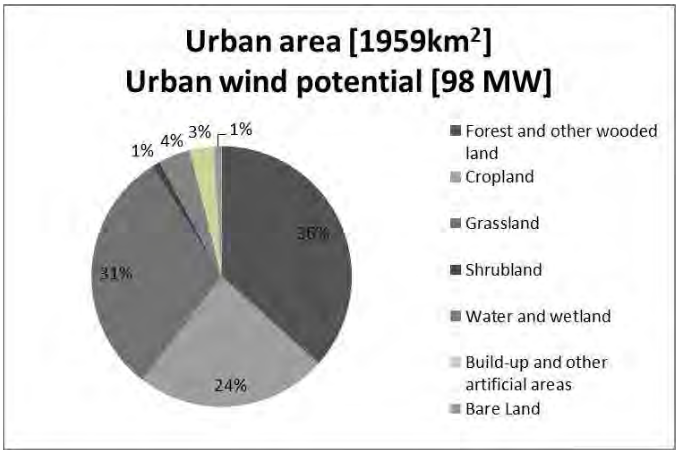
Lithuania

The wind sector develops slowly in Lithuania. Developments have been influenced by one of the most unfavorable wind energy support schemes in the EU. Since 20012 developers have to compete to each other. National Energy Strategy has set 500 MW as the goal for wind energy for 2020. However, small scale wind turbines are popular in Lithuania. The reason of small-scale wind turbines popularity is the new legal basis for installation with its wind turbine power differentiation in national legislation. Turbines with an installed power of <30 kW are permitted quite easily, which has led to an increase of small scale wind turbines.

Status

The main goal of Lithuania government is 500 MW in 2020.

Status & targets	Total wind	Urban
Target 2020	500	-
Installed [MW]	225	n.a.
Number of turbines	103	n.a.



Legal

In Lithuania wind turbines are differentiated according to their installed power (<35kW, 35-350 kW, >350 kW) Depending on the size several permissions are required to construct a wind turbine and generate electricity to the grid. For small scale wind turbines (<350 kW) territorial planning procedures are not required. Changing of land use purpose is not required either. The technical requirements of the application are simple compared to larger wind turbines.

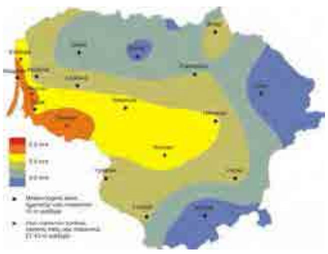
No general legal restrictions for wind turbines apply. Each project is therefore separately reviewed and assessed.

Commonly used in the assessment are:

- Noise: 45 dB at night,
- Shadow: limit of 30 hrs per year and 30 min/day

Other remarks

The differentiation of wind turbines according to their installed power has recently led to the expansion of small scale turbines, and it is likely that this will continue in the future.



Economical

Electricity from renewable sources is supported through a feed-in tariff. The tariff for wind projects >10 kW are awarded through tenders. The tariff for plants <10kW are fixed

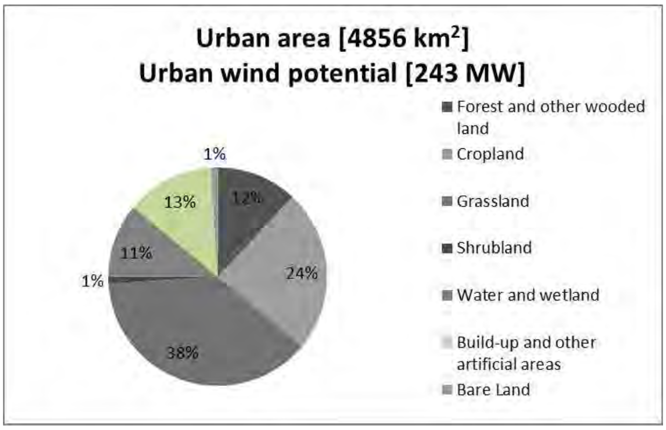
Economical	
Feed in <10kW	9,56c/kWh; <12 yrs
Feed in >10kW	9,27c/kWh (10-350 kW) or 7,53c/kWh (>350 kW) <12 yrs
LEIF Investment subsidy	Max 199.826 euro (or 80% of the investment) over 3 years
Rural dev. subsidy	Max 65% of the investment
Local Climate subsidy	Sunbsidy or loan
Excise taks relief	RES exempt from excise tax

Projects that have received financial support from national or European funds, are not entitled to compete for feed-in tariffs, because double support is not allowed for the same project. In such case wind electricity must be sold in the market.

