

# Wind Energy in Turkey and Cost Benefit Analysis of Wind Turbines in Smart Grid Systems



JRC Workshop, June 23-24, 2016, Bari/Italy

# Outlines

- Developing Wind Energy in Turkey
- Some Statistics about wind energy
  - Installed Capacity, wind turbine brands
- Wind Turbine Components
- Cost Benefit Analysis of turbines
  - Comparison of different wind turbine models
  - Efficient operating lifetime
  - Capacity factors
- The adaption to Smart Grid

# Introduction

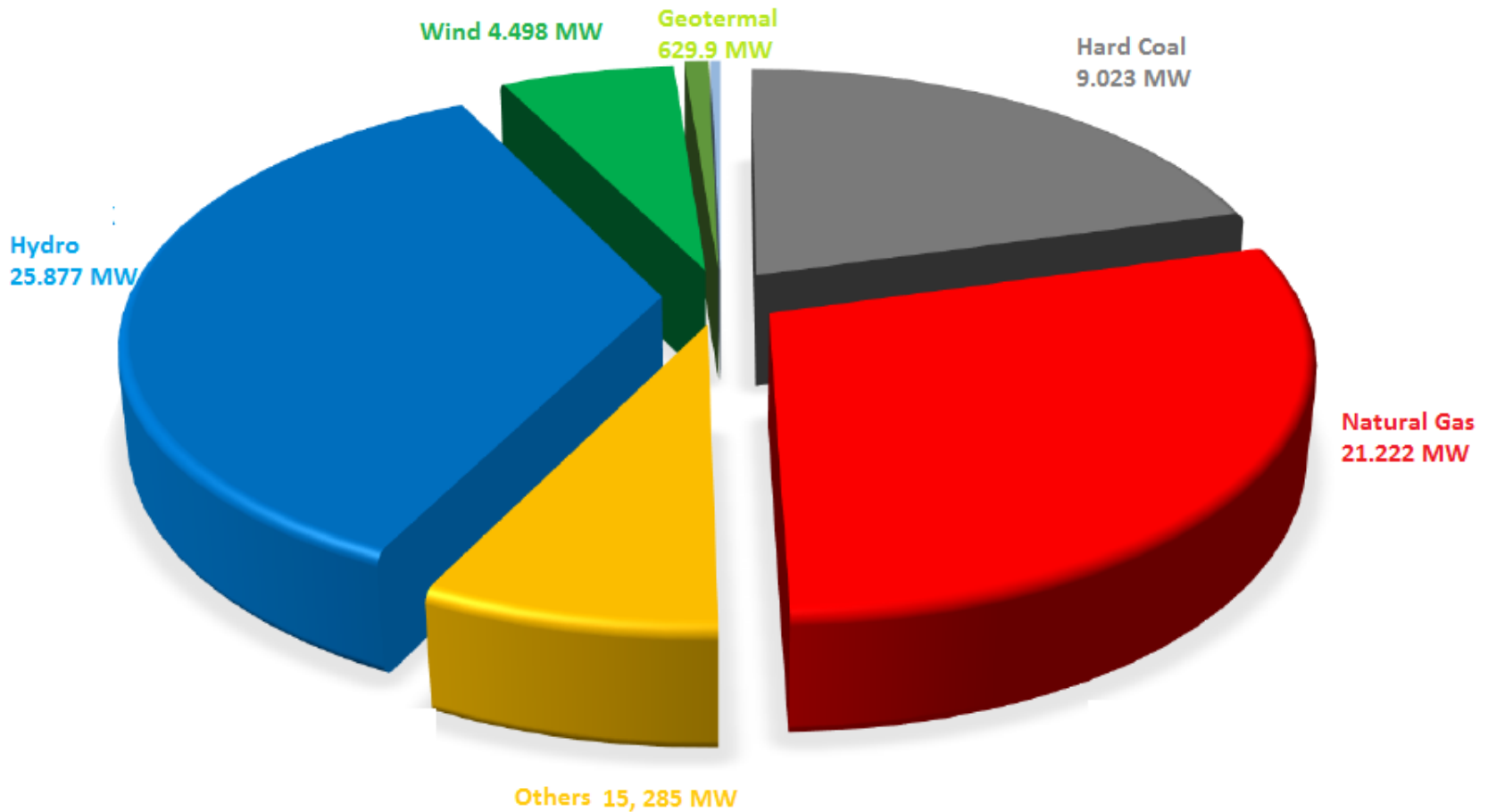
- Global warming issue has led to discover the importance of renewable energy
- National and international policies support renewable energy
- Renewable plants unit cost of energy is higher than conventional plants. However, governments provide incentive & cost based tariff to support renewable
- Cost benefit analysis give an idea about the acceptability of any renewable energy plant

## Total Installed Capacity in Turkey

Total installed capacity in Turkey is 73.147,6 MW (end of the year 2015)

- Hard coal 9.023 MW
- Imported coal 6.064 MW
- Natural gas 21.222 MW
- Fossil resources 4.326 MW
- Hydro 25.877 MW
- Wind 4.498 MW
- Geothermal 623,9 MW
- Solar 585 MW (under operation)

# By the end of year 2015 Source Based Electricity Production Rates



# 1. Development of Wind Energy in Turkey

- Today, total installed capacity in Turkey is above **73.519 GW**. (coal, gas, renewables )
- Total wind power installed capacity represents only 6% of the total capacity, at just above **4.7 GW**. The capacity under construction is **1.9 GW**, waiting to join operation.
- Turkey is increasingly turning into renewable energy sources to improve its energy security, and seeking to provide **30%** of its electricity from renewable energy including wind, solar and hydro power, by **2023**.

# 1. Developing Wind Energy in Turkey

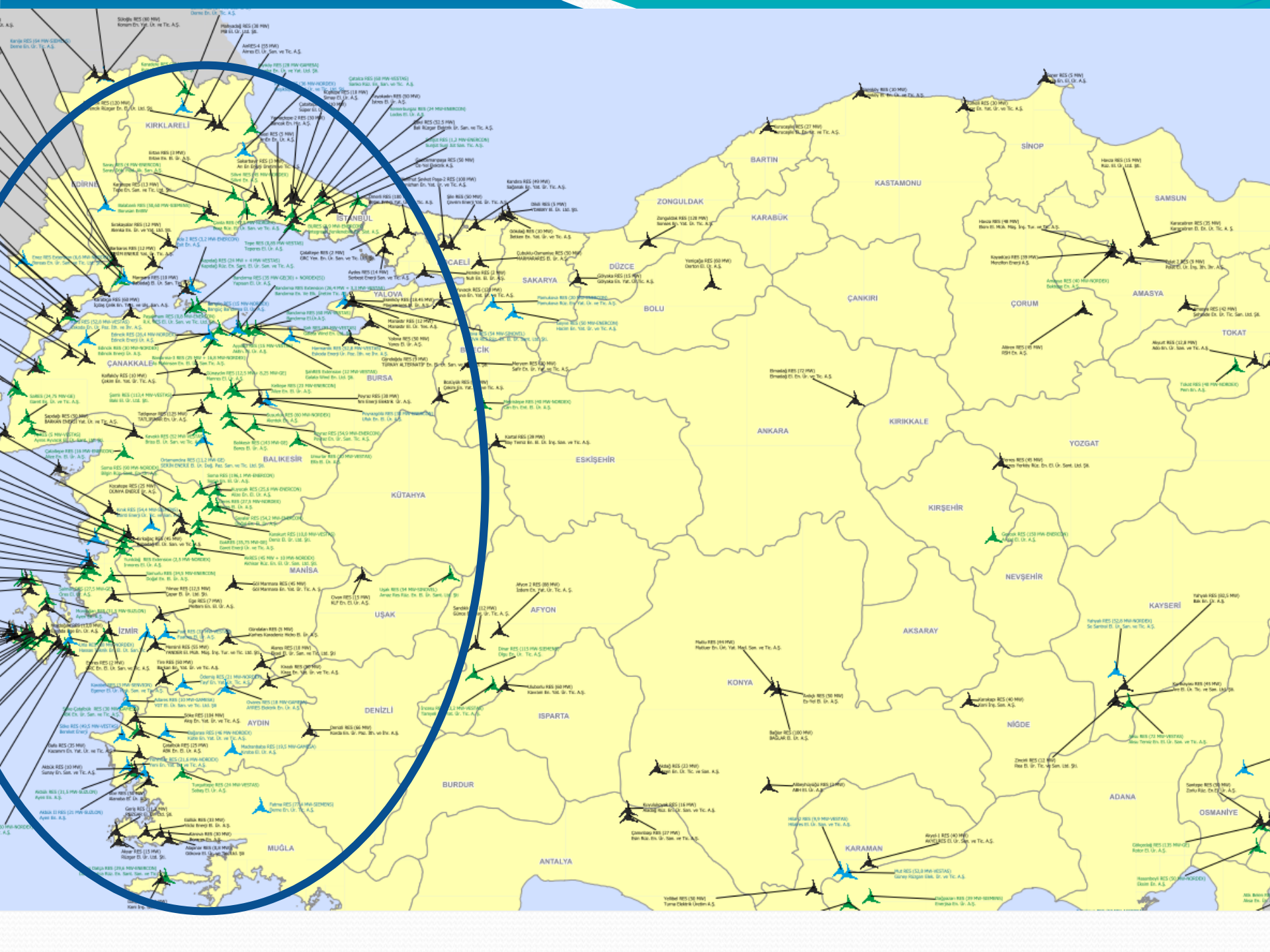
- Turkey's best wind resources are located in the provinces of Çanakkale, Izmir, Balıkesir, Hatay and Manisa.
- As of the end of 2013, the Aegean region had the highest installed wind capacity with a total of **1600** MW, followed by the Marmara region with **1517** MW and the Mediterranean region with **543** MW.
- One of the objectives set out in the 2009 Electric Energy Market and Supply Security Strategy Paper for Wind Energy is to reach a total installed capacity of 20GW by 2023.

## Turkish Wind Power Plant Atlas(2014)

Turkish Wind Energy Association, has been publishing the Turkish Wind Power Plant Atlas of Turkey, twice every year. The update atlas is the 2015 year end version.

