PORT-SAID ENGINEERING RESEARCH JOURNAL
Faculty of Engineering - port said university
Volume 19 No. 2 September2015 pp: 19 : 31

A Review of the State of the Art Wind Technologies for Suitable Integration Concept

Ashraf A. ELmokadem [1], Naglaa A. Megahed [2] and Dina S. Noaman [3]

ABSTRACT

The renewed interest that has being paid by architects, project developers and local governments to erect wind technologies is mainly connected to the attractive prospects of future applications in the built-environment. In this paper, a review of academic literature regarding the State of the Art Wind Technologies for buildings is presented. The review starts with presenting the suitable wind technologies types. Then, various wind technologies with different characteristics are described and compared. In addition, the study proposes a framework towards the suitable selection of available wind technologies according to the selected integration method which is considered the first stage towards any efficient integration.

Keywords: Building integrated wind technologies; Framework; Integration method; Wind technology.

1. INTRODUCTION: CONCEPT OVERVIEW

Energy crisis and environmental issues led the global attention to rely on renewable energy (RE) especially wind energy (WE) as alternative. WE resource is available on the earth in large unused quantities that enough to provide much more than the global energy consumption [1]. In addition, it is one of the lowest installed capital cost and environmental impact energy form [2; 3]. A wide range of wind technologies (WTs) types appeared all around the world with various characteristics integrations into buildings.

Building integrated wind technology (BIWT) is a building that is designed and shaped with WTs in mind [4]. Moreover, WTs, which have many types, can be integrated into buildings in many forms (see Figure 1). Hence, this paper aims to introduce the suitable WTs types for integration into the buildings, in addition to the framework for the determination of suitable WT for each integration method as a stage towards the efficient integration of wind technologies into buildings.

[1] Professor and Head of Architecture and Urban Planning Department, Faculty of Engineering, Port-Said University, Port Said, Egypt, E-mail: elmokadem1@gmail.com

[2] Associate Professor of Architectural Engineering and Urban Planning Department, Faculty of Engineering, Port-Said University, Port Said, Egypt, E-mail: naglaaali257@hotmail.com

[3] Assistant Lecturer in Architectural Engineering and Urban Planning Department, Faculty of Engineering, Port-Said University, Port Said, Egypt, E-mail: dinasamy87@gmail.com

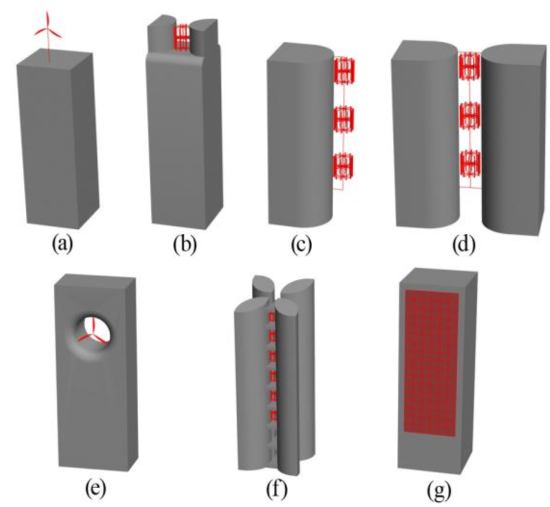

Figure 1: The main methods of WTs integration into buildings: (a) on building roof; (b) concentrator on building roof; (c) on building side; (d) between twin buildings; (e) concentrator within a building façade; (f) combined concentrator within the building; and (g) as an external envelop of building. Note that each main integration method has sub-methods. Source: the authors after [4; 5; 6].

2. CURRENT WIND-POWER TECHNOLOGY

This section focuses on the review of the recent developments of wind power technology and the state of the art of the implemented WTs systems. In general; energy from the wind can be harnessed by the conversion of kinetic energy in the wind into electrical energy through using WTs [7]. WTs types that are used as BIWTs can be divided into three main types: two types based on the axis in which the WT rotates: HAWTs (Horizontal Axis Wind Technologies) as shown in Table 1 and VAWTs (Vertical Axis Wind Technologies) as shown in Table 2, in addition to the third type, which includes other WTs such as vibration, hybrid, millimeter and bladeless WTs as shown in Table 3. Moreover, the average values of WTs characteristics that affect the selection of WT are shown in Tables from Table1 to 3.

Table 1: The most common average values of the several characteristics of HAWTs types that can be integrated into buildings. The values in this table are concluded by studying HAWTs products that can be integrated with buildings and are produced by reliable manufacturers.

Characteristics \ HAWTs types		Two blades		Three blades			Multi blades		DAWT			Spiral Flugel		Dual-Rotor		Co-Axial multi rotor	
WT Size	Size*	P	S	P	S	M	P	S	P	S	M	P	S	P	S	P	S
	Diameter (m)	<2.5	2.5 <19.5	<2.5	2.5 <19.5	19.5 ≤41	<2.5	2.5 <19.5	<2.5	2.5 <19.5	19.5 ≤41	<2.5	2.5 <19.5	<2.5	2.5 <19.5	<2.5	2.5 <19.5
Grid connection		on-grid / off-grid									on-grid	on-grid / off-grid					
WT speeds (m/s)	Cut-in speed	2.3 ~4	2.5 ~3.5	1.5 ~5	1.4 ~4	3 ~4	1 ~5	1~ 3	0.1 ~4	2.5 ~4	~ 2.5	2 ~3	~ 3	2.5 ~3	2.5~3	~3.6	~3.6
	Cut-out speed*	13 ~60	14 ~60	14 ~70	14 ~70	20 ~25	12 ~ 37.5 or NL	16 ~18	8.3~25 or NL	18 ~25	~ 25	~ 22	~20	~40	~40	~25	~25
	Survival wind Speed*	60 or NL	50 ~60 or NL	31.3 ~70 or NL	16.7 ~70 or NL	59.5 ~67	27.8 ~70 or NL	50 ~60	50 ~55 or NL	~55	~ 55	45 ~51	~50	~40	~40	NL	NL
Coping with multitude wind directions		Y	Y	Y	N/Y	N/Y	N/Y	Y	N/Y	Y	Y	Y	Y	Y	Y	Y	Y
Yaw mechanism to trace wind direction		Y	N/Y	N/Y	N/Y	N/Y	N/Y	N/Y	N/Y	Y	Y	Y	Y	N/Y	N/Y	Y	Y
Coping with the skew angle above the building parapet		Y	Y	Y	Y	Y	N/Y	N/Y	N	N	N	N	N	Y	Y	Y	Y
Nuisance impacts	Noise (dB)**	> 63.4 ≤ 100	> 63.4 ≤ 100	≤ 100	≤ 100	> 53.4 ≤ 100	≤ 100	≤ 63.4	≤ 100	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	> 53.4 ≤ 63.4	> 48.4 ≤ 63.4
	Shadow flicker	N	N/Y	N/Y	N/Y	N/Y	N/Y	N/Y	N/Y	N/Y	N	N/Y	N/Y	N/Y	N/Y	Y	Y
	Avian risks	Y	Y	Y	Y	Y	N/Y	N/Y	N	N	N	N	N	Y	Y	Y	Y
Maintenance requirement***		Mo	Mo	Mo/ H	Mo/ H	Mo/ H	Mo/ H	Mo	Mo	Mo	Mo	Mo	Mo	Mo	Mo	Mo	Mo
Suitable integration methods of WTs ****		R, CC	R, CR, C, CC	R, RP, CR, S, C, CC	R, CR, S, B, C, CC	R, CR, C, CC	R, RP, CR, S, C, CC	R, RP, CR, S, B, C, CC	R, RP	R	R	R, RP, CC	R, RP, CC	R, CR, B, C, CC	R, CR, B, C, CC	R, CC	R, CC
Power coefficient max. (Cp)		~ 0.4	0.4~0.45	~ 0.4	0.4~ 0.48	~0.48	0.38~ 0.4	0.38~ 0.4	0.42 ~0.7	0.42 ~0.7	~0.7	~ 0.4	~ 0.4	~ 0.5	~ 0.5	~ 0.4	~ 0.4
WT cost*		L	L	L	L	L	L	L	Mo	Mo	Mo	Mo	Mo	Mo	Mo	L	L
Products availability*		A	A	A	A / UT	A	A	A / UT	A	A	A	A	A	A	A	UT	L A

