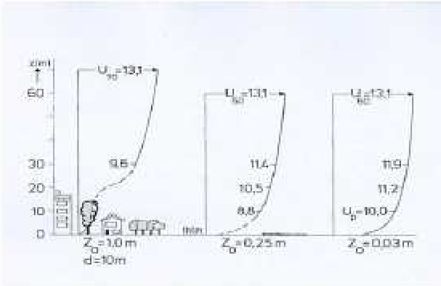
Wind

Wind is the result of pressure differences in the atmosphere; the speed and the direction of wind are determined by the ratio of the pressure differences and the distance between the centres of high and low pressure.
At sufficient height (100 meters) wind speed and direction will be the same in a large area. Closer to the ground the pattern changes due to the resistance the wind has met on its way.
At ground level wind speed is practically zero. Depending on the terrain over which the wind blows, speed increases faster or slower with increasing height. A surface of water offers little resistance and therefore at little height the wind is already very noticeable. That's why we always experience wind on the water[1].
In urban or built-up areas the wind is severely obstructed. There is air movement between buildings, but that is turbulence, not wind. Only above the average building height does the air movement become wind; the "reference height level" for wind in an urban or built-up area is 10 meters and higher.
Wind speed data are normally collected at a height of 10 m above ground level or are converted to that height. On the basis of the average wind speed at 10m height, the terrain roughness, and the geographic location, the expected wind speed distribution for an intended turbine placement can be calculated.

In summary:
The wind speed at a certain location is determined by the geographical location, the height and the terrain roughness.

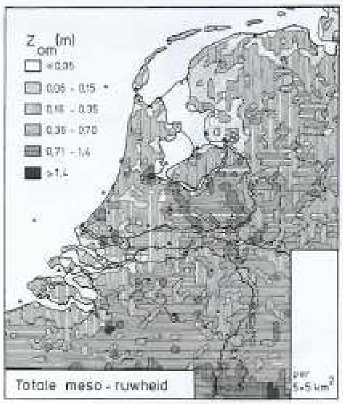
Figure 3.24



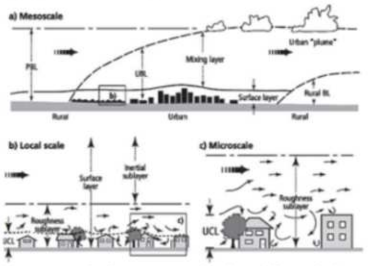
Windspeed profiles above different terrain roughness z_0 (and displacement height d) at a mesoscale wind speed
Um=13.1 m/s at approx. 60m

Note: the terrain roughness is indicated as the "roughness length" of the terrain and stated as a measure of length.
For the Netherlands the KNMI[2] has depicted these data in a "stain chart"[3].

The roughness:

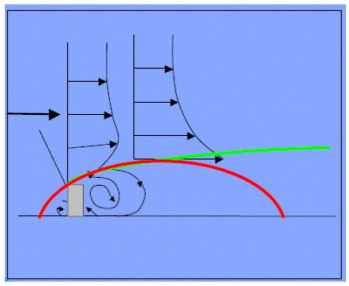


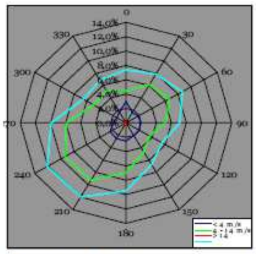
Urban population is more than half of the world population nowadays. Urban environment is crucial for urban inhabitants' health and comfort.



There are three scales used to distinguish atmospheric processes in urban area and different atmospheric layers are typically identified at each scale.
a)Mesoscale: planetary boundary layer (PBL);
b)Local scale: Surface layer;
c)Microscale: Urban canopy layer (UCL) and Roughness sublayer (RSL). Due to the heterogeneity of urban areas, the microscale processes in the UCL are dominated by turbulence and are strongly affected by urban morphology.

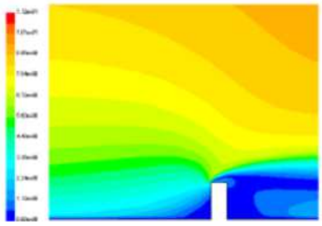
Thermal stratification (due to solar radiation, anthropogenic heat, etc) plays an important role in the wind flow and pollutant dispersion processes. It will not only affect human comfort, but also contribute to the urban heat island (UHI) effect.

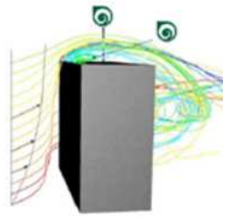


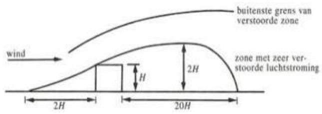


The chart above shows as an example the wind distribution for Schiphol airport. For the wind speeds relevant to small rooftop turbines (4–14 m/s range) the wind is about 35 % of the time blowing from the south-westerly quadrant; the remaining 65 % of the year the winds blows from other directions.

Wind over buildings
Depicted below are the results of computer calculations showing the effect of an obstacle on the wind flow around that obstacle.
The picture below shows the influence of a long obstacle (e.g. a building) on the wind in the vicinity of that obstacle. Note that the deviations start long before the wind reaches the obstacle and continue far beyond it.