Turkish Wind Power Atlas 2015





## 1.2.Supports for Wind Energy

- Turkey's Renewable Energy Law (No. 5346 dated 18th May 2005) was amended in December 2010 and the notification was issued on 8th January 2011 .
- After the amendment of the law the feed-in tariff was set at USD 7.3 cent/kWh (EUR 5.4 cent) for wind power, for a period of ten years and will apply to power plants that come into operation before 1st January 2016.
- In 2014, 11.65 percent increase in wind production enabled Turkey to pay \$850 million less for natural gas, while Turkey uses almost half of its natural gas imports for power generation.

## 1.3.Outlook For 2015 And Beyond

- The Turkish Wind Energy Association expects the market to reach an installed capacity of 5,000 MW by the end of 2015.
- Turkey's National Transmission Company expects annual installations to reach 1,000 MW per year from 2014 onwards
- Presently, Turkey is one of the biggest on-shore wind markets in Europe with an 11 GW pipeline of wind power projects, and it could be as high as 20 GW in the following ten years.

Source: Turkish Wind Power Association (TUREB)

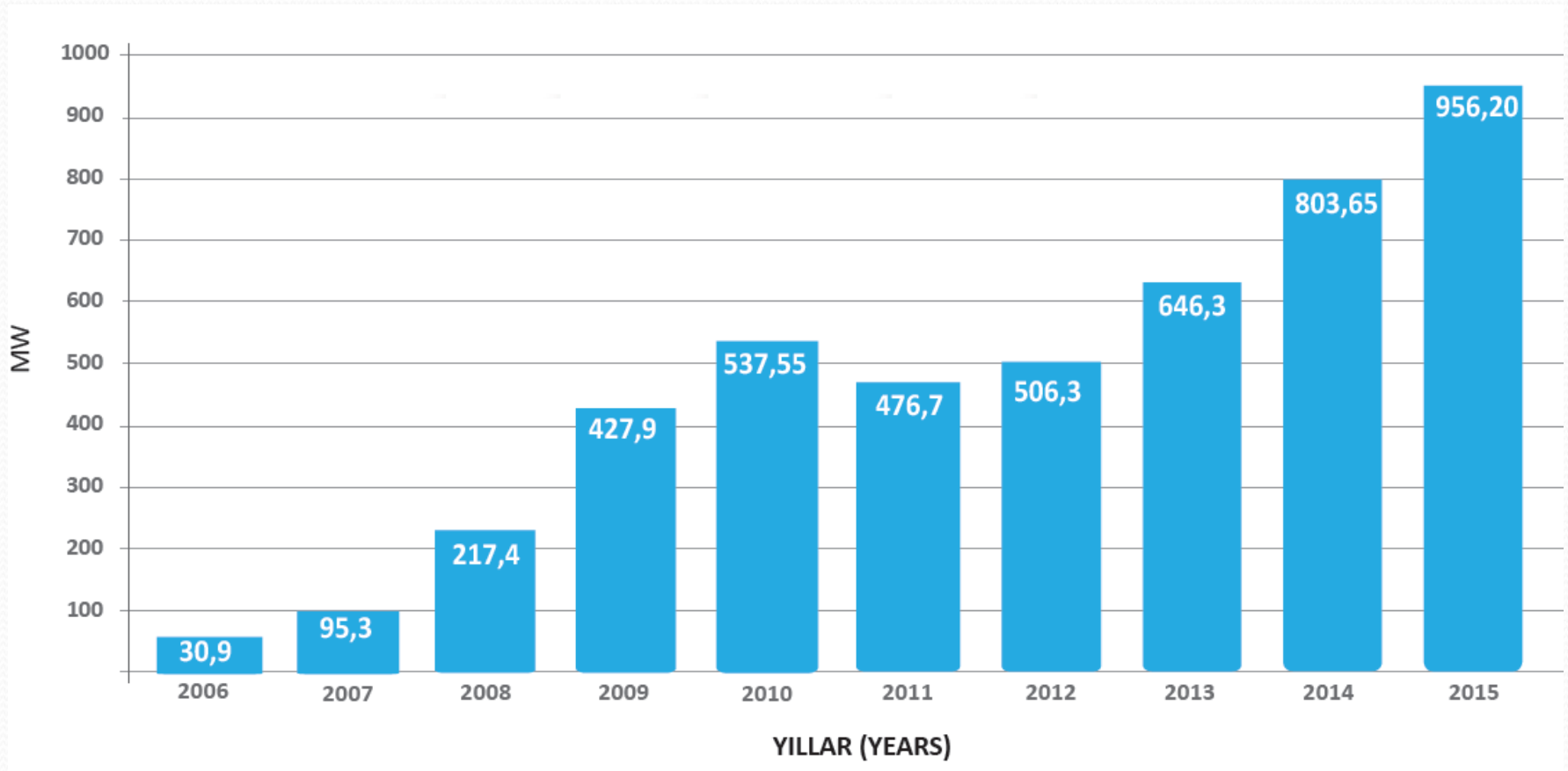
# 2.Wind Power Plants Under Operation

COMPANY NAME	PROJECT NAME	INSTALLED CAPACITY (MW)	CITY	TURBINE MANUFACTURERS	TURBINE MODEL	TURBINE POWER	COMMISSIONING OF OPERATION
Ayten En. A.Ş.	Akbük RES	31,50	Aydın	SUZLON	S 88	2,1 MW	2009
Akhisar Rüz. En. El. Ür. San.Ltd. Şti.	AKRES	45,00	Manisa	NORDEX	N90	2,5 MW	2000
Aksu Temiz En. El. Ür. San. ve Tic. A.Ş.	Aksu RES	72,00	Kayseri	VESTAS	V100-2.0	2 MW	2012
Tan Elektrik Ür. A.Ş.	Alağa RES	9,60	İzmir	NORDEX	N117	2,4 MW	2014
Baktepe En. A.Ş.	Amasya RES	40,00	Amasya	NORDEX	N100	2,5 MW	2008
Ares Alaçatı Rüz. En. San. Tic. A.Ş.	ARES	7,20	İzmir	VESTAS	V44-600	600 KW	1998
Aksa Enerji Ür. A.Ş.	Atık Belen RES	18,00	Hatay	GAMESA	G90	2,0 MW	2014
Ayres Ayvack El. Ür. Sanit. Ltd. Şti.	AyRES	5,00	Çanakkale	VESTAS	V90-1.8	1,8 MW	2011
AkEn. El. Ür. A.Ş.	Ayyıldız RES	15,00	Balıkesir	VESTAS	V90-3.0	3 MW	2009
Borusan EnBW	Balıbanlı RES	50,60	Tekirdağ	SIEMENS	SWT-2.3-108	2,3 MW	2014
Bares El. Ür. A.Ş.	Balıkesir RES	143,00	Balıkesir	GE	GE2.75-103	2,75 MW	2012
Yapısan El. Ür. A.Ş.	Bandırma RES	30,00	Balıkesir	GE	GEL.5se	1,5 MW	2006
Borasco En. Ve Kim. San. Tic. A.Ş.	Bandırma RES	60,00	Balıkesir	VESTAS	V90-3.0	3 MW	2009/2010
Bandırma En. ve El. Ür. Tic. A.Ş.	Bandırma RES Ext - 1	26,40	Balıkesir	VESTAS	V112-3.3	3,3 MW	2014
Yapısan El. Ür. A.Ş.	Bandırma RES Ext.	5,00	Balıkesir	NORDEX	N90	2,5 MW	2012
As Makinsan En. El. Ür. San.Tic. A.Ş.	Bandırma-3 RES	25,00	Balıkesir	NORDEX	N90	2,5 MW	2008
Belen El. Ür. A.Ş.	Belen RES	48,00	Hatay	VESTAS	V90-3.0	3 MW	2009/2010/2012
Bergama RES En. Ür. A.Ş.	Bergama RES	90,00	İzmir	NORDEX	N90	2,5 MW	2007
Boros Bozcaada Rüz. En. San.Tic. A.Ş.	Bozcaada RES	10,20	Çanakkale	ENERCON	E-40	0,6 MW	2000
Kardemir Haddocılık San.Tic. Ltd.Şti.	Bozyaka RES	12,50	İzmir	NORDEX	N100	2,5 MW	2012
Intogreen Yenilenebilir Enerji Sistemleri A.Ş.	BURES	0,90	İstanbul	ENERCON	E-44	0,9 MW	2014
Doğal En. El. Ür. A.Ş.	Burgaz RES	14,90	Çanakkale	ENERCON	E-48/E-44	0,8 MW/0,9 MW	2007
Alize En. El. Ür. A.Ş.	Çamseki RES	20,80	Çanakkale	ENERCON	E-82/E-48	2 MW/0,8 MW	2009
BORA Rüz. El. Ür. San. ve Tic. A.Ş.	Çarşı RES	47,50	İstanbul	NORDEX	N100	2,5 MW	2013/2014
Sanko Rüz. En. San. ve Tic. A.Ş.	Çatalca RES	60,00	İstanbul	VESTAS	V90-3.0	3 MW	2008
Alize En. El. Ür. A.Ş.	Çataltepe RES	16,00	Balıkesir	ENERCON	E-82	2 MW	2010
Alize En. El. Ür. A.Ş.	Çeşme RES	1,50	İzmir	ENERCON	E-40	0,5 MW	1998
Enerjisa En. Ür. A.Ş.	Dağpazarı RES	39,00	Mersin	SIEMENS	SWT-3.0-101	3,0 MW	2011
Dares Datca Rüz. En. Sanit. San. ve Tic. A.Ş.	Dares Datca RES	29,60	Muğla	ENERCON	E-48/E-44	0,8 MW/0,9 MW	2008
Olgu En. Ür. Tic. A.Ş.	Dınar RES	115,00	Afyon	SIEMENS	SWT-2.3-108	2,3 MW	2013
Ütopya En. Ür. San. Tic. A.Ş.	Düzova RES	51,50	İzmir	GE	GE2.5-100	2,5 MW	2009/2010/2012/2013
"Edincik Enerji El. Ür. A.Ş."	Edincik RES	30,00	Balıkesir	NORDEX	N100	2,5 MW	2013
Boreas En. Ür. San. ve Tic. Ltd. Şti.	Enez RES	15,00	Edirne	NORDEX	N90	2,5 MW	2008
Geres Enerji Ür. Tic. A.Ş.	GERES	27,50	Manisa	NORDEX	N90	2,5 MW	2014
Al-Yel El. Ür. A.Ş.	Göycek RES	150,00	Kırşehir	ENERCON	E-82	2 MW/3 MW	2013/2014
Garet En. Ür. ve Tic. A.Ş.	GökRES	35,75	Manisa	GE	GE2.75-103	2,75 MW	2014
Rotor El. Ür. A.Ş.	Gökpedağ RES	135,00	Osmaniye	GE	GE2.5-100	2,5 MW	2009/2010
Manres El. Ür. A.Ş.	Günaydın RES	12,50	Balıkesir	GE	GE2.5-100	2,5 MW	2012
Manres El. Ür. A.Ş.	Günaydın RES Ext.	8,25	Balıkesir	GE	GE2.75-100	2,75 MW	2014
Elsim Enerji Ür. A.Ş.	Hasanbeyli RES	50,00	Osmaniye	NORDEX	N100	2,5 MW	2014
Tamyol Enerji Üretim A.Ş.	İncesu RES	13,20	Afyon	VESTAS	V112-3.3	3,3 MW	2014
Anemon En. El. Ür. A.Ş.	İntepe RES	35,00	Çanakkale	ENERCON	E-48 /E-82	0,8 MW/2,3 MW	2007/2014
Kangal Elektrik Üretim A.Ş.	Kangal RES	44,00	Sivas	VESTAS	V100-2.0	2,0 MW	2014
Kapıdağ Rüz. En. Sanit. El. Ür. San. ve Tic. A.Ş.	Kapıdağ RES	24,00	Balıkesir	VESTAS	V80-2.0	2,0 MW	2013
Kapıdağ Rüz. En. Sanit. El. Ür. San. Tic. A.Ş.	Kapıdağ RES	4,00	Balıkesir	VESTAS	V80-2.0	2,0 MW	2014
Lodos El. Ür. A.Ş.	Karaburun RES	120,00	İzmir	ENERCON	E-82	2 MW/3 MW	2013
Garet En. Ür. ve Tic. A.Ş.	Karadağ RES	10,00	İzmir	GE	GE2.5-100	2,5 MW	2012