***Symbols Key**: P (Pico)/ S (Small)/ M (Medium)// NL (No Limit)// N (No)/ Y (Yes)// H (High)/ Mo (Moderate) / L (low)// A (available)/ LA (Little Available)/ UT (Under Testing).

**The used limits are selected from the maximum total sound pressure level of WTs in different area types, as discussed in Section 3.1.4.

*** WTs maintenance requirement can be: H (High i.e. twice a year) or Mo (Moderate i.e. once a year) or L (little i.e. every five years).

****The integration methods of WTs are: on building roof (R), on parapet of building roof (RP), concentrator on building roof (CR), on building side (S), between twin buildings (B), concentrator within a building façade (C), Combined concentrator within the building (CC) and external envelope of building (E).

Table 2: The most common average values of the several characteristics of VAWTs types that can be integrated into buildings. The values in this table are concluded by studying VAWTs products that can be integrated with buildings and are produced by reliable manufacturers.

VAWTs types / Characteristics		Savonius			Darrieus				Alternative Designs											
		Savonius			Curved-blade rotor	H-rotor (Giromill)			avonius helica blade scoops		Darrieus helica twisted blades		Darrieus with blades in the orm of savoniu scoops		Magnetic levitation WT		Cycloturbine		Darrieus with savonius blades on the central mast	
WT Size	Size*	P	S	M	S	P	S	M	P	S	P	S	P	S	P	S	S	M	P	S
WT Size	Width (m)	<3.4	1 ≤10.2	10.3 ≤36	2 ≤17.3	<2.5	1.2 ≤20	18 ≤30	<1.3	1.2 ≤4	<2.1	1.7 ≤11.5	<2.6	2 ≤6	<4.1	2.4 ≤8	4.3 ≤15.9	16 ≤36	<3.1	2 ≤4
WT Size	Height (m)	<2.6	2.4 ≤20	20.1 ≤36	≤17.3	<2.5	1.4 ≤16	16.1 ≤36	<4.1	4 ≤6	<2.9	2.9 ≤19	<2.5	1.6 ≤9	<3.2	2.9 ≤4.9	≤9.8	9.9 ≤36	<2.6	1.8 ≤4.16
Grid connection		on-grid / off-grid		off-grid	on-grid / off-grid															
WT speeds (m/s)	Cut-in speed	1~4.5	1~5.4	~5.4	3.6 ~4	1.2 ~4	1.8 ~4	2.5 ~3	2~5	2~5	2 ~3.5	3 ~5	1.2 ~3.6	1.2 ~4	1.3 ~4	1.5 ~2.2	~2.2	~2.2	2 ~3	2.5 ~3.5
WT speeds (m/s)	Cut-out speed*	17.8 ~30	20~ 31.3	~31.3	20 ~26	20~ 45	12 ~45	15 ~35	30 ~45	18 ~45	25 ~67	16~45	17.9 ~45 or NL	24 ~30 or NL	22.4 ~60 or NL	22.4 ~60	~35.7	~35.7	15 ~40	15 ~40
WT speeds (m/s)	Survival wind Speed*	24.7 ~65 or NL	52 ~67	~67	52.6 ~55	40 ~63	40 ~63	~63	40 ~50	35 ~54.6	50 ~67 or NL	26 ~50	40 ~60.4 or NL	40 ~90 or NL	47 ~57 or NL	50 ~57	NL	NL	40 ~65	40 ~65
Coping with multitude wind directions		Y	Y	Y	Y/N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/Y	Y	N/Y	N/Y
Yaw mechanism to trace wind direction		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Coping with the skew angle above the building parapet		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Nuisance impacts	Noise (dB)**	≤ 63.4	≤ 63.4	≤ 63.4	≤ 100	≤ 100	≤ 100	≤ 63.4	≤ 100	≤ 100	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4
Nuisance impacts	Shadow flicker	N	N	N	Y	Y	Y	N	N	N	N/Y	Y	N/ Y	Y	N/ Y	N/ Y	N	N	N/Y	Y
Nuisance impacts	Avian risks	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Maintenance requirement* **		L / Mo	L / Mo	Mo	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Suitable integration methods of WTs ******		R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC	R, RP, CR, S, B, C, CC
Power coefficient max. (Cp)		0.2~ 0.54	0.2~ 0.54	~ 0.45	~ 0.25	0.3~ 0.4	0.3~ 0.4	~ 0.4	0.1~ 0.2	0.15~ 0.2	0.15~ 0.3	0.3 ~ 0.45	0.25~ 0.4	~ 0.4	~ 0.4	~ 0.4	~ 0.4	~ 0.4	~ 0.25	0.25~ 0.3
WT cost*		Mo	Mo	Mo	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Products availability*		A	A	A	A	A	A/ UT	A	A	A	A/ UT	A	A	A	A/ UT	A	A	A	A	A

, **, ** and ******** are as in Table 1.

Table 3: The most common average values of the several characteristics of other WTs types that can be integrated into buildings. The values in this table are concluded by studying other WTs products that can be integrated with buildings and are produced by reliable manufacturers.