The Netherlands are market leader in urban wind turbines; more than 20 manufacturers of urban wind turbines have developed and installed urban turbines. Dutch manufacturers are front-runners in developing new technologies. Urban turbines are not certified, although the Dutch Wind Energy Association (NWEA) and some developers have started a pilot project in certification their turbines. In the Netherlands most urban turbines are installed at industrial companies and at municipal buildings to enlarge their green image.

Status

The Dutch Government does not take urban turbines into account for their targets of 6000 MW onshore wind. Therefore urban turbines are not financially stimulated with the feed in tariff SDE+.



Status & targets	Total wind	Urban
Installed [MW][2013]	2,434	1
Number of turbines [2013]	1,950	400
Target [2020]	6,000	-

Legal

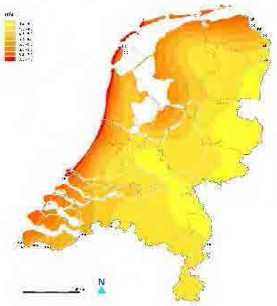
Certification of urban turbines is -in contrast to normal wind turbines- not required. Certification could significantly reduce permitting procedure, which takes now 3-6 months.

Required permits:

- Building permit according to "Activiteitenbesluit": Noise: Lden 47 dB and Lnight 41 dB, Shadow: max 6 hrs per year.
- "Bouwbesluit": Safety aspects and load calculations for construction.
- "Welstandcheck": Architectural check.

Other remarks

In 2007 the Province of Zeeland started a pilot project of urban turbines on the Technopark test field. The first results led to changes in design of some urban turbines. Noise was one of the most critical aspects.



Economical

The Dutch Ministry of Economic Affairs translated their goals in the feed-in (tariff) support scheme SDE+. the scheme supports the production of renewable gas and electricity. There is no such a category for urban wind, although urban turbines are allowed to apply for the common wind turbine tariff.

Economical	
Feed in tariff (2013)	Max 9.5 ct/kWh for 15 yrs
Energy Investment Subsidy	44% tax reduction on the investment costs
Local Climate subsidy	Depends on region/province

Some provinces or regions have specific investment subsidies for urban turbines because of their local climate targets .For companies there is an energy Investment Subsidy (called EIA) which allows developers to use 44% tax reduction on investment costs.

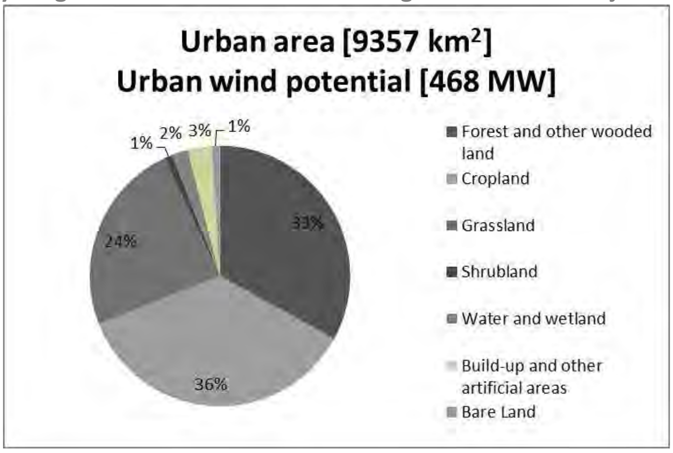
The Polish small wind turbines market is a developing one. SWTs capacity in Poland at the beginning of 2013 was 8,2 MW. 150 companies offer SWT models, while only 6% of them reported significant annual sales and another 27% only a few units annually. 4 polish manufacturers offer 12 SWT models in a capacity range from 1 to 75 kW. The sector gives 300 full-time jobs.