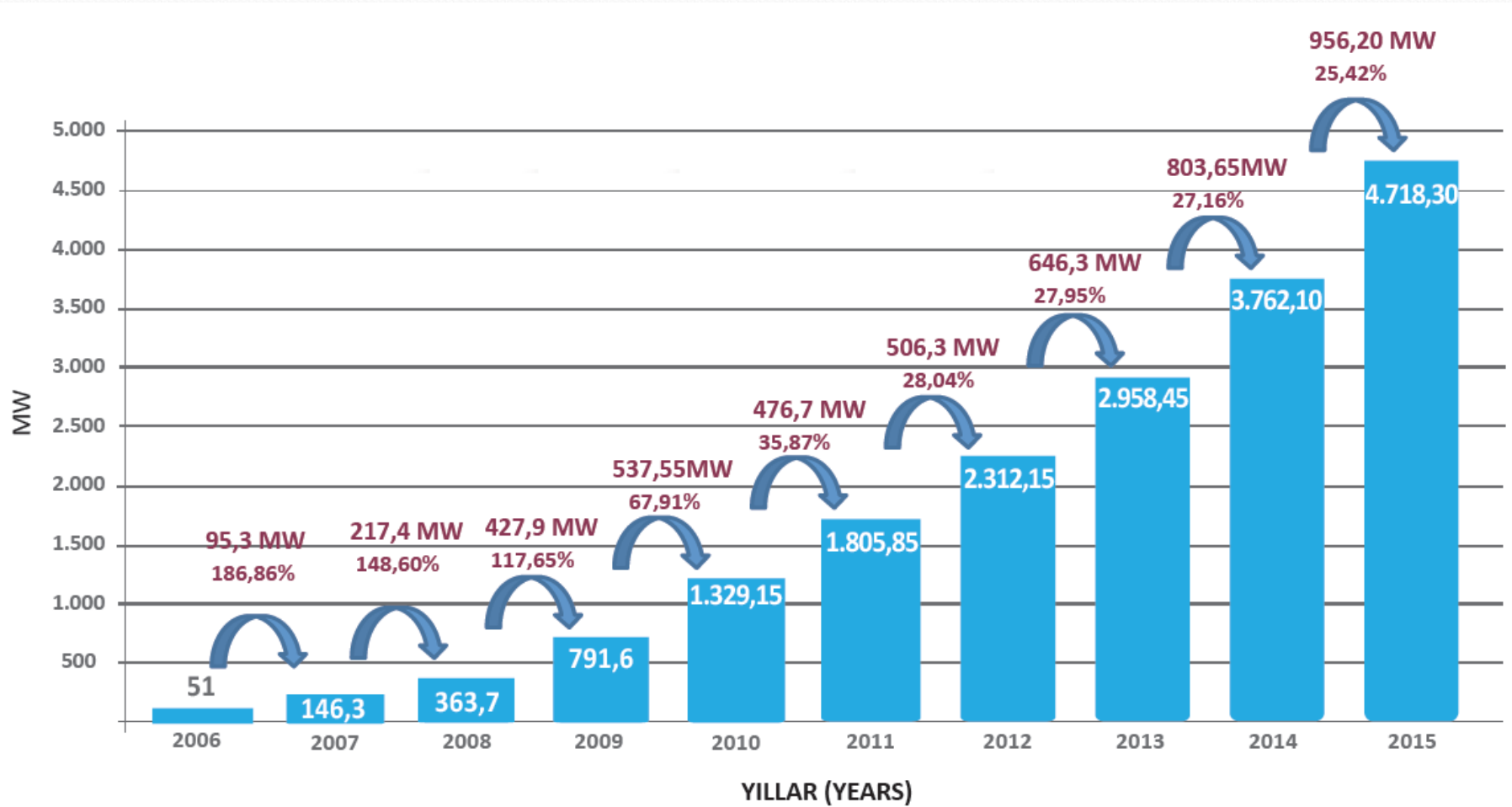
COMPANY NAME	PROJECT NAME	INSTALLED CAPACITY (MW)	CITY	TURBINE MANUFACTURERS	TURBINE MODEL	TURBINE POWER	COMMISSIONING OF OPERATION
Aysu En. San. ve Tic. A.Ş.	Karadere RES	16,00	Kirkareli	GE	GE1.6-100	1,6 MW	2014
Deniz El. Üc. Ltd. Şti.	Karakurt RES	10,80	Manisa	VESTAS	V90-1.8	1,8 MW	2007
Briza El. Üc. A.Ş.	Kavaklı RES	52,00	Balıkesir	VESTAS	V112-3.3	3,3 MW	2014
Alize En. El. Üc. A.Ş.	Keitpepe RES	23,00	Balıkesir	ENERCON	E-44/E-70	0,9 MW/2,3 MW	2009/2014
Lodos El. Üc. A.Ş.	Kemerburgaz RES	24,00	İstanbul	ENERCON	E-82	2 MW	2008
Alenka Enerji Üc. ve Yat. Ltd. Şti.	Kryköy RES	28,00	Kirkareli	GAMESA	G90/G97	2,0 MW	2014
Kores Kocadağ Rüz. En. Sant. Üc. A.Ş.	KORES	17,50	İzmir	NORDEX	N90	2,5 MW	2012
Ayen En. A.Ş.	Korkmaz RES	25,20	İzmir	SUZLON	S88	2,5 MW	2014
Doğal En. El. Üc. A.Ş.	Kozbeyli RES	32,20	İzmir	ENERCON	E-70	2,3 MW	2012/2013
Alize En. El. Üc. A.Ş.	Kuyucak RES	25,60	Manisa	ENERCON	E-70/E-44	2MW/0,9MW	2010
Kıroba El. Üc. A.Ş.	Madranbaba RES	19,50	Aydın	GAMESA	G90	2,0 MW	2013
Enerjisa En. Üc. A.Ş.	Mahmudiye RES	29,90	Çanakkale	SIEMENS	SWT-2.3-101	2,3 MW	2010
Mare Manastır Rüz. En. San. Tic. A.Ş.	Mare Manastır RES	39,20	İzmir	ENERCON	E-48/E-44	0,8MW/0,9MW	2006/2007
Mazi-3 Rüz. En. Sant. El. Üc. A.Ş.	Mazi-3 RES	30,00	İzmir	NORDEX	N90	2,5 MW	2011
Akdeniz El. Üc. A.Ş.	Mersin Mut Extension	9,00	Mersin	VESTAS	V90-3.0	3,0 MW	2013
Akdeniz El. Üc. A.Ş.	Mersin Mut RES	33,00	Mersin	VESTAS	V90-3.0	3 MW	2010
Can Enerji Ent. El. Üc. A.Ş.	Metriştepe RES	40,00	Bilecik	NORDEX	N100	2,5 MW	2011
Ayen En. A.Ş.	Mordoğan RES	31,50	İzmir	SUZLON	S88	2,1 MW	2014
R.K. RES El. Üc. San. ve Tic. Ltd. Şti.	Papalımanı RES	0,80	Balıkesir	ENERCON	E-53	0,8MW	2013
Pitane Elektrik Üc. Ltd. Şti.	Pitane RES	4,80	İzmir	NORDEX	N117	2,4 MW	2014
Poyraz En. El. Üc. A.Ş.	Poyraz RES	54,90	Balıkesir	ENERCON	E-82	2MW	2012/2013
Öres El. Üc. A.Ş.	Salman RES	27,50	İzmir	GE	GE2.75-100	2,75 MW	2014
Doğal En. El. Üc. A.Ş.	Samurlu RES	34,50	İzmir	ENERCON	E-70	2,3 MW	2012/2013
Saray Dök. Mad. Ak. San. Tic. A.Ş.	Saray RES	4,00	Tekirdağ	ENERCON	E-82	2MW	2012
Garet En. Üc. ve Tic. A.Ş.	SARES	24,75	Çanakkale	GE	GE2.75-100	2,75 MW	2010/2011
Alize En. El. Üc. A.Ş.	Sarıyaka RES	28,80	Tekirdağ	ENERCON	E-82/E-70/E-48	2MW/0,8MW	2009
Doğal En. El. Üc. A.Ş.	Sayalar RES	54,20	Manisa	ENERCON	E-82/E-70/E-44	2MW/0,9MW	2008/2013
Deniz El. Üc. Ltd. Şti.	Sebenoba RES	34,00	Hatay	VESTAS	V80-2.0	2 MW	2008
Eolos Rüz. En. Üc. A.Ş.	Senkoy RES	36,00	Hatay	ALSTOM	ECO100 / ECO110	3 MW	2012 / 2013
Doruk En. Üc. San. Tic. A.Ş.	Seytali RES	30,00	İzmir	ENERCON	E-70	2 MW	2011
Silivri Enerji Üc. A.Ş.	Silivri RES	45,00	İstanbul	NORDEX	N100	2,5 MW	2014
Tektaş El. Üc. A.Ş.	Sıncık RES	27,50	NORDEX	N100	2,5 MW	2013	
Soma En. El. Üc. A.Ş.	Soma RES	196,10	Manisa	ENERCON	E-70/E-44	2MW/0,9MW	2011/2012/2014
Bilgin Rüz. Sant. En. Üc. A.Ş.	Soma RES	90,00	Manisa	NORDEX	N90	2,5 MW	2007
ABK En. Üc. San. ve Tic. A.Ş.	Söke-Çatalbük RES	30,00	Aydın	GAMESA	G90	2,0 MW	2010
Sunçüt Sını Jüt San. Tic. A.Ş.	Sunçüt RES	1,20	İstanbul	ENERCON	E-40	0,6MW	2006
Alentez En. A.Ş.	Susurluk RES	60,00	Balıkesir	NORDEX	N100/N90	2,5 MW	2012
Çarşes El. Üc. A.Ş.	Şadıllı RES	38,50	Çanakkale	GE	GE2.75-100	2,75 MW	2014
Galata Wind En. Ltd. Şti.	ŞahRES	93,00	Balıkesir	VESTAS	V90-3.0	3 MW	2011
Galata Wind En. Ltd. Şti.	ŞahRES Extension	12,00	Balıkesir	VESTAS	V90-3.0	3,0 MW	2013
Baki El. Üc. Ltd. Şti.	Şanlı RES	113,40	Balıkesir	VESTAS	V90-3.0	3 MW	2008/2010
Yeni Belen Enerji Elektrik Üretim	Şenbök RES	27,00	Hatay	VESTAS	V112-3.0	3,0 MW	2013
Bakras Enerji Elektrik Üc. ve Tic. A.Ş.	Şenbök RES	15,00	Hatay	VESTAS	V90-3.0	3 MW	2010
Bakras Enerji Elektrik Üc. ve Tic. A.Ş.	Şenbök Res Extension	23,00	Hatay	VESTAS	V112-3.3	3,3 MW	2014
Teperes El. Üc. A.Ş.	TepeRES	0,85	İstanbul	VESTAS	V52-850	850 KW	2006
Pem En. A.Ş.	Tokat RES	40,00	Tokat	NORDEX	N100	2,5 MW	2010 / 2011
Sabaş El. Üc. A.Ş.	Turguttepe RES	24,00	Aydın	VESTAS	V90-2.0	2 MW	2010
Efa Elektrik Üretim A.Ş.	Umrurlar RES	10,00	Balıkesir	VESTAS	V100-2.0	2,0 MW	2014
Armaz RES Rüzgar En. El. Üc.	Uşak RES	54,00	Uşak	SINOVEL	SL1500/90	1,5 MW	2013
Innores El. Üc. A.Ş.	Yuntdağ RES	57,50	İzmir	NORDEX	N90	2,5 MW	2011
Innores El. Üc. A.Ş.	Yuntdağ RES Ext.	2,50	İzmir	NORDEX	N100	2,5 MW	2014
Zeytineli RES El. Üc. A.Ş.	Zeytineli RES	50,00	İzmir	NORDEX	N100/N90	2,5 MW	2013
Ziyaret RES El. Üc. San.Tic. A.Ş	Ziyaret RES	65,00	Hatay	GE	GE2.5-100	2,5 MW	2010/2011/2013
Ziyaret RES El. Üc. San.Tic. A.Ş	Ziyaret RES Ext.	11,00	Hatay	GE	GE2.75-100	2,75 MW	2014