Other WTs types / Characteristics		Vibration technology	Hybrid WT			Millimetre WT	Bladeless WT
WT Size	Size*	P	P	S	M	P	P
WT Size	Width (m)	≤1	<2.5	1.8 ≤8	8.1 ≤24	≤0.1	≤1.2
WT Size	Height (m)	1	-	≤5.5	5.6 ≤12	≤ 0.025	≤2.4
Grid connection		on-grid / off-grid					

Characteristics / Other WTs types		Vibration technology	Hybrid WT			Millimetre WT	Bladeless WT
WT speeds (m/s)	Cut-in speed	~2	1.5 ~1.8	1.5 ~1.8	~1.5	~2	~1.4
	Cut-out speed*	~12	~40 or NL	~40 or NL	~40	~25	~42
	Survival wind Speed*	NL	NL	NL	NL	~50	~69
Coping with multitude wind directions		Y	Y	Y	Y	Y	Y
Yaw mechanism to trace wind direction		N	N	N	N	N	N/Y
Coping with the skew angle above the building parapet		Y	Y	Y	Y	-	Y
Nuisance impacts	Noise (dB)**	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4	≤ 63.4
	Shadow flicker	N	N	N	N	N	N
	Avian risks	N	N	N	N	N	N
Maintenance requirement***		L	L	L	L	L	L
Suitable integration methods of WTs ****		R, RP, CR, S, B, C, CC, E	R, CR	R	R	E	R, RP, CR, S, B, C, CC
Power coefficient max. (Cp)		-	~0.35	0.37 ~0.4	~0.4	0.15 ~0.38	0.5 ~0.8
WT cost*		L	L	L	L	-	L
Products availability*		UT	UT	A	A	UT	LA / UT

*, **, *** and **** are as in Table 1.

3. THE FRAMEWORK FOR DETERMINING SUITABLE WIND TECHNOLOGY

Recently, many types of WTs appeared and large numbers of it have been made for the integration into buildings. As a result, the architects may face difficulties in selecting the suitable WT. This selection of suitable WTs includes the determination of suitable type, size with specified dimensions, characteristics and number. Therefore, a framework is created based on three main points: (1) Site variables, (2) Integration methods variables and (3) WTs variables, as shown in Figure 2. These three points are illustrated in Sections from 3.1 to 3.3.

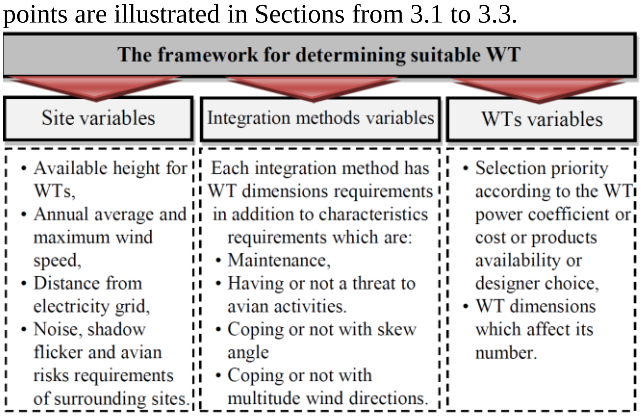

Figure 2: Framework for the determination of suitable WT for the selected integration method.

3.1. SITE VARIABLES…… UNDERSTAND THE BUILT-ENVIRONMENT WIND RESOURCE

Site variables that affect the selection of suitable WTs include many variables from available height for WTs to avian activities of surrounding sites which are illustrated in Sections from 3.1.1 to 3.1.6.

3.1.1. AVAILABLE HEIGHT FOR WTS

Integration on building roof and in a concentrator on building roof methods can only be used above building height, i.e. in the distance between building height and construction permitted height. In addition, other methods can only be used under building height i.e. in the distance between minimum suitable height for WTs and building height. On one hand, the minimum suitable height for WTs equals 1.5 times the surrounding obstacles heights, particularly that within 500 m or within 4.5 times the surrounding obstacles heights, whichever is longer upwind for the prevailing or exploited wind directions [8; 9; 10]. On the other hand, the minimum suitable height to exploit HAWTs equals two times the surrounding obstacles height particularly that within 1km or ten times the surrounding obstacles height whichever is longer) upwind; and 500m or five times the surrounding obstacles height whichever is longer downwind for the prevailing or exploited wind directions [4; 8; 9; 10]. Furthermore, each integration method has height conditions. Therefore, by comparing minimum suitable height for exploiting WTs with building dimensions and construction permitted height in the site, some integration methods can't exploit HAWTs or all WTs types, as shown in Table 4.

3.1.2. ANNUAL AVERAGE AND MAXIMUM WIND SPEED

WT cut-in speed (where WT starts to generate usable power) should be lower than the annual average wind speed of the site at the integration method. In addition, WT cut-out speed (where WT shuts down immediately to avoid damaging) should be higher than this annual average wind speed. Furthermore, the WT survival speed (where WT withstands without damage) should be higher than the maximum wind speed of the site at the integration method [4; 26].

Table 4: The cases of the comparison between the minimum suitable height for WTs and construction permitted height or building dimensions, in addition to excluded integration methods for each case (marked with o). Source: the authors after [4; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25].

Cases No. in Figure 3	Cases explanation	Excluded integration methods to exploit WTs										
		On roof			Concentrator on roof		On building side	Between twin buildings		Concentrator within a building façade	Combined concentrator within the building	As an external envelope of building
		On parapet	Vaulted	Domed	Between two shrouds	Others		between airfoil-shaped buildings	between two half sphere-shaped buildings			
-	The construction permitted height equals or less than minimum suitable height for WTs.	o	o	o	o	o	o	o	o	o	o	o
-	Building height much lower (with more than 30% of building height) than the minimum suitable height for WTs.	o	o	o	o	o	o	o	o	o	o	o
A	Building height = The construction permitted height	o	o	o	o	o						
B	Building height < The construction permitted height		o	o	o							
C	Building height = The minimum suitable height for WTs						o	o	o	o	o	o
D	Building height > The minimum suitable height for WTs							o	o	o	o	
E	Building height < The minimum suitable height for WTs	o					o	o	o	o	o	o
-	The distance between the suitable height for exploiting WTs and the building height is less than 10% of the building dimension which in the same direction with the prevailing wind flow							o				
-	The distance between suitable height for exploiting WTs and building height is less than 108% of the building dimension which in the same direction with the prevailing wind flow									o		

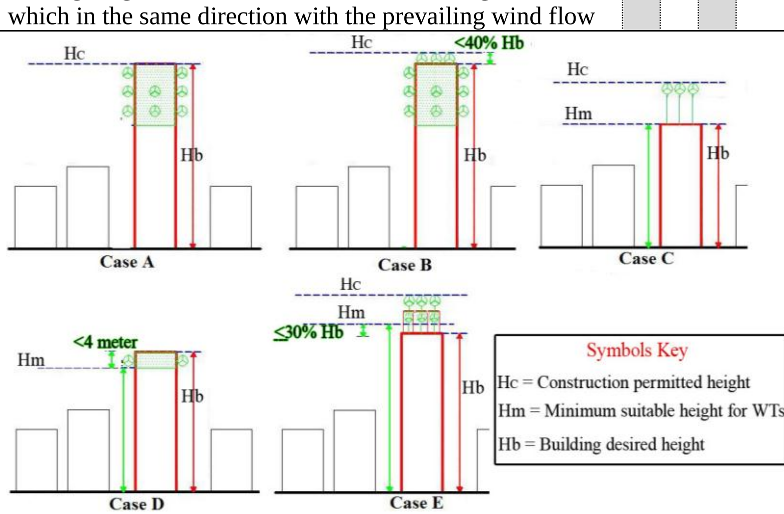

Figure 3: The cases of the comparison between building height, construction permitted height and suitable height to exploit HAWTs. Source: the authors after [4; 11; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21; 22; 23; 24; 25].