Status

According to the Polish National Renewable Energy Action Plan (2010) there should be 550 MW small wind turbines installed by 2020. This is equivalent to approx. 100 000 installations. There is no feed-in-tariff in Poland – tradable 'green certificates' system is set instead resulting in lack of support for small installations.

Status & targets	Large onshore[1)]	Small [2)]
Installed [MW][2013]	3,080	8,2
Number of turbines [2013]	795	3000[3)]
Target [MW] [2020]	5,600	550

[1)] as of 30.09.2013; [2)] urban <5 %; [3)] estimated; only 1% on-grid



Legal

SWTs (up to 30 m) and outside protected areas do not require EIA procedure. When WT is located on top of building and the construction is lower than 3 m – no building permission is required. In case the WT is higher or it is situated on the ground but without foundations – so called construction notification is required (if authorities have no objections one can start building after 30 days). In case of other WTs it is necessary to acquire planning permission and building permit (ca. 3-6 months).

Other remarks

Energy production off-grid does not require additional permissions. In case investor decides to sell energy (on-grid installation):

RES micro-installation	Small RES installation
up to 40 kW$_e$	over 40 – 200 kW$_e$
no fee for grid connection	50% fee for grid connection
energy production is not a business activity (natural persons do not have to establish companies)	natural persons have to establish companies to become energy producer
no license for the production of energy is required	license for the production of energy is required
guaranteed price for electricity (80% of the average selling price of electricity on the competitive market in the previous year)	green certificates for MWh of electricity produced + average selling price of electricity on the competitive market in the previous year

Economical

Presently uniform green certificates (certificates of origin) scheme supports all renewable energy generators. Retailers are obliged to source specified and increasing share of their final electricity from renewable generators or to pay a 'substitute fee'. In 2013 price of certificates at the Polish Power Exchange has fallen by 20-35% as compared with the substitute fee and previous certificates price.

Economical	
Green Certificate (2013)	3.0-4.5 c/kWh
Energy sale (2013)	4.5 c/kWh
Investment Subsidy	N/A
Climate subsidy	N/A

The new Renewable Energy Law is discussed; special support to micro- and small installations is expected.

No general support system for installation of small WTs is available. Installations of SWTs can get support within general modernization projects, where use of RES is supported. This includes EU, EEA, Swiss, AUU funds and national environmental funds.

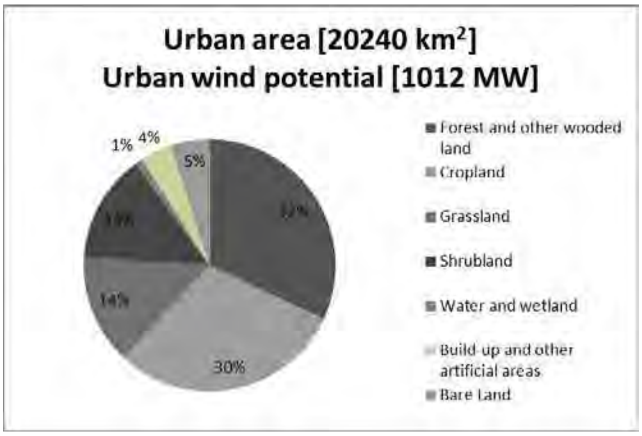
Spain is characterized by its great potential in wind resource and currently is the fourth country in the world regarding wind energy power (22785 MW at the end of the year 2012), behind China, US and Germany. As for small wind turbines, Spain has a broad market: more than a dozen domestic manufacturers of urban wind turbines, which have developed and installed multiple models, increasing technological competitiveness. It is important to emphasize the growing interest of public and private actors about small wind turbines and the support from IDAE and CIEMAT.

Status

The Spanish Government takes into account urban wind turbines (300 MW) and offshore turbines (750 MW) for their targets of 35750 MW wind power.

