

HAWT farm energy production

example		HAWTs	Farm 20x	Energy
Wind Speed	probability	rating	12 MW	=
m/s	% of time	Cp	MW	Probability
				x MW
				x20
1	0.3%	0		
2	2.3%	0		
3	4.1%	0.200	0.1	0.1010
4	5.5%	0.350	0.5	0.5620
5	6.3%	0.420	1.2	1.5087
6	7.2%	0.450	2.2	3.1924
7	7.8%	0.470	3.7	5.7359
8	8.2%	0.480	5.6	9.1927
9	8.2%	0.480	8.0	13.0888
10	7.8%	0.480	10.9	17.0786
11	7.3%	0.400	12.0	17.5514
12	6.5%	0.305	12.0	15.6269
13	5.6%	0.240	12.0	13.4693
14	4.5%	0.192	12.0	10.8147
15	3.8%	0.156	12.0	9.1264
16	3.1%	0.128	12.0	7.4139
17	2.6%	0.107	12.0	6.2348
18	2.1%	0.090	12.0	5.0280
19	1.6%	0.077	12.0	3.8547
20	1.3%	0.066	12.0	3.1311
21	1.0%	0		
22	0.8%	0		
23	0.6%	0		
24	0.3%	0		
25	0.2%	0		
Total	99.0%			142.7113
			capacity	59.46%

Note

An HAWT wind farm can only extract energy up to its rated power. The Cp decreases until a limiting wind speed when the blades are feathered

The actual generated output will be site specific

Cp = collectable wind energy divided by total wind energy

capacity: as % of continuous rated generation power.

Enhanced energy harvesting due to kinetic storage

Example	probability	VAWT rating	240 MW	Energy = Probability x MW	Stored Energy	% loss of stored energy	Loss
Wind Speed m/s	% of time	Cp	MW				
1	0.3%	0					
2	2.3%	0					
3	4.1%	0.300	3.6	0.1476			
4	5.5%	0.400	11.5	0.6325			
5	6.3%	0.400	22.5	1.4175			
6	7.2%	0.400	38.9	2.8008			
7	7.8%	0.400	61.7	4.8126			
8	8.2%	0.400	92.2	7.5604			
9	8.2%	0.400	131.2	10.7584			
10	7.8%	0.400	180	14.0400			
11	7.3%	0.400	240	17.5200			
12	6.5%	0.400	311	20.2150	4.6150	5.0%	0.2308
13	5.6%	0.400	395.5	22.1480	8.7080	10.0%	0.8708
14	4.5%	0.400	493.9	22.2255	11.4255	15.0%	1.7138
15	3.8%	0.400	607.5	23.0850	13.9650	20.0%	2.7930
16	3.1%	0.362	667.2	20.6832	13.2432	25.0%	3.3108
17	2.6%	0.324	716.3	18.6238	12.3838	30.0%	3.7151
18	2.1%	0.282	740.1	15.5421	10.5021	35.0%	3.6757
19	1.6%	0.243	750	12.0000	8.1600	40.0%	3.2640
20	1.3%	0.209	750	9.7500	6.6300	45.0%	2.9835
21	1.0%	0.18	750	7.5000	5.1000	50.0%	2.5500
22	0.8%	0.157	750	6.0000	4.0800	55.0%	2.2440
23	0.6%	0.137	750	4.5000	3.0600	60.0%	1.8360
24	0.3%	0.121	750	2.2500	1.5300	65.0%	0.9945
25	0.2%	0.107	750	1.5000	1.0200	70.0%	0.7140
Total	99.0%		harvested	245.712	104.423		30.896
			Dir Gen	141.290			
			Boost	73.527			
			Generated	214.816		Benchmark	
			capacity	89.51%			

allowing time for wind to slow to level where boost is required

A massive VAWT can harvest and store the extra energy above its generator rating enabling more power generation in periods of lower wind speeds.

Energy leaching from viscous drag and the time between high and low winds reduces the effectiveness of the kinetic store.

The actual generated output will be site specific.

Cp = collectable wind energy divided by total wind energy capacity: as % of continuous rated generation power.