3.1.3. DISTANCE FROM ELECTRICITY GRID

If the building site isn't remote (i.e. not more than approximately 400 m away from the electricity grid [27]); off-grid WT such as savonius with medium size should be excluded. In addition, in remote sites, DAWT with medium size (on-grid WT) should be excluded.

3.1.4. NOISE REQUIREMENTS

There is a legal limit for noise level at different times of day in different areas of the built environment. The Environmental Protection low No. 4 of 1994 and its executive regulations determined the legal limit for noise level, as shown in Table 5 (second column) [28]. Hence, the selected WTs shouldn't cause overall noise by more five dB(A) than these legal limits for the "worst case" i.e. during the night at a wind speed of approximately 8 m/s [29]. To calculate overall sound pressure level from *n* WTs and background; the following equation can be used [30]:

$$\text{Overall sound pressure level} = 10 \log \left(10^{0.1 L_{P,n}} + 10^{0.1 \text{background noise}}\right) \quad \text{(Eq. 1)}$$

Where overall sound pressure level (dB (A)) is the legal limit for sound pressure level of background noise plus 5 dB(A).

In addition, the maximum total sound pressure level from *n* WTs ($L_{p,n}$) for different areas shouldn't exceed the values in the third column in Table 5. Therefore, some WTs should be excluded in each area type as shown in the fourth column in Table 5.

Table 5: The sound pressure level and types of excluded WTs for different areas. Source: the authors after Eq. 1, Table 1 and [28].

Type of area	The legal limits for sound pressure level at night (dB(A))	Sound pressure level of excluded WTs [$L_{p,n}$ (dB(A))]	Types of excluded WTs
Industrial areas (heavy industries)	60	more than 63.4	Two blades HAWT
Commercial, administrative and downtown areas	55	more than 58.4	Two blades HAWT
Residential areas in which can be found some workshops or commercial establishments or which are located on a main road	50	more than 53.4	Two blades HAWT/ Three blades HAWT (medium)/ Co-Axial multi rotor (pico)
Residential areas in the city	45	more than 48.4	Two blades HAWT/ Three blades HAWT (medium)/ Co-Axial multi rotor
Residential suburbs with low traffic	40	more than 43.4	
Residential rural areas, hospitals and gardens	35	more than 38.4	

3.1.5. SHADOW FLICKER REQUIREMENTS

Shadow flicker, which happens when the sun passes behind the WT blades as they rotate, tends to be more noticeable in buildings with windows oriented to the WTs and away by less than 300m from the WT [4; 31]. The shadow flicker impact area can be determined from the sun path chart of the country (see Figure 4). Therefore, if there are buildings with windows oriented to the WT at the impact area, WTs types that cause shadow flicker should be excluded as follow:

- Co-Axial multi rotor.
- Curved-blade rotor.
- H-rotor (pico and small sizes).
- Darrieus Helical twisted blades (small size).
- Darrieus with blades in the form of Savonius scoops (small size).
- Darrieus with Savonius blades on the central mast (small size).

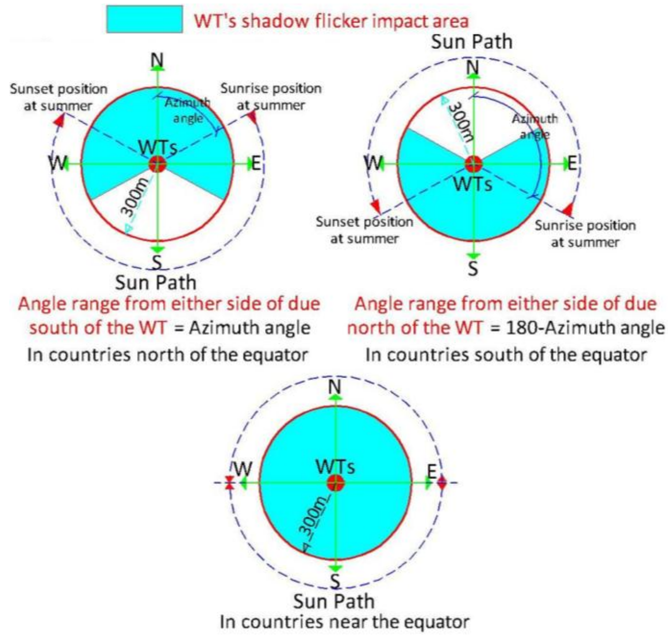

Figure 4: WT's shadow flicker impact area at the sun path chart of countries: north of the equator (up left), south of the equator (up right), near the equator (bottom middle). Source: the authors after [4; 31].

3.1.6. AVIAN ACTIVITIES IN SURROUNDING SITES

In sites that have avian activities (i.e. 120m away from hedgerows, water courses or any wildlife habitat [32]); WTs types that have a threat to avian; two blades HAWT, three blades HAWT, Dual-Rotor HAWT and Co-Axial multi rotor. As a result they should be excluded in the integration methods that don't provide avian protection which are all integration methods except the following:

- Concentrator on building roof (excluding Aeolian Roof and Between two shrouds sub-methods).
- Concentrator within a building façade.

3.2. INTEGRATION METHODS VARIABLES: CHARACTERISTICS AND DIMENSIONS

Each integration method has WTs characteristics and dimensions requirements. This means that, each integration method has some un-suitable WTs types that should be excluded (see Tables from Table 6 to 10). Then the largest suitable WT in dimensions should be selected.

Table 6: Excluded WTs types and suitable WTs characteristics & dimensions for on building roof integration method. Source: the authors after Table 1, Table 2, Table 3 and [4; 10; 11; 22; 23; 24; 25; 33].