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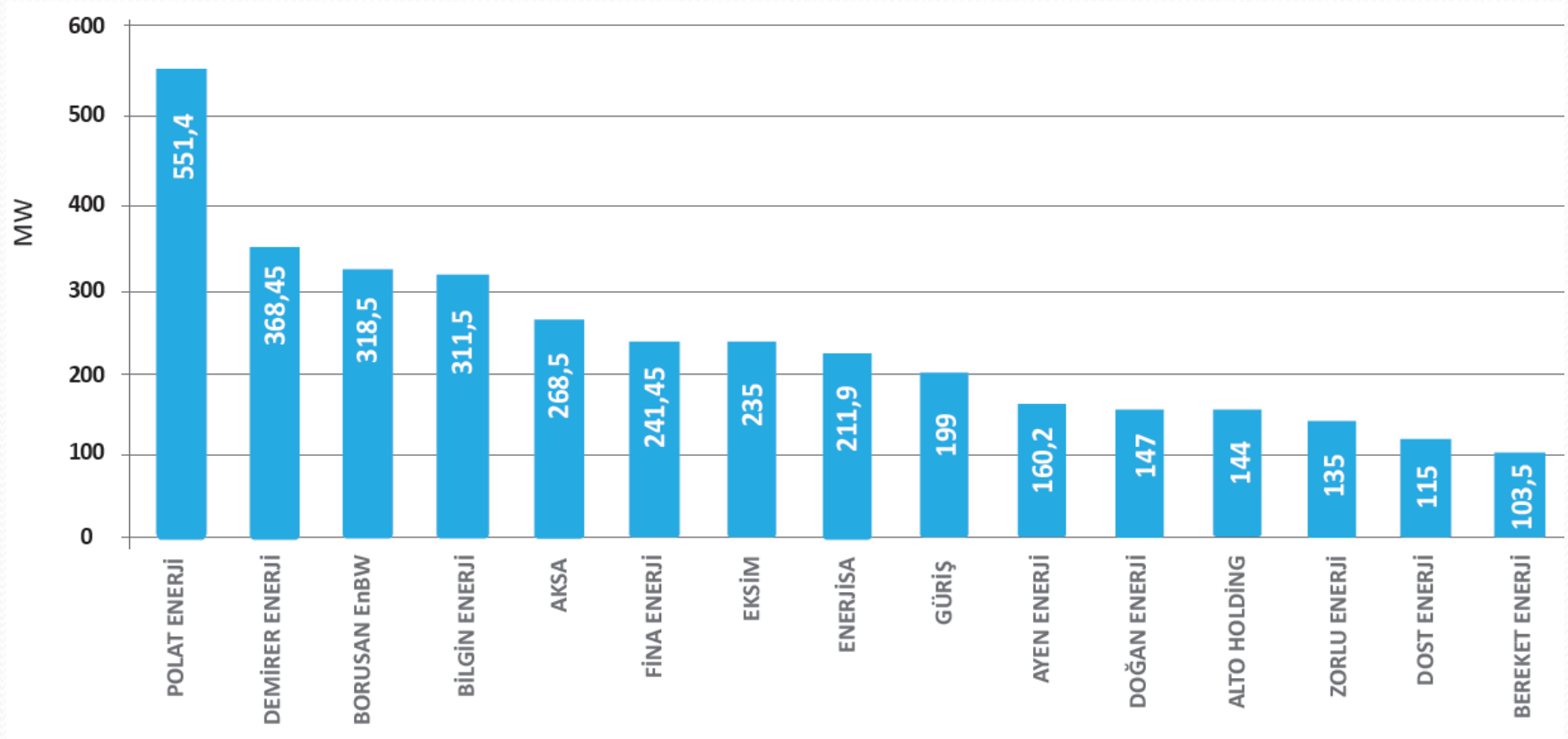
## 2.1. Annual Installations for WPPs in Turkey(MW)