Enhanced energy harvesting due to kinetic storage

Example	VAWT	Energy =	Stored	% loss	Loss
Wind Speed m/s	probability % of time Cp	300 MW MW	Probability x MW	Energy	of stored energy
1	0.3%	0			
2	2.3%	0			
3	4.1%	0.300	3.6	0.1476	
4	5.5%	0.400	11.5	0.6325	
5	6.3%	0.400	22.5	1.4175	
6	7.2%	0.400	38.9	2.8008	
7	7.8%	0.400	61.7	4.8126	
8	8.2%	0.400	92.2	7.5604	
9	8.2%	0.400	131.2	10.7584	
10	7.8%	0.400	180	14.0400	
11	7.3%	0.400	240	17.5200	
12	6.5%	0.400	311	20.2150	0.7150
13	5.6%	0.400	395.5	22.1480	5.3480
14	4.5%	0.400	493.9	22.2255	8.7255
15	3.8%	0.400	607.5	23.0850	11.6850
16	3.1%	0.362	667.2	20.6832	11.3832
17	2.6%	0.324	716.3	18.6238	10.8238
18	2.1%	0.282	740.1	15.5421	9.2421
19	1.6%	0.243	750	12.0000	7.2000
20	1.3%	0.209	750	9.7500	5.8500
21	1.0%	0.18	750	7.5000	4.5000
22	0.8%	0.157	750	6.0000	3.6000
23	0.6%	0.137	750	4.5000	2.7000
24	0.3%	0.121	750	2.2500	1.3500
25	0.2%	0.107	750	1.5000	0.9000
Total	99.0%	harvested	245.712	84.023	23.053
		Dir Gen	161.690		
		Boost	60.969		
		Generated	222.659		
		capacity	74.22%		
				7.8	Higher
				than	240 VAWT

allowing time for wind to slow to level where boost is required

A massive VAWT can harvest and store the extra energy above its generator rating enabling more power generation in periods of lower wind speeds.

Energy leaching from viscous drag and the time between high and low winds reduces the effectiveness of the kinetic store.

The actual generated output will be site specific.

Cp = collectable wind energy divided by total wind energy capacity: as % of continuous rated generation power.

Enhanced energy harvesting due to kinetic storage

Example	probability	VAWT	180 MW	Energy	Stored	% loss	Example
Wind Speed	% of time	Reduced rating	MW	= Probability x MW	Energy	to stored energy	Loss
m/s		Cp					
1	0.3%	0					
2	2.3%	0					
3	4.1%	0.300	3.6	0.1476			
4	5.5%	0.400	11.5	0.6325			
5	6.3%	0.400	22.5	1.4175			
6	7.2%	0.400	38.9	2.8008			
7	7.8%	0.400	61.7	4.8126			
8	8.2%	0.400	92.2	7.5604			
9	8.2%	0.400	131.2	10.7584			
10	7.8%	0.400	180	14.0400			
11	7.3%	0.400	240	17.5200	4.3800	5.0%	0.2190
12	6.5%	0.400	311	20.2150	8.5150	10.0%	0.8515
13	5.6%	0.400	395.5	22.1480	12.0680	15.0%	1.8102
14	4.5%	0.400	493.9	22.2255	14.1255	20.0%	2.8251
15	3.8%	0.400	607.5	23.0850	16.2450	25.0%	4.0613
16	3.1%	0.362	667.2	20.6832	15.1032	30.0%	4.5310
17	2.6%	0.324	716.3	18.6238	13.9438	35.0%	4.8803
18	2.1%	0.282	740.1	15.5421	11.7621	40.0%	4.7048
19	1.6%	0.243	750	12.0000	9.1200	45.0%	4.1040
20	1.3%	0.209	750	9.7500	7.4100	50.0%	3.7050
21	1.0%	0.18	750	7.5000	5.7000	55.0%	3.1350
22	0.8%	0.157	750	6.0000	4.5600	60.0%	2.7360
23	0.6%	0.137	750	4.5000	3.4200	65.0%	2.2230
24	0.3%	0.121	750	2.2500	1.7100	70.0%	1.1970
25	0.2%	0.107	750	1.5000	1.1400	75.0%	0.8550
Total	99.0%			245.712			41.838
		after losses Harvested		203.874			
		still stored		23.874			
		Generated by VAWT		180.000	100%	-34.8	lower
		Generated on 240 MW HAWT farm		142.711		than	240 VAWT
180 MW VAWT compared to 240 MW HAWT farm				126.13%			

allowing time for wind to slow to level where boost is required

A massive VAWT with lower generator ratings can harvest and store the extra energy generating more power overall than an HAWT wind farm of a higher generator rating.

Energy leaching from viscous drag and the time between high and low winds reducing the effectiveness of the kinetic store shown in the example above

The actual generated output will be site specific.

Cp = collectable wind energy divided by total wind energy