On roof sub-methods		Excluded WTs types	Suitable WTs						
			Characteristics*					Dimensions**	
			Integration method	Maintenance	Yaw mechanism	Coping with multitude wind directions	Coping with skew angle	Rotor diameter or height	Rotor diameter or width
On parapet		• **HAWT:** Two blades/ Three blades (small and medium)/ DAWT (small and medium)**/** Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor**.** • **Other WT:** Millimeter / Hybrid WT**.**	RP	L/ Mo	N	--	Y	• ≤10% of the building height.	• $\leq D_2$
Domed		• **Other WT:** Millimeter WT	R	L/ Mo	--	Y	--	• ≤the distance from building height or suitable height for WT(the largest) to the construction permitted height in the site	
Vaulted	(in strongly unidirectional Wind***)	• **HAWT:** Two blades/ Three blades (Pico)/ Multi blades (small)/ DAWT(small and medium)**/** Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor • **VAWT:** Savonius/ H-rotor/ Savonius helical blade scoops/ Darrieus helical twisted blades/ Darrieus with blades in the form of savonius scoops/ Magnetic levitation WT/ Cycloturbine **(**medium**)/** • **Other WT**	R	L/ Mo	--	N	--		
	(in bi-directional Wind***)	• **HAWT:** Two blades **(**pico**)/** DAWT(small and medium)**/** Spiral Flugel/ Co-Axial multi rotor • **Other WT:** Millimeter WT	R	L/ Mo	N	Y	--		

* Symbols Key: as in Table 1.

** D_1 is the building dimension which in the same direction with the prevailing wind flow; and D_2 is the building dimension which faces the prevailing wind flow.

*** Wind directions type in the site can be uniform (no more than 60 % of the wind comes from the prevailing wind direction) or weakly unidirectional (more than 60 % of the wind comes from the prevailing wind direction) or strongly unidirectional (more than 75 % of the wind comes from the prevailing wind direction) or bi-directional (more than 95 % of the wind comes from two opposite wind directions).

Table 7: Excluded WTs types and suitable WTs characteristics & dimensions for integration in a concentrator on building roof method. Source: the authors after Table 1, Table 2, Table 3 and [4; 12; 13; 14; 15; 16; 17; 18; 19; 20; 21].

Concentrator on roof sub-methods	Excluded WTs types	Suitable WTs				
		Characteristics*			Dimensions**	
		Integration method	Yaw mechanism	Coping with multitude wind directions	Rotor diameter or height	Rotor diameter or width
Ducted WT Module	• **All WTs excluded as the used WT is a HAWT** in vertical configuration from the University of Strathclyde in Glasgow.	--	--	--	= 0.6m	
Robertson and Leaman's Roof	• **HAWT**: Two blades/ Three blades (pico)/ Multi blades (small)/ DAWT**/** Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor • **VAWT** • **Other WT**	CR	--	N	≤ 10% of lower D_2.	
IRWES	• **HAWT** • **VAWT**: Savonius (medium) • **Other WT**	CR	N	Y	• ≤ 10% of the building height • ≤ the distance from building height or suitable height for WT (the largest) to the construction permitted height in the site.	• ≤ 10% of the lower D_2 that surmounted by IRWES

Concentrator on roof sub-methods		Excluded WTs types	Suitable WTs				
			Characteristics*			Dimensions**	
			Integration method	Yaw mechanism	Coping with multitude wind directions	Rotor diameter or height	Rotor diameter or width
Aeolian Roof	(in strongly unidirectional wind)	•**HAWT:** Two blades/ Three blades (Pico)/ Multi blades (small)/ DAWT/ Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor •**VAWT:** Savonius/ H-rotor/ Savonius helical blade scoops/ Darrieus helical twisted blades/ Darrieus with blades in the form of savonius scoops/ Magnetic levitation WT/ Cycloturbine **(**medium**)/** •**Other WT**	CR	--	N	•≤ 30% of D_1 •≤ the distance from building height or suitable height for exploiting WT (the largest) to the construction permitted height in the site.	•≤ D_2
	(in bi-directional wind)	•**HAWT:** Two blades **(**Pico**)/** DAWT **/** Spiral Flugel/ Co-Axial multi rotor •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT (small and medium)	CR	N	Y		
Between two shrouds	(in weakly unidirectional or strongly unidirectional wind***)	•**HAWT:** Two blades/ Three blades (Pico)/ Multi blades (small)/ DAWT/ Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor •**VAWT:** Savonius/ H-rotor/ Savonius helical blade scoops/ Darrieus helical twisted blades/ Darrieus with blades in the form of savonius scoops/ Magnetic levitation WT/ Cycloturbine **(**medium**)/** •**Other WT**	CR	--	N	•≤ 10% of the building height •≤ the distance from building height or suitable height for exploiting WT (the largest) to the construction permitted height in the site.	•≤30% of D_1 •≤50% of D_2
	(in bi-directional wind)	•**HAWT:** Two blades **(**Pico**)/** DAWT**/** Spiral Flugel/ Co-Axial multi rotor •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT (small and medium)	CR	N	Y		
In a duct on building roof	(in weakly unidirectional or strongly unidirectional wind)	•**HAWT:** Two blades/ Three blades (Pico)/ Multi blades (small)/ DAWT/ Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor •**VAWT:** Savonius/ H-rotor/ Savonius helical blade scoops/ Darrieus helical twisted blades/ Darrieus with blades in the form of savonius scoops/ Magnetic levitation WT/ Cycloturbine **(**medium**)/** •**Other WT**	CR	--	N	•≤ 50% of the distance from building height or suitable height for exploiting WT (the largest) to the construction permitted height in the site.	•≤50% of D_2
	(in bi-directional wind)	•**HAWT:** Two blades **(**Pico**)/** DAWT **/** Spiral Flugel/ Co-Axial multi rotor •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT (small and medium)	CR	N	Y	≤ 91% of the duct depth.	

*, **and *** are as in Table 6.

Table 8: Excluded WTs types and suitable WTs characteristics & dimensions for integration on building side method. Source: the authors after Table 1, Table 2, Table 3 and [12; 16; 18; 25; 34; 35; 36].

On building side sub-methods	Excluded WTs types	Suitable WTs					
		Characteristics*				Dimensions**	
		Integration method	Maintenance	Yaw mechanism	Coping with multitude wind directions	Rotor diameter or height	Rotor diameter or width
Edge or corner **Curved side**	•**HAWT** •**VAWT**: Savonius (medium) •**Other WT**	S	L/ Mo	N	Y	•≤ the distance between suitable height for VAWT and building height.	•≤20% of D_2 that accelerates the wind.
Aeolian Corner	•**HAWT** •**VAWT**: Savonius (medium) •**Other WT**	S	L/ Mo	N	Y	•≤ the distance between suitable height for VAWT and building height.	•≤ 30%of the half sphere diameter on building side
WARP system	•**HAWT:** Two blades / Three blades (medium)/ DAWT/ Spiral Flugel/ Co-Axial multi rotor •**VAWT:** Savonius (medium) •**Other WT**: Millimeter WT / Hybrid WT	S	L/ Mo	N	--	•≤ 60% of the distance between suitable height for WT and building height. ≤22.8% of D_2.	--

*****and ****** are as in Table 6.

Table 9: Excluded WTs types and suitable WTs characteristics & dimensions for integration between twin buildings. Source: the authors after Table 1, Table 2, Table 3 and [12; 13; 25].