## 2.2.Cumulative Installations for WPPs in Turkey(MW)

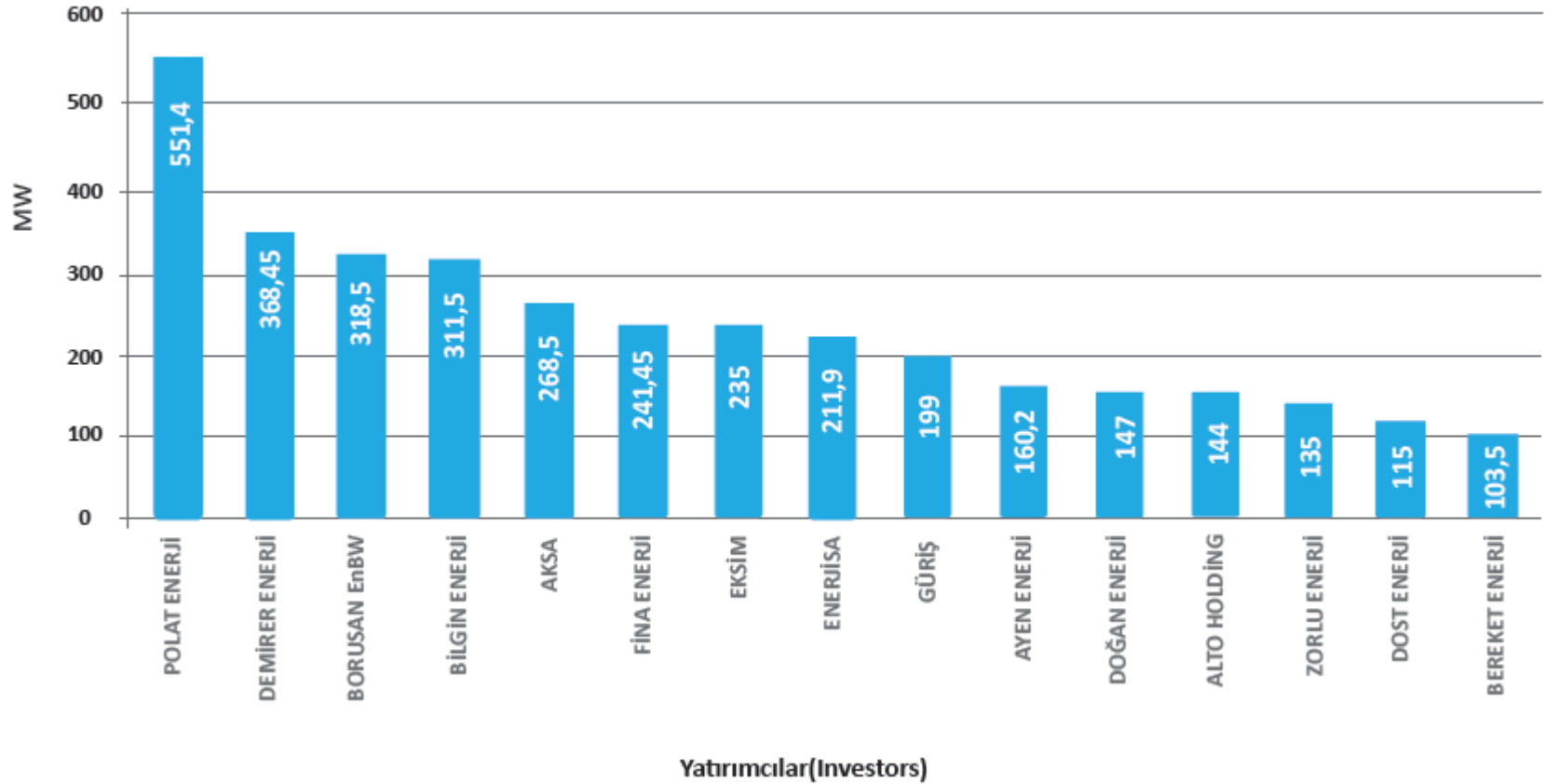


## 2.3.1. Investors According to Installed capacity for operational wind power plants(MW)

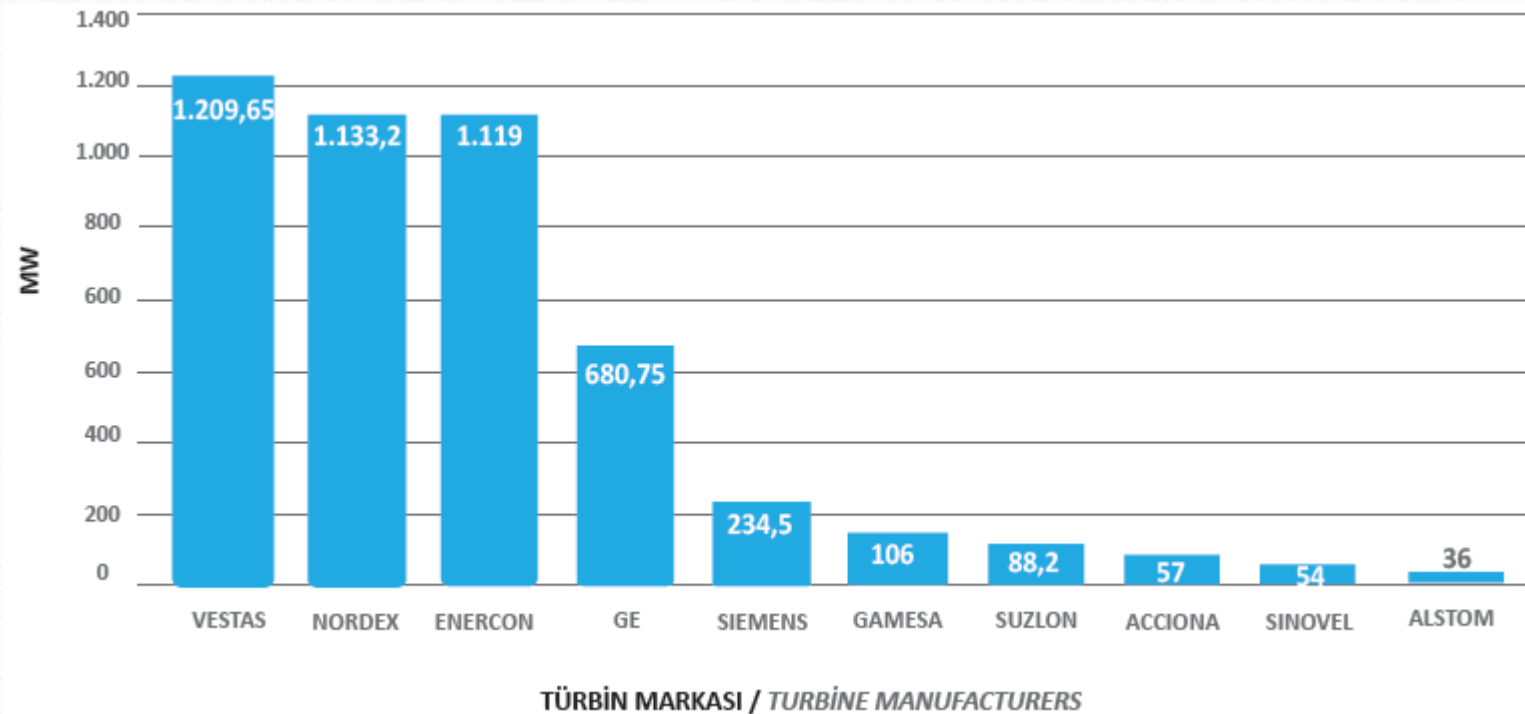




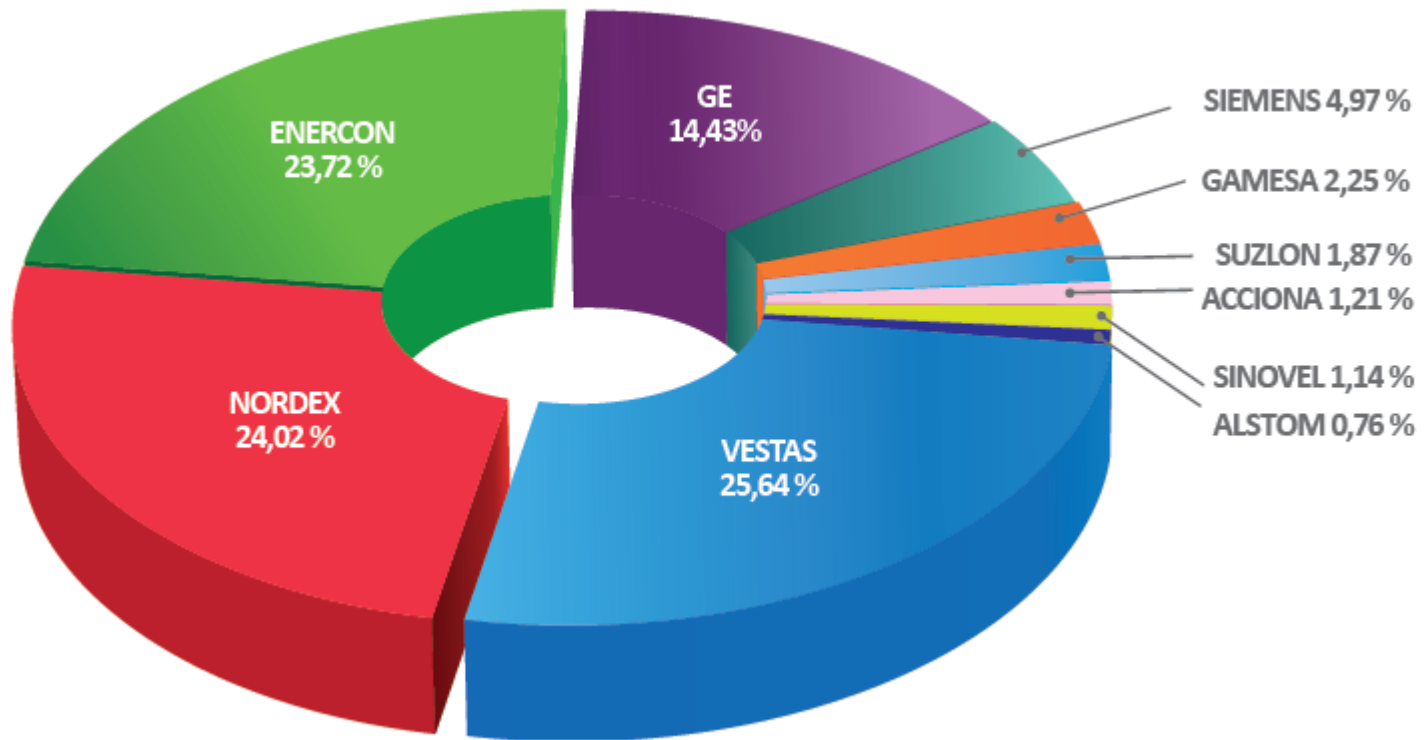
## 2.3.2. Investors According to operational wind power plants(%)



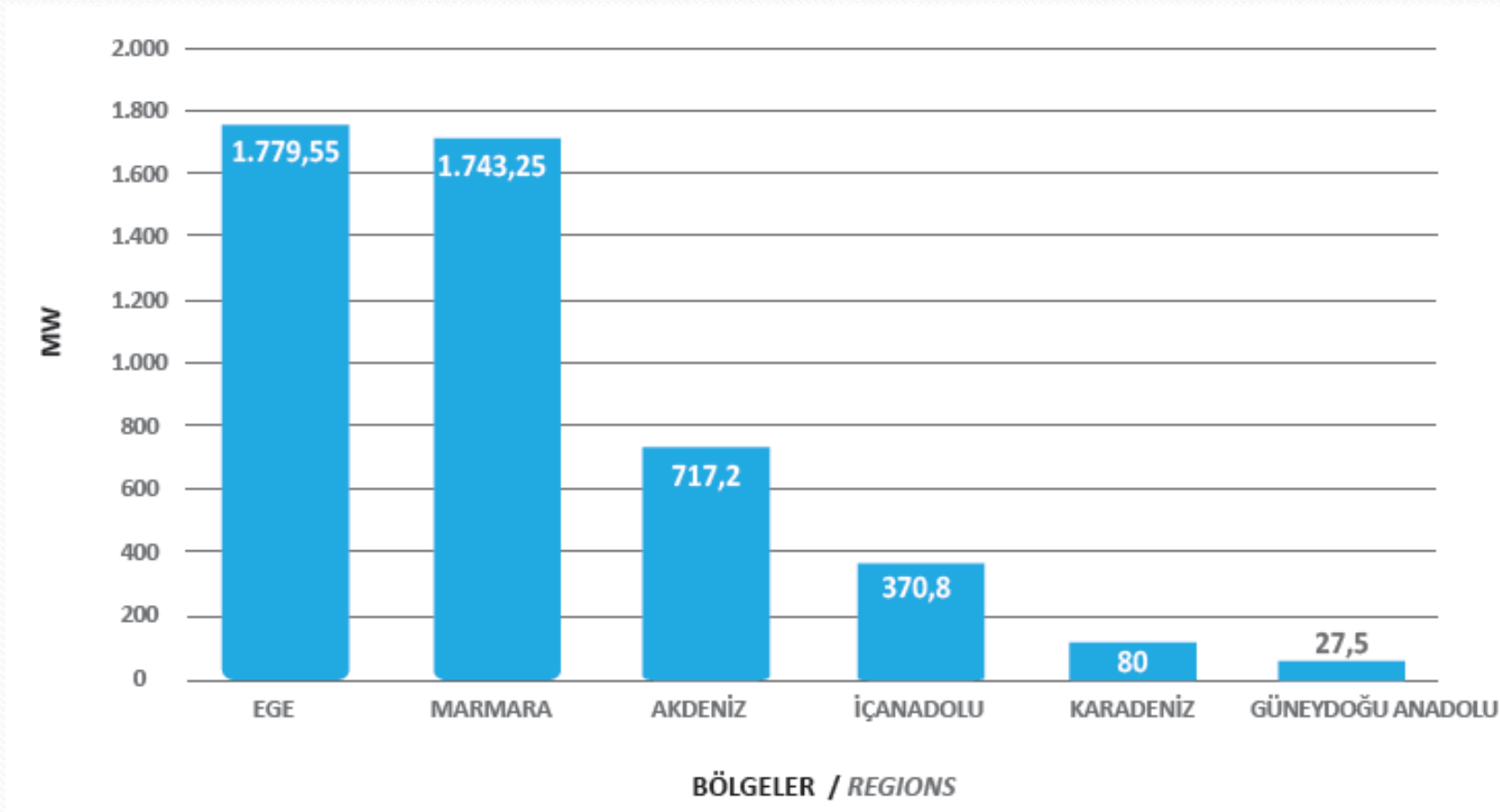
## 2.4.1. Turbine Manufacturers according to Installed Capacity for Operational WPPs (MW)