Status & targets	Total wind	Urban
Installed [MW][2012]	22785	1
Number of turbines [2013]	20190	Unknown
Target [2020][MW]	35750	300

The information of the above data has been obtained from the AEE (Asociación Empresarial Eólica) Annual Report (2013) and PER (Spanish Government Renewable Energy Plan) 2011-2020



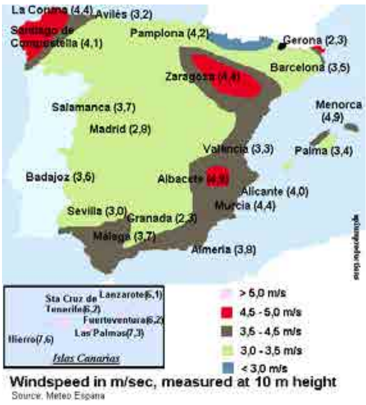
Legal

The certification of urban turbines is required. (Standardization of technical instructions and procedures affecting the equipment). Facilities <100 kW require specific steps in the following administrations, according to RD 1699/2011 (Electrical company, Central and local government and Council)

Other remarks

Great efforts are being undertaken to realize a wind resource map in different parts of Spain.

In 2010, Lanzarote island started a project of urban wind resource map for modeling the wind resource in the island.



Economical

The short-term scenario in terms of economic retribution for renewable energy has a large uncertainty. There is no such a category for urban wind, although urban turbines are allowed to apply for the common wind turbine tariff.

The Spanish government modified the law by RD 1/2012, eliminating the incentives for renewable energies so new facilities have to sell their energy production to the electric market without incentives.

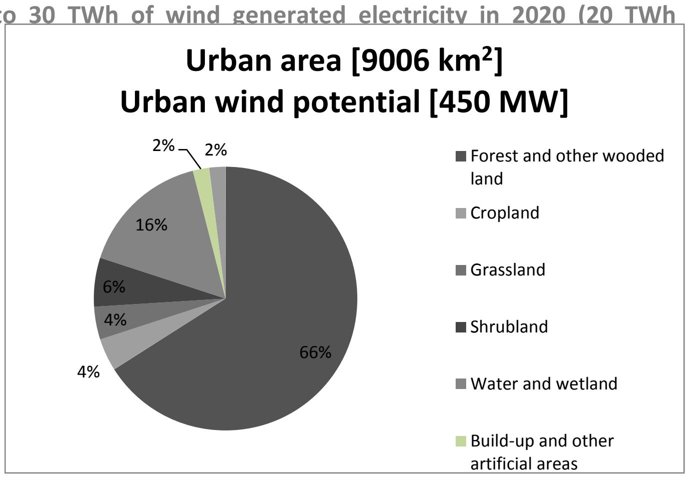
Economical	
Pool price average (2012)	47.23 €/MWh

Spanish government is going to launch a new law, which treats about self-consumption to regulate the use of small scale renewable energy, especially small wind turbines.

Other theories are being studied as the net energy balance that would go in the same direction, encouraging consumers to install small wind turbines or photovoltaic panels at their homes.

Sweden

In Sweden the market for small scale turbines has grown rapidly over the last ten years. There are several domestic manufacturers are active on the (inter)nation market. These turbines are mainly built for small businesses, residential homes and remote locations. Based on EU renewables directive the target for Sweden is 49% pf renewables by 2020. Based on this directive the Swedish government has set the national goal to 30 TWh of wind generated electricity in 2020 (20 TWh onshore)



Status

For the target of 30 TWh of generated electricity by wind, 20 TWh is onshore and 10 TWh is for offshore wind. This policy is however not adapted to small scale wind turbines.

Status & targets	Total wind	Urban
Installed [MW][2012]	3745	1
Number of turbines [2013]		Unknown
Target [2020][TWh]	30	n.a.