Between twin buildings sub-methods		Excluded WTs types	Suitable WTs: Characteristics*: Integration method	Maintenance	Yaw mechanism	Coping with multitude wind directions	Dimensions**: Rotor diameter or height	Rotor diameter or width
Between airfoil-shaped buildings	(in weakly unidirectional or strongly unidirectional wind)	•**HAWT:** Two blades/ Three blades (Pico)/ Multi blades (small)/ DAWT/ Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor •**VAWT:** Savonius/ H-rotor/ Savonius helical blade scoops/ Darrieus helical twisted blades/ Darrieus with blades in the form of savonius scoops/ Magnetic levitation WT/ Cycloturbine **(**medium**)/** •**Other WT**	B	L/ Mo	--	N	•≤ the distance between suitable height for exploiting WT and building height.	•≤ 30% of the airfoil lengths which is 130% of site width.
	(in bi-directional wind)	•**HAWT:** Two blades **(**Pico**)/** DAWT**/** Spiral Flugel/ Co-Axial multi rotor •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT	B	L/ Mo	N	Y		
Between half sphere-shaped buildings	(in weakly unidirectional or strongly unidirectional wind)	•**HAWT:** Two blades/ Three blades (Pico)/ Multi blades (small)/ DAWT/ Spiral Flugel/ Dual-Rotor/ Co-Axial multi rotor •**VAWT:** Savonius/ H-rotor/ Savonius helical blade scoops/ Darrieus helical twisted blades/ Darrieus with blades in the form of savonius scoops/ Magnetic levitation WT/ Cycloturbine **(**medium**)/** •**Other WT**	B	L/ Mo	--	N	•≤ the distance between suitable height for exploiting WT and building height.	•≤30% of D_1
	(in bi-directional wind)	•**HAWT:** Two blades **(**Pico**)/** DAWT**/** Spiral Flugel/ Co-Axial multi rotor •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT	B	L/ Mo	N	Y		

*, **and *** are as in Table 6.

Table 10: Excluded WTs types and suitable WTs characteristics & dimensions for integration in a concentrator within a building façade, in a combined concentrator within the building and as an external envelope of building. Source: the authors after Table 1, Table 2, Table 3 and [6; 11; 13; 14; 25; 37; 38; 39].

Integration methods		Excluded WTs types	Suitable WTs: Characteristics*: Integration method	Yaw mechanism	Coping with multitude wind directions	Dimensions**: Rotor diameter or height	Rotor diameter or width
Concen-trator within a building façade		•**HAWT:** Two blades **(**Pico**)/** DAWT**/** Spiral Flugel/ Co-Axial multi rotor •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT	C	N	Y	•≤ 50% of the distance between suitable height for exploiting WT and building height. ≤ 91% of the duct depth (D_1).	•≤ 50% of D_2
Combined concentrator within the building	Flower concept with three or four petals	•**HAWT:** DAWT •**VAWT**: Savonius (medium) •**Other WT:** Millimeter WT / Hybrid WT	CC	--	Y	•≤ 90% of the distance between suitable height for exploiting WT and building's height.	•≤ 25% of the total D_2 that accelerates the wind.
	Between building floors	•**All WTs excluded as the used WT is a special designed WT blades** with vertical rotation axis	--	--	--	•≤ 20% of the floor height.	•≤ the lowest D_2.
As an external envelope of building		•**HAWT** •**VAWT** •**Other WT:** Bladeless WT/ Hybrid WT	E	--	--	•WT's swept area for millimeter WT equals $0.0005m^2$ and for Vibration technology equals $0.03m^2$	

and * are as in Table 6.

3.3. WIND TECHNOLOGIES VARIABLES

WTs variables that affect its selection are selection priority and WT dimensions. The analyses of these variables are in Sections 3.3.1 and 3.3.2.

3.3.1. SELECTION PRIORITY

The selection priority of suitable WTs can depend on the WT power coefficient; cost; products availability or designer choice. In addition, there is an opportunity to combine between priorities as in the following:

1) Depending on the WT power coefficient (C_p): (see Table 11).
2) Depending on the WT cost and taking into accounts the power coefficient: (see Table 12).
3) Depending on the WT products availability and taking into account the power coefficient and cost: in this case the order of selection is like in Table 12 with excluding unavailable products which are Bladeless WT, Co-Axial multi rotor and Millimeter WT.
4) Depending on the designer choice: the designer can choose WT type from suitable types for each integration method. In addition, he can determine power coefficient, generator efficiency, gearbox efficiency of the WT. Furthermore, he can determine WT dimensions that shouldn't exceed the determined dimensions in Tables from 6 to 10.

Table 11: Order of WTs types selection priority in the case of depending on the WT power coefficient (C_p) (concluded from Table 1).

Order of selection priority	Wind technologies types	C_p
1	Bladeless WT	~0.80
2	DAWT	~0.70
3	Savonius (Pico and small)	0.54
4	Dual-Rotor	~ 0.50
5	Three blades (small and medium)	~ 0.48
6	Two blades (small)/ Savonius (medium)/ Darrieus Helical twisted blades (small)	~ 0.45
7	Two blades (Pico)/ Three blades (Pico)/ Multi blades/Spiral Flugel/Co-Axial multi rotor/H-rotor/Darrieus with blades in the form of Savonius scoops/ Magnetic levitation/Cycloturbine/Hybrid WT (small and medium)	~ 0.4
8	Millimeter WT	~ 0.38
9	Hybrid WT (Pico)	~0.35
10	Darrieus Helical twisted blades (Pico)/ Darrieus with Savonius blades on the central mast (small)	~0.30
11	Curved-blade rotor/ Darrieus with Savonius blades on the central mast (Pico)	~ 0.25
12	Savonius Helical blade scoops	~0.20
13	Vibration technology [the lower value is assumed]	~0.10

Table 12: Order of WTs types selection priority in the case of depending on the WT cost and with taking into account the power coefficient (concluded from Tables 1, 2 and 3).

Order of selection priority		Wind technologies types (ordering by power coefficient of the WT)	WT cost
1	1-1	Bladeless WT	low
	1-2	Three blades (small and medium)	
	1-3	Two blades (small)	
	1-4	Two blades (Pico)/ Three blades (Pico)/ Multi blades/Co-Axial multi rotor/Hybrid WT (small and medium)	
	1-5	Hybrid WT (Pico)	
	1-6	Vibration technology	
2	2-1	DAWT	Mod-erate
	2-2	Savonius (Pico and small)	
	2-3	Dual-Rotor	
	2-4	Savonius (medium)	
	2-5	Spiral Flugel	
3	3-1	Darrieus Helical twisted blades (small)	high
	3-2	H-rotor/Darrieus with blades in the form of Savonius scoops/ Magnetic levitation/Cycloturbine	
	3-3	Darrieus Helical twisted blades (Pico)/ Darrieus with Savonius blades on the central mast (small)	
	3-4	Curved-blade rotor/ Darrieus with Savonius blades on the central mast (Pico)	
	3-5	Savonius Helical blade scoops	
4		Millimeter WT	-

3.3.2. WIND TECHNOLOGY DIMENSIONS

WT dimensions affect its number at each integration method. In addition, the building and integration method dimensions affect this number (see Table 13).