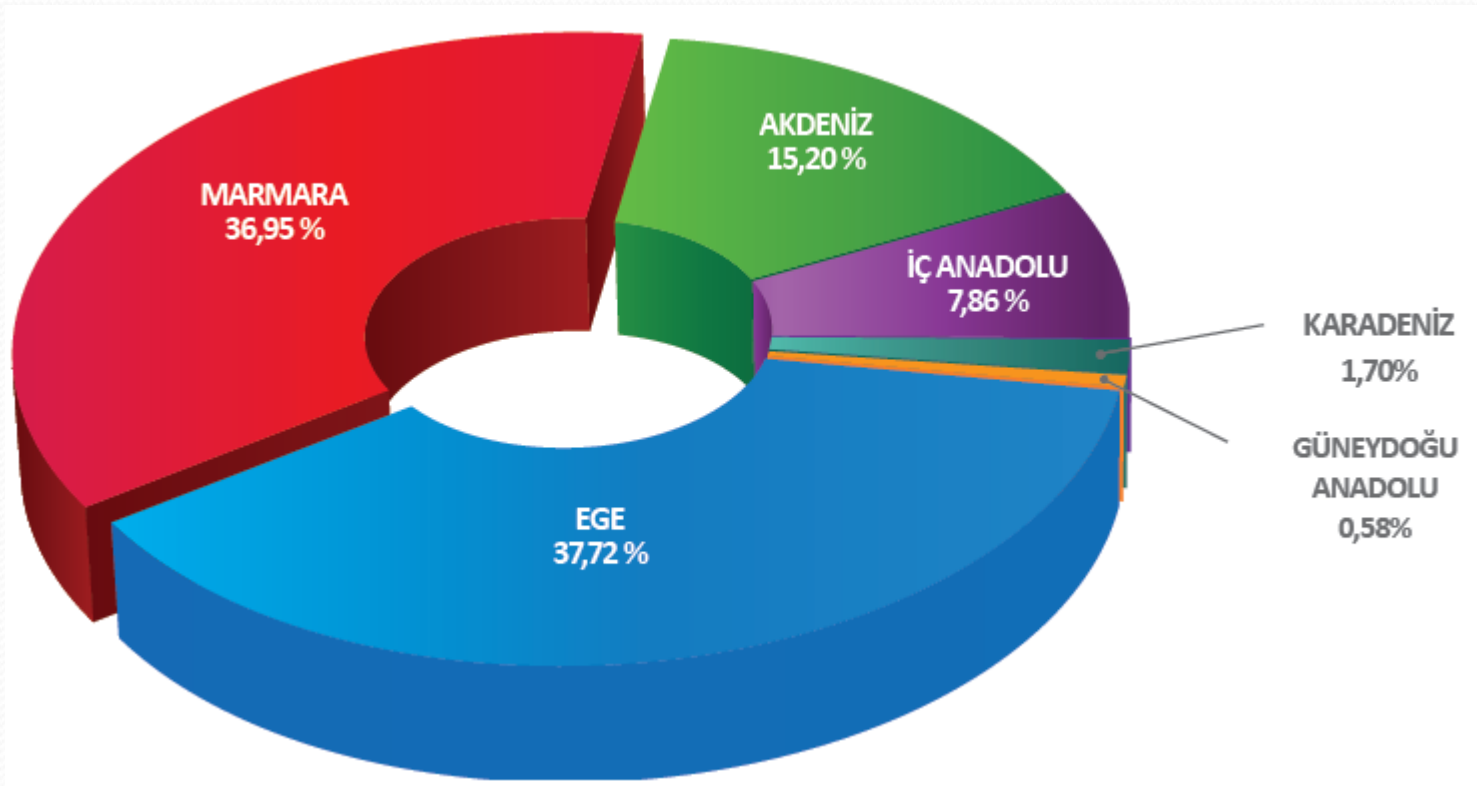
## 2.4.2. Turbine Manufacturers According to Operational WPPs (%)



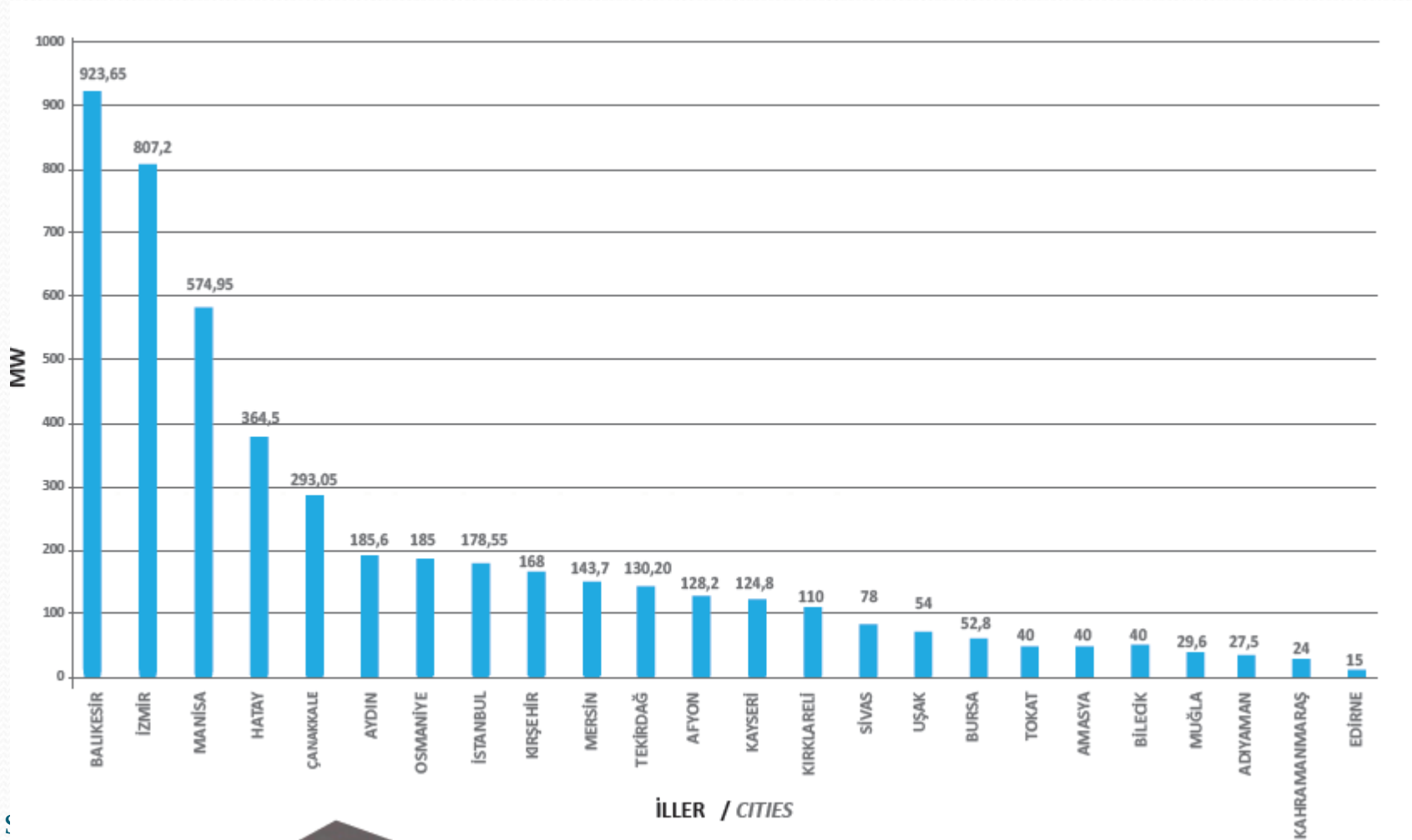
## 2.5.1.Regions According to the Installed Capacity of Operational WPPs(MW)