Legal

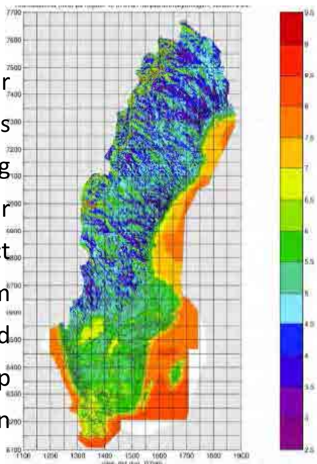
Depending on the size, Small scale wind turbines planning permission under the Planning and Building Act is required if:

- 20-50m height,
- Rotor diameter >3m,
- rotor area max 200m2,
- max 43.5 kW.

Building permit for small scale wind turbines is not required if the rotor diameter is less than 2m.

Other remarks

In Sweden the market for small scale wind turbines is expected to grow coming years even more. For instance in the project „Vision for Stockholm 2050"small scale urban wind turbines for built up environment has been planned.



Economical

In Sweden, electricity of renewables is supported through a quota system, based on a certificate trading system (Electricity Certificates Act) One certificate is issued for every MWh of electricity produced, regardless of the generation technology employed. Since the 1st of January 2012 the Swedish electricity certificate system has been expanded and has become a common Swedish-Norwegian market for electricity certificates.

Economical	
Amount of quota	0.135 (2013), 0.142 (2014)
Annual average certificate price	Per MWh 178.50 kronor (EUR 20.26) in 2013 for 15 years
Reduced real estate tax	0.2 % of the value of the wind plant
RD&D policy Grants for investments in energy efficiency (small enterprises)	80 % of the eligible costs

Some provinces or regions have specific investment subsidies for urban turbines because of their local climate targets .For companies there is an energy Investment Subsidy (called EIA) which allows developers to use 44% tax reduction on investment costs.

United Kingdom

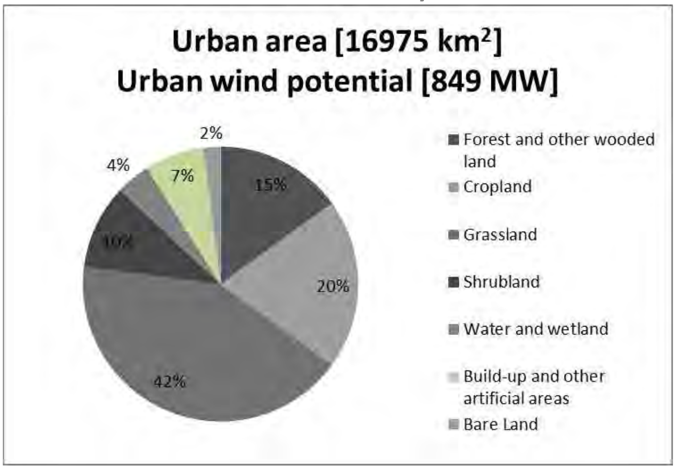
The UK is one of the best locations for wind power in the world. Onshore wind, as one of the most cost effective and proven renewable energy technologies, has an important part to play in the UK energy policy. Significant progress has been made in 2013 to reform electricity market to set the right conditions to support investments in renewable energy. The Renewables Obligation (RO) and Feed in Tariffs (FITs) scheme continue to play a crucial role in supporting commercial and small scale renewables electricity capacity. In April 2013support rates for onshore wind under the R.O. were cut by 10%.

Status

The UK Government does not take urban turbines into account for their targets in 2020

Status & targets	*Total wind*	*Urban*
Target 2020	*29 [GW]*	-
Installed	*10,5 [GW]**	*26,3 [MW]***
Number of turbines	*5903****	*27866***

*June 2013, **2009, *** Large wind turbines



Legal

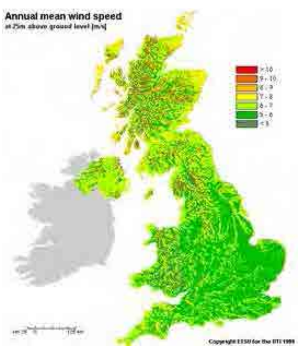
In England and Scotland, an urban turbine may be classified as Permitted Development, in which case planning permission will not be needed. Criteria for both countries are different. England;

- Building mounted turbines; the top of the turbine blades is no more than three metres above the top of the house, or 15 metres above the ground and >5m from the edge of the property
- Pole mounted; the top of the turbine is no more than 11.1 metres above ground and at least 1.1 times the height of the turbine away from the edge

In Scotland a planning permission is required for building mounted turbines.