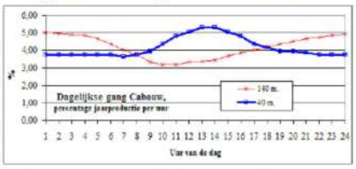
[1] With thanks, this figure has been taken from [1] Wind Climate of the Netherlands

[2] =Royal Netherlands Meteorological Institute
[3] With thanks, figures have been taken from [1] Wind Climate of the Netherlands

Beaufort number	Description	Wind speed	Wave height	Land condition
0	Calm	< 1 km/h < 1 mph < 1 knot **< 0.3 m/s**	0 m 0 ft	Calm. Smoke rises vertically.
1	Light air	1.1–5.5 km/h 1–3 mph 1–3 knot **0.3–1.5 m/s**	0–0.2 m 0–1 ft	Smoke drift indicates wind direction. Leaves and wind vanes are stationary.
2	Light breeze	5.6–11 km/h 4–7 mph 4–6 knot **1.6–3.4 m/s**	0.2–0.5 m 1–2 ft	Wind felt on exposed skin. Leaves rustle. Wind vanes begin to move.
3	Gentle breeze	12–19 km/h 8–12 mph 7–10 knot **3.5–5.4 m/s**	0.5–1 m 2–3.5 ft	Leaves and small twigs constantly moving, light flags extended.
4	Moderate breeze	20–28 km/h 13–17 mph 11–16 knot **5.5–7.9 m/s**	1–2 m 3.5–6 ft	Dust and loose paper raised. Small branches begin to move.
5	Fresh breeze	29–38 km/h 18–24 mph 17–21 knot **8.0–10.7 m/s**	2–3 m 6–9 ft	Branches of a moderate size move. Small trees in leaf begin to sway.
6	Strong breeze	39–49 km/h 25–30 mph 22–27 knot **10.8–13.8 m/s**	3–4 m 9–13 ft	Large branches in motion. Whistling heard in overhead
7	High wind, moderate gale, near gale	50–61 km/h 31–38 mph 28–33 knot **13.9–17.1 m/s**	4–5.5 m 13–19 ft	Whole trees in motion. Effort needed to walk against the wind.
8	Gale,	62–74 km/h 39–46 mph 34–40 knot **17.2–20.7 m/s**	5.5–7.5 m 18–25 ft	Some twigs broken from trees. Cars veer on road. Progress on foot is seriously impeded.
9	Strong gale	75–88 km/h 47–54 mph 41–47 knot **20.8–24.4 m/s**	7–10 m 23–32 ft	Some branches break off trees, and some small trees blow over. Construction /temporary signs and barricades
10	Storm,[6] whole gale	89–102 km/h 55–63 mph 48–55 knot **24.5–28.4 m/s**	9–12.5 m 29–41 ft	Trees are broken off or uprooted, saplings bent and deformed. Poorly attached asphalt
11	Violent storm	103–117 km/h 64–73 mph 56–63 knot **28.5–32.6 m/s**	11.5–16 m 37–52 ft	Widespread damage to vegetation. Many roofing surfaces are damaged; asphalt tiles that have
12	Hurricane [6]	≥ 118 km/h	≥ 14 m	Very widespread damage to vegetation. Some windows may break; mobile homes and poorly constructed sheds and

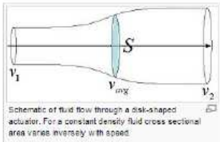
daytime: low more wind

nighttime: higher more wind



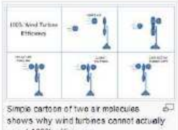
horizontal: 24 hours of the day

Betz's law calculates the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow. It was published in 1919, by the German physicist Albert Betz.[1] The law is derived from the principles of conservation of mass and momentum of the air stream flowing through an idealized "actuator disk" that extracts energy from the wind stream. According to Betz's law, no turbine can capture more than 16/27 (59.3 percent) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit.



Schematic of fluid flow through a disk-shaped actuator. For a constant density fluid cross sectional area varies inversely with speed.

Betz law means that wind turbines are limited to 59.3% efficiency. Consider that if all of the energy coming from wind movement into the turbine were extracted as useful energy then the wind speed afterwards would drop to zero. If the wind stopped moving at the exit of the turbine, then no more fresh wind could get in - it would be blocked. In order to keep the wind moving through the turbine there has to be some wind movement, however small, on the other side with a wind speed greater than zero. Betz law shows that as air flows through area, and when it slows from losing energy to extraction from a turbine, it must spread out to a wider area. Geometry is what limits Betz efficiency to 59.3%.



Simple cartoon of two air molecules shows why wind turbines cannot actually run at 100% efficiency.

Calculate it yourself: with are Archimeteo or Also possible:
buy an hand-wind meter/mini weather station, and extrapolate/compare it with an local weather station for min. 30 days. And calculate the difference between the local weather station and your local wind meter (m/s).
Use the weather station wind data (minus or plus m/s with your roof per day-hour).
For the global calculation for the wind you can capture on your roof. Also try different good wind locations on your roof (it can be > of < 70%), due to wind-shadow.

more info: www.knmi.nl/cms/content/27059/windmetingen
www.knmi.nl/cms/content/36825/wind
www.knmi.nl/klimatologie/windrozen/index.cgi
www.nauticlink.com/nieuws/knmi/windverwachting.html
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