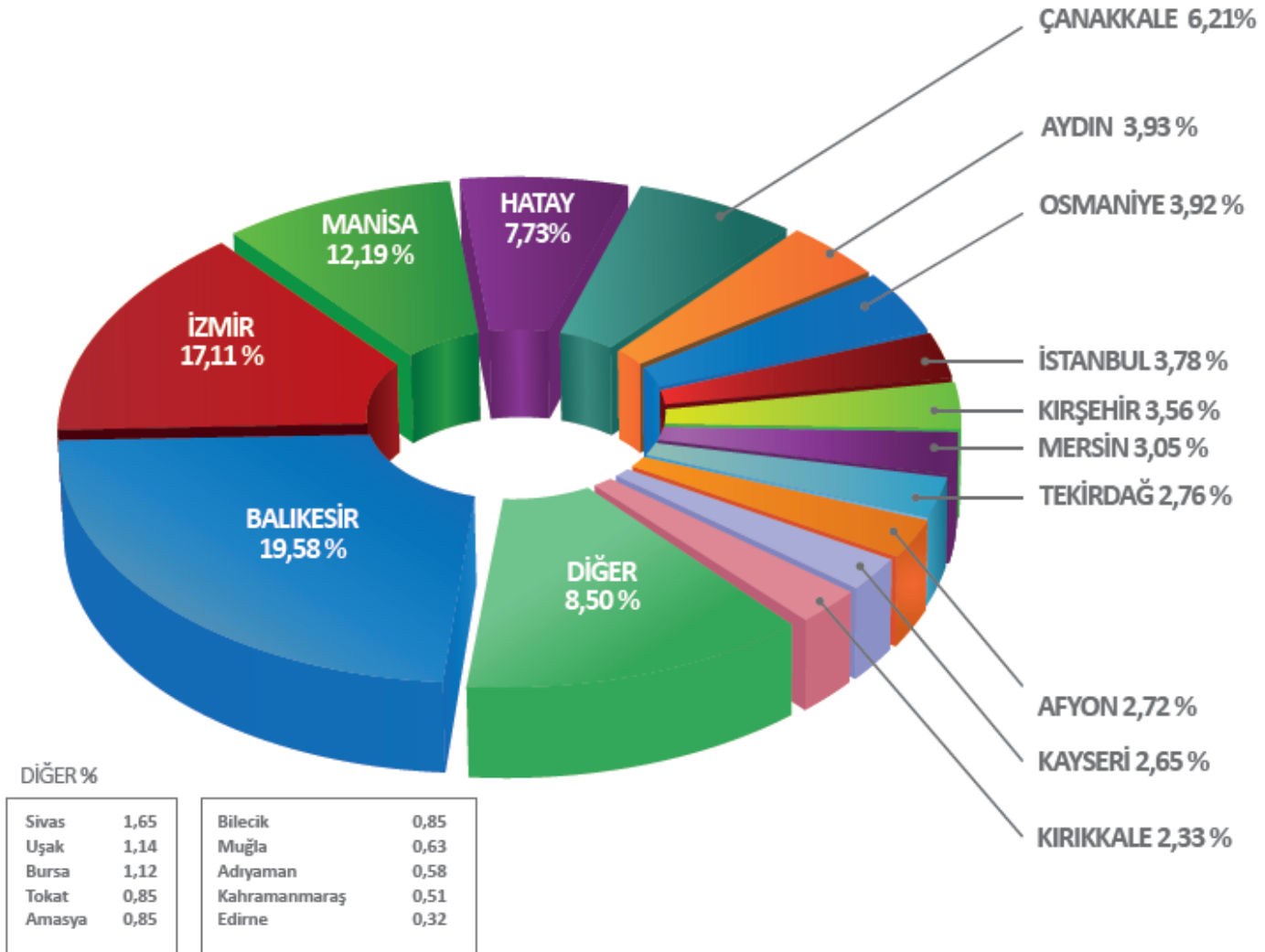
## 2.5.2.Regions According to the Installed Capacity of Operational WPPs (%)