Other remarks

In 2006-2008the Warwick windtrials project monitored 23 rooftop wind installations on a variety of urban and rural sites. Results of the trial showed an average capacity factor of 4.15%.



Economical

The feed-in tariff (FIT) of the UK supports most forms of renewable energy. For wind energy projects the amount depends on the installed power of the turbine. Urban turbines (<100 kW) receive the highest tariff for production; 24,65c/kWh. In addition to the main generation tariff, an additional payment is received for electricity exported to the grid. A bonus payment for every kWh of (surplus) electricity exported to the grid.

Economical	
Feed in tariff (2013)	24.65 c/kWh for 20 years
Bonus payment	5.54 c/kWh

In December 2013 the government announced major changes for renewable energy subsidies. Rebalancing the subsidies include a subsidy cut for onshore wind and solar from 2015, while the amount paid for offshore wind will be increased.

4 Conclusions

Benchmarking of small-scale wind turbines has involved collection of basic data on the technical parameters (not always comparable) available to the general public. The data has been compiled from the information and materials published on the websites of wind turbine manufacturers.

The data does not make it possible to compare the produced wind machines in order to choose a wind turbine which is best in a given category.

The study has set a basis from where the project can develop its improvements beyond the state of the art. Outcome of the present benchmarking study supports the planned activities within the project aiming at technological development and setting new practices in use of WTs in urban environment. This implies continuation of activities within the project, including modelling of wind conditions at WT location in order to optimise WT selection and location, design of WTs better suited to urban environment, development of technology of WT components in order to reduce costs and make construction robust and proper selection of WTs for operation at urban locations characterized by high energy generation, low noise and vibration and low maintenance costs.

There are many regulations, policies and standards that apply to the wind sector. It is clear that none of the SWIP countries did include urban wind in their 2020 targets. Policies and regulations are mainly lacking for urban wind turbines. In most SWIP countries SWT are treated economical equally as large wind turbines making it highly unattractive to invest in SWTs. For now SWTs seem to play only a roll in niche markets. For a high market penetration not only the technical aspects of the SWTs need to improve but also specific policies and regulations for SWT are needed. This seems justified because looking only at the urban wind potential numbers show that it can play a substantial roll in the future electricity market with a total installed capacity of 6,4 GW for the SWIP countries. This installed capacity is calculated assuming a yield of 5MW per km^2 of urban area at 10 m altitude.

The market outlook is summarized in four categories in the table below.

Table 6. Market outlook

Market Outlook	Wind speed	Legal	Economical	Size Market
Belgium	+	+/-	+/-	+/-
Denmark	++	+/-	-	+/-
France	+	+	+/-	++
Germany	+	+	+/-	++
Ireland	++	+	+	+/-
Lithuania	+/-	++	+	-
Netherlands	+	+	+/-	+/-
Poland	+	++	-	+
Spain	-	+/-	-	++
Sweden	+	+	+/-	+
United Kingdom	++	+	++	+

Almost all countries have favourable wind speeds with Denmark, Ireland and the UK as most promising countries. Only Spain is less favourable, only in a small part of the country wind speeds are above 5 – 6 m/s at 10 meter. Most countries permits are needed even for the SWT, but some of the countries allow free installations if the SWT are below a certain level or if they are installed on the roofs and don’t have long blades. All countries have noise level requirements for WTs and some of them have rules about shadows and vibrations. Most favourable countries legally speaking are Poland and Lithuania. Economical almost none of the countries have a specific FIT system for SWT; only the UK is a positive exception. The size of the market is dependent on the size of the country and the amount of urban area. Overall the UK seems to have the most favourable market outlook for urban wind with Ireland as runner up.

5 References

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6 Annex

Technical data of reviewed small WTs is attached.