Table 13: Equations for the determination of WTs number at each integration method. Source: the authors after Tables from 6 to 10 and [11; 12; 13; 14; 16; 17; 18; 19; 25; 34; 35; 36; 37; 38; 40; 41].

Integration methods		The WTs number at each integration method*
On roof	On parapet	$= \frac{\text{Building dimension } D_2 - (2 \times (\text{WT height or diameter} + 3\text{meter}))}{3 \times \text{WT width or diameter}}$
	Domed/ Vaulted	$= \frac{\text{Building dimension } D_2 - (2 \times (30\% \text{of building height} + \text{WT height or diameter} + 3\text{meter}))}{3 \times \text{WT width or diameter}}$
Concentrator on roof	Ducted Wind Turbine Module	$= \frac{\text{Building dimension } D_2}{0.6 \text{ meter}}$
	Robertson and Leaman's Roof/ IRWES	$= \frac{\text{Building dimension } D_2 \text{ or } D_1 \text{ (the lowest of them)}}{10 \times \text{WT width or diameter}}$

Integration methods		The WTs number at each integration method*
On building side*	Aeolian Roof	$= \dfrac{\textbf{Building dimension } D_2}{\textbf{WT width or diameter}}$
	Between two shrouds/ In a duct on building roof	$= \dfrac{\textbf{Building dimension } D_2}{\textbf{2} \times \textbf{WT width or diameter}}$
	Edge/ Curved side/ Aeolian Corner	$= \left[\dfrac{\textbf{Building height - Suitable height for exploiting VAWT}}{\textbf{VAWT height}} \right] \times$ **Exploited sides or corners**
	WARP system	$= \textbf{2} \times \left[\dfrac{\textbf{Building height - Suitable height for exploiting WT}}{\textbf{1.66} \times \textbf{WT height or diameter}} \right]$
Between twin buildings		$= \dfrac{\textbf{Building height - Suitable height for exploiting WT}}{\textbf{WT height or diameter}}$
Concentrator within a building façade		**WTs number in horizontal configuration** $= \dfrac{\text{Building dimension } D_2}{2 \times \text{WT width or diameter}}$ **WTs number in vertical configuration** $= \dfrac{\text{Building height - Suitable height for exploiting WT}}{2 \times \text{WT height or diameter}}$ **Hence, total WTs number =** **WTs number in the horizontal configuration × in the vertical configuration**
Combined concentra--tor within the building	Flower concept with three petals / four petals	$= \dfrac{\textbf{Building height - Suitable height for exploiting WT}}{\textbf{WT height or diameter + (0.4 WT width or diameter with a minimum of 6m)}}$
	Between building floors	$= \dfrac{\textbf{Building height - Suitable height for exploiting WT}}{\textbf{1.2} \times \textbf{Floor height}}$
As an external envelope of building		$= \dfrac{\textbf{(Perimeter of building at integration height)} \times \textbf{(Building height - Suitable height for exploiting WT)}}{\textbf{WT swept area}}$ **In the case of integration with other methods which are S (WARP) or C or CC** $= \dfrac{\textbf{(Perimeter of building at integration height)} \times \textbf{(Building height - Suitable height for exploiting WT- the exploited height in other integration method)}}{\textbf{WT swept area}}$ Where WT swept area for millimeter WT equals $0.0005m^2$ and for Vibration technology equals $0.03m^2$. In addition, the exploited height in other integration methods can be calculated as follows: • In S (WARP) integration method = 1.66 × WT height or diameter at WARP method × (WTs number at WARP method /2) • In C integration method= 2 × WT height or diameter at C method× WTs number in the vertical configuration at C method • In CC (three or four petals) integration method= WTs number in the CC (three or four petals) integration method × (WT height or diameter + 0.4 WT width or diameter with a minimum of 6m) • In CC (Between building floors) integration method= WT height × WTs number in the CC(Between building floors) method

Symbols Key: D_1 (building dimension which in the same direction with the prevailing wind flow); D_2 (building dimension which faces the prevailing wind flow); S (on building side); C (concentrator within a building façade); and CC (combined concentrator within the building).

* The fraction of calculated WTs number and equations between brackets [ ] should be approximated to the lowest integral number.

4. CONCLUSIONS

This paper has reviewed the up-to-date progress of WTs integration into buildings, by illustrating and comparing types and characteristics. It also illustrated that; the WTs can be integrated with buildings by varied methods from integration on building roof to integration as an external envelope of building. In addition, there is no preferable WT or integration method in general. But each integration method into specific building in specific site has the most preferable WT which makes the determination of suitable WT very difficult. In this regard, and according to the huge variables and priorities that are required to fully achieve the efficient integration of WTs into buildings; the future study will focus on designing a computer program that gathers all affecting variables in one package to achieve the best BIWT designs.

5. REFERENCES

[1] Wiser, R., & Yang, Z., et al. (2011). Wind Energy:Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge, United Kingdom: Cambridge University Press.

[2] International Energy Agency. (2010). Energy Technology Perspectives 2010: Scenarios and Strategies to 2050. Retrieved May 5, 2014 from the world wide web: http://www.iea.org/publications/freepublications/publication/etp2010.pdf: Organisation for Economic Co-operation and Development (OECD. Publishing).

[3] Wright, S. (2004). Community-Scale Wind Energy. University of Massachusetts: Renewable Energy Research Laboratory.

[4] Stankovic, S., & Campbell, N., & Harries, A. (2009). Urban Wind Energy. London, UK: Earthscan.

[5] Dunster, B. (2006). Skyzed the Flower Tower. Retrieved May 27, 2014, from the world wide web: http://www.soe-townsville.org/external_pages/SkyZED_The_Flower_Tower.html : ZED Factory.

[6] Mexico NOS "Wind Technologies Products: A Design Consultancy." Retrieved March 20, 2014, from the world wide web: http://www.nos.mx/nano_eng.html.

[7] American Wind Energy Association. (2003). Wind Energy Teacher's Guide. Retrieved May 4, 2014 from the world wide web: http://www.mmpa.org/Uploaded_Files/55/554e954a-f600-4d89-9261-2c4f2fc4c871.pdf: American Wind Energy Association, U.S Department of Energy.

[8] Wineur (2007). Wind Energy Integration in the Urban Environment: Report on Resource Assessment (5.1). Retrieved March 6, 2014 from the world wide web: http://www.iee-library.eu/images/all_ieelibrary_docs/514%20wineur.pdf: Wineur.

[9] Mcguire, D. (2003). Small Wind Electric Systems: A Guide Produced for the American Corn Growers Foundation .(DOE/GO-102003-1751). Washington: U.S. Department of Energy.

10] Mertens, S. (2008). Theory and Applications of Building-Integrated Turbines. PhD, Delft University of Technology.

[11] Abohela, I. (2012). Effect of Roof Shape, Wind Direction, Building Height and Urban Configuration on the Energy Yield and Positioning of Roof Mounted Wind Turbines. PhD Thesis, Newcastle University.

[12] Kang-Pyo, & Perwita, D., & Seung-Hwa, S. (2011). Increasing Potential Wind Energy for High Rise Building Integrated Wind Turbines. Retrieved May 25, 2014, from the world wide web: http://www.dbpia.co.kr/Journal/ArticleDetail/1495697: New & Renewable Energy of the Korea Institute of Technology Evaluation and Planning (KETEP).

[13] Beller, C. (2007). Layout Design for a Venturi to Encase a Wind Turbine, Integrated in a High Rise. Diploma Thesis, Universität Stuttgart.

[14] DIN German Institute for Standardization. (2003). Flow Measurement of Fluids with Primary Devices in Conduits Running Full Circular Cross-Section. Part 1: General Principles and Requirements. Berlin, Germany: DIN German Institute for Standardization.

[15] Perwita, D., & Cho, K.-P. (2014). "Cfd and Wind Tunnel Analysis for Mounted-Wind Turbine in a Tall Building for Power Generation." Mechatronics, Electrical Power, and Vehicular Technology (05), (pp. 45-50). Retrieved May 27, 2014, from the world wide web: www.mevjournal.com.

[16] Aguiló, A., & Taylor, D., et al. (2008). Computational Fluid Dynamic Modelling of Wind Speed Enhancement through a Buildingaugmented Wind Concentration System. Altechnica: Uttlesford District Council

[17] Ferraro, R., & Khayrullina, A., et al. (2012). "Aerodynamic Study of an Integrated Roof Wind Energy System by Means of Computational Fluid Dynamics Simulations." Europe's Premier Wind Energy Event. Copenhagen, Denmark.

[18] Dutton, A., & Halliday, J., & Blanch, M. (2005). The Feasibility of Building-Mounted/Integrated Wind Turbines(Buwts):Achieving Their Potential for Carbon Emission Reductions. the Carbon Trust: Energy Research Unit, CCLRC.

[19] Pagola, M., & Antón, L., et al. (2013). "Systems for Sustainable Energy Supply for Small Villages." European Construction Engineering. Retrieved May 11, 2014, from the world wide web: http://www.slideshare.net/victormarcosmeson/gp1-final-report.

[20] Grant, A., & Kelly, N. (2003). The Development of a Ducted Wind Turbine Simulation Model. Eighth International IBPSA Conference Eindhoven, Netherlands, 11-14 August 2003

[21] Grant, A., & Johnstone, C., & Kelly, N. (2008). "Urban Wind Energy Conversion: The Potential of Ducted Turbines." Renewable Energy (33), (pp. 1157-1163).

[22] Sharpe, T. (2010). "The Role of Aesthetics, Visual and Physical Integration in Building Mounted Wind Turbines – an Alternative Approach." INTECH, (pp. 280-300). Retrieved May 8, 2014 from the world wide web: http://cdn.intechweb.org/pdfs/12520.pdf.

[23] Department for Communities and Local Government :The Planning Inspectorate. (2003). Small Wind Energy Facilities Retrieved May 11, 2014, from the world wide web: http://ecode360.com/11456537 General Code LLC, the Town Board of the Town of Ithaca, NY.

[24] California Wind Energy Collaborative. (2006). Permitting Setback Requirements for Wind Turbines in California. California, USA: California Energy Commission.

[25] Mertens, S. (2006). Wind Energy in the Built Environment: Concentrator Effects of Buildings. Essex, United Kingdom: Multi-Science.

[26] Tong, W. (2010). Wind Power Generation and Wind Turbine Design. WITeLibrary: WIT Press.

[27] Noaman, D. (2012). Solar Energy as an Approach for Sustainable Architecture in Egypt (Case Study: Residential Buildings). Master of Science In Architectural Engineering, Port Said University.

[28] Minister of State for Environmental Affairs. (1994). The Environmental Protection Low No. 4 Egypt: Minister of State for Environmental Affairs.

[29] Al-Shemmeri, T. (2010). Wind Turbines. Retrieved May 5, 2014 from the world wide web: http://www.zums.ac.ir/files/research/site/ebooks/mechanics/wind-turbines.pdf: T. Al-Shemmeri & Ventus Publishing ApS.

[30] American Wind Energy Association. (2009). Awea Small Wind Turbine Performance and Safety Standard. (AWEA 9.1). Washington, USA: American Wind Energy Association.

[31] Giovanello, A., & Kaplan, C. (2008). Wind Energy Siting Handbook. Washington,USA: American Wind Energy Association.

[32] Gadawski, A., & Lynch, G. (2011). The Real Truth About Wind Energy: A Literature Review on Wind Turbines in Ontario. Ottawa: Sierra Club Canada.

[33] Bussel, V., & SM, M. (2005). Small Wind Turbines for the Built Environment. Proceedings of the 4th European and African Conference on Wind Engineering, Prague, Czech Republic, 9-11 July 2005.

[34] Vollen, J., & Dyson, A., & Amitay, M. (2008). Building Integrated Wind: Power System Opportunity. Retrieved May 27, 2014 from the world wide web: http://www.case.rpi.edu/: Center for Architecture Science and Ecology (CASE).

[35] Buttgereit, V. (2010). Aerodynamic Fundamentals of Large Scale Building-Integrated Wind Turbines. Remaking Sustainable Cities in the Vertical Age, India, 3-5 February 2010. CTBUH

[36] Perwita, D., & Banar, W. (2014). "A Technical Review of Building Integrated Wind Turbine System and a Sample Simulation Model in Central Java, Indonesia." Energy Procedia (47), (pp. 29-36).

[37] Pelken, P. (2010). Vertical Axis Wind Turbines Integrated in High-Rise Structures. UK: Syracuse Center of Excellence in Environmental and Energy Systems and the Syracuse University School of Architecture.

[38] Hughes, B., & Chaudhry, H. (2011). "Power Generation Potential of Dynamic Architecture." World Academy of Science, Engineering and Technology (73), (pp. 288- 294).

[39] USA Humdinger Wind Energy LLC. "Wind Technologies Products." Retrieved March 12, 2014, from the world wide web: www.humdingerwind.com/.

[40] Glenney, P. (2008). Sustaining the Future through Building-Integrated Wind Turbines. Greenbuild International Conference & Expo: Revolving Green, Boston, U.S.A, 19 - 21 November 2008. Retrieved May 20, 2014 from the world wide web: http://www.ingreenious.com/images/boston.pdf: Greenbuild.

[41] Haupt, S., & Stewart, S., et al. (2011). Simulating Wind Power Density around Buildings for Siting Building Integrated Wind Turbines. Second Conference on Weather, Climate, and the New Energy Economy, Seattle, Washington, USA, January 22 - 27, 2011. American Meteorological Society.