## 2.6.Cities According to Installed Capacity for Operational WPPs(MW)



## Cities According to operational WPPs

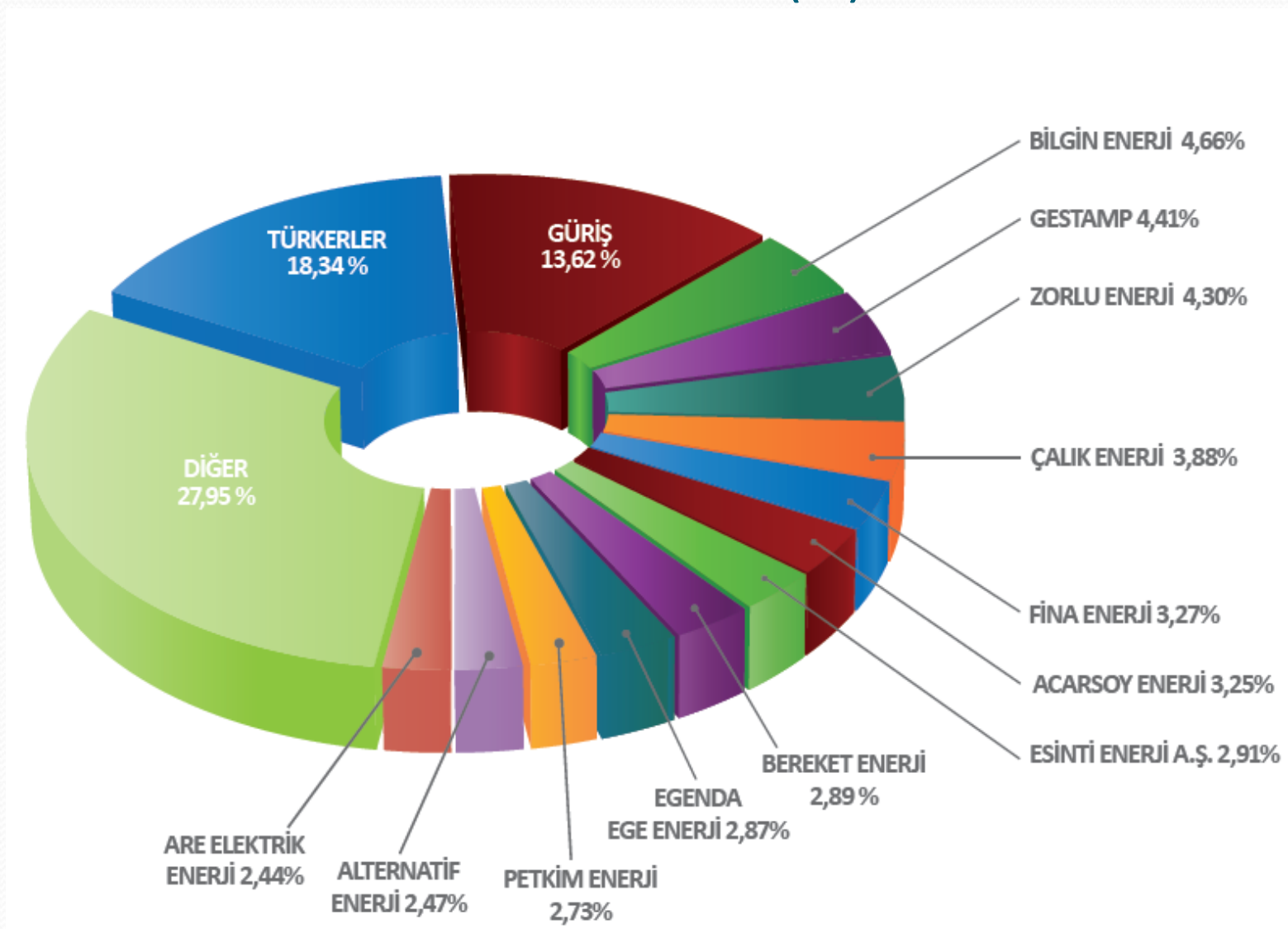


# 3.WPPs Under Construction

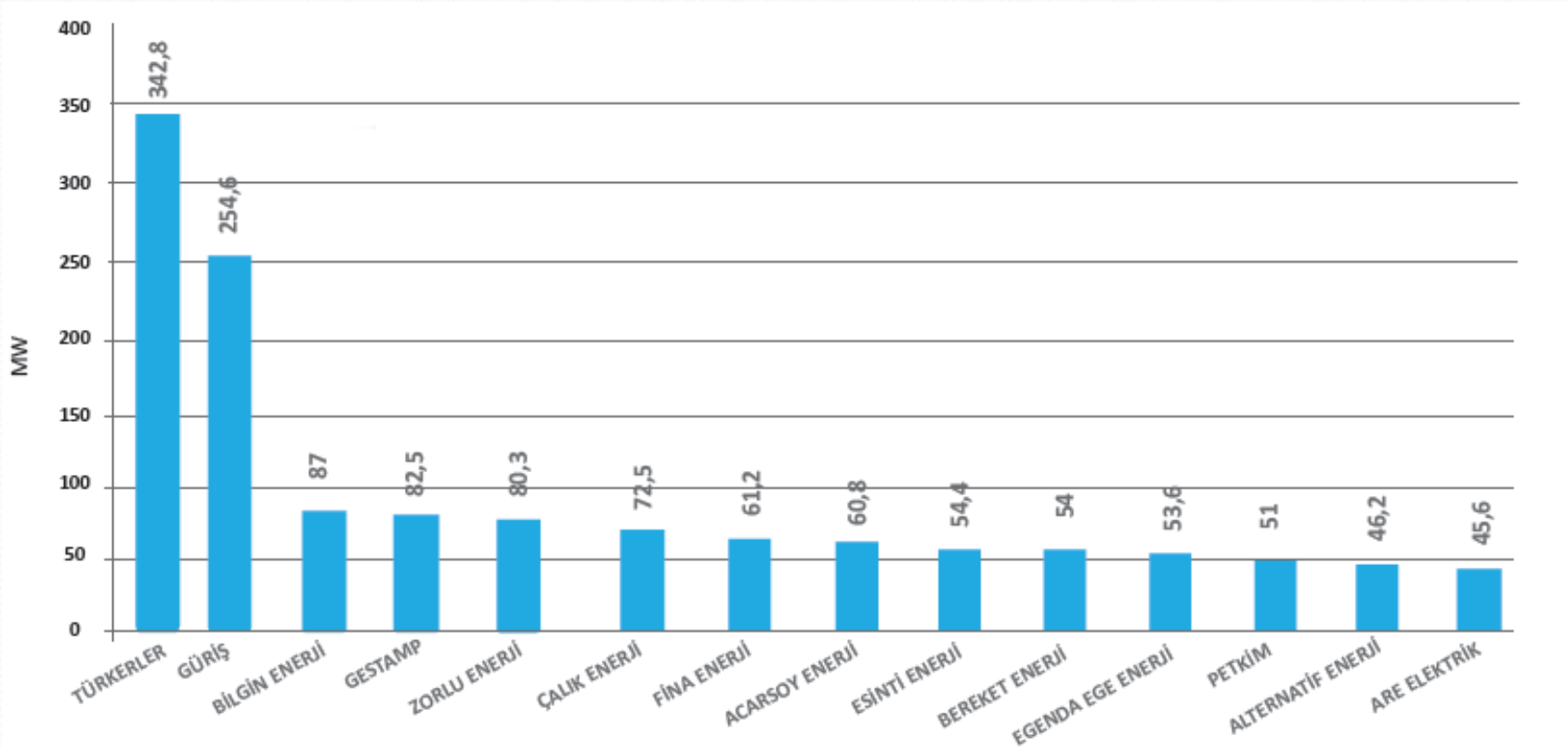
COMPANY NAME	PROJECT NAME	CAPACITY(MW)	CITY	TURBINE MANUFACTURERS	TURBINE MODEL	TURBINE POWER
YGT Elektrik Ür. San. ve Tic. Ltd. Şti.	AdaRES	10,00	İzmir	GAMESA	G97	2 MW
Ayen En. A.Ş.	Akbük II RES	21,00	Muğla	SUZLON	S95	2,5 MW
Akhisar Enerji Ür. A.Ş.	Akres Ext.	10,00	Manisa	NORDEX	N100	2,5 MW
Aksa Enerji Ür. A.Ş.	Atik Belen RES	12,00	Hatay	GAMESA	G90/G97	2 MW
Kütle Enerji Yat. Ür. ve Tic. A.Ş.	Bağarası RES	48,00	İzmir	NORDEX	N117	2,4 MW
Bandırma En. ve El. Ür. Tic. A.Ş.	Bandırma RES Ext - 2	3,30	Balıkesir	VESTAS	V112-3.3	3,3 MW
As Makinsan En. El. Ür. San.Tic. A.Ş. B	Bandırma-3 RES Ext.	16,80	Balıkesir	NORDEX	N117/2400	2,4 MW
Kardemir Haddecilik San.Tic. Ltd.Şti.	Bozyaka RES Ext.	4,80	İzmir	NORDEX	N117/2400	2,4 MW
Z.T Enerji A.Ş.	Çerçikaya RES	57,00	Hatay	ACCIONA	AW125/3000	3 MW
ABK Çeşme Enerji	Çeşme RES	18,00	İzmir	NORDEX	N117	3 MW
Kale Enerji Üretim Tic. ve San. A.Ş.	Dilek RES	21,60	Kahramanmaraş	NORDEX	N117/2400	2,4 MW
"Edincik Enerji El. Ür. A.Ş."	Edincik RES Ext.	26,40	Balıkesir	NORDEX	N117	2,4 MW
BOREAS Enerji	Enez RES Ext.	6,60	Edirne	NORDEX	N100	3,3 MW
Deme En. Ür. Tic. A.Ş.	Fatma RES	77,40	Muğla	SIEMENS	SWT 3.0/3.2-113	3,2MW/3,0MW
FuatRES Elektrik Üretim A.Ş.	Fuat RES	33,00	İzmir	VESTAS	V112-3.3	3,3 MW
Hacim Enerji Yat. Ür. ve Tic. A.Ş.	Geyve RES	50,00	Sakarya	ENERCON	E82	2 MW
Eskoda Enerji Ür. Paz. İth. İhr. A.Ş.	Harmanlık RES	52,80	Bursa	VESTAS	V112-3.3	3,3 MW
Hilalres Elektrik Üretim San. ve Tic. A.Ş.	Hilal-2 RES	9,90	Mersin	VESTAS	V112-3.3	3,3 MW
Deme En. Ür. Tic. A.Ş.	Kaniye RES	64,00	Edirne	SIEMENS	SWT-3.2-113	3,2 MW
Egener El. Ür. ve Mak. San. ve Tic. A.S.	Karabel RES	3,00	İzmir	SENVION	3.4M104	3,4 MW
Esinti En. Ür. Tic. A.Ş.	Kınık RES	54,40	İzmir	SIEMENS	SWT-3.2-108	3,2 MW
Beşiktepe Enerji Üretim ve Tic. A.Ş.	Kıyıköy RES	36,00	Tekirdağ	NORDEX	N117/3000	3 MW
Dost Enerji	KORES Ext.-II	7,50	İzmir	NORDEX	N100/2500	2,5 MW
Eskoda Enerji Ür. Paz. İth. İhr. A.Ş.	Koru RES	52,80	Çanakkale	VESTAS	V112-3.3	3,3 MW
Güney Rüzgan El. Ür. Tic. A.Ş.	Mut RES	52,80	Mersin	VESTAS	V112-3.3	3,3 MW
Serin En. El. Ür. A.Ş.	Ortamandira RES	11,20	Balıkesir	GE	GE1.6-100	1,6 MW
AYRES Elektrik Üretim A.Ş.	OvaRES	18,00	Aydın	GAMESA	G97	2 MW
Tayf Enerji Yat. Üretim Tic. A.Ş.	Ödemiş RES	21,00	Aydın	NORDEX	N117/3000	3 MW
Pamukova Rüz. En. Yat. Ür. ve Tic. A.Ş.	Pamukova RES	20,00	Sakarya	ENERCON	E82	2 MW/3 MW
Petkim Petrokimya Holding A.Ş.	Petkim RES	51,00	İzmir	ALSTOM	ECO110	3 MW
Ufuk En. El. Ür. A.Ş.	Poyrazgözü RES	30,00	Balıkesir	ENERCON	E70/E82	2,3 MW
Deniz El. Ür. Ltd. Şti.	Sebenoba RES Ext.	24,00	Hatay	VESTAS	V112-3.0	3,0 MW
Bereket Enerji	Söke RES	49,50	Aydın	VESTAS	V112-3.3	3,3 MW
STEAG Rüzgar Süloğlu En.Ür. ve Tic.A.S.	Süloğlu RES	66,00	Kırklareli	VESTAS	V126-3.3	3,3 MW
Hassas Teknik Enerji El. Ür. San. Tic. A.Ş.	Urta RES	18,00	İzmir	NORDEX	N117/3000	3 MW
SE Santral Elektrik Üretim San. ve Tic. A.Ş.	Yahyalı RES	52,80	Kayseri	NORDEX	N117/2400	2,4 MW
Arova RES Elektrik Ür.	Yalova RES	54,00	Yalova	SINOVEL	SL1500/90 SL1500/82	1,5 MW
Yeni Enerji Yat. Üretim Tic. A.Ş.	Yenihisar RES	21,60	Aydın	NORDEX	N117/2400	2,4 MW
Deme En. Ür. Tic. A.Ş.	Zeliha RES	24,00	Kırklareli	SIEMENS	SWT-3.0-113	3,0 MW



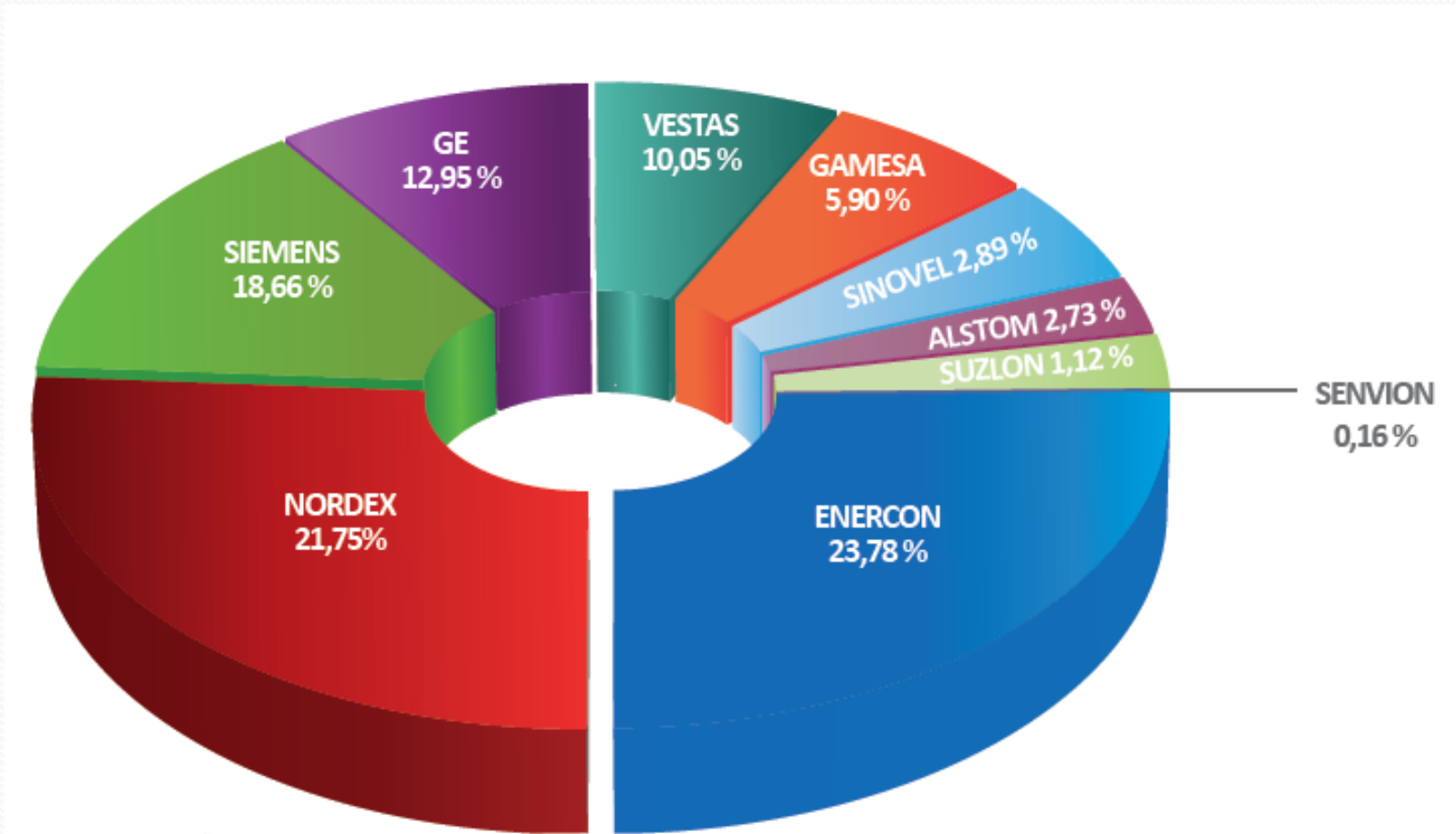
### 3.1.1. Investors According to capacity for WPPs UnderConstruction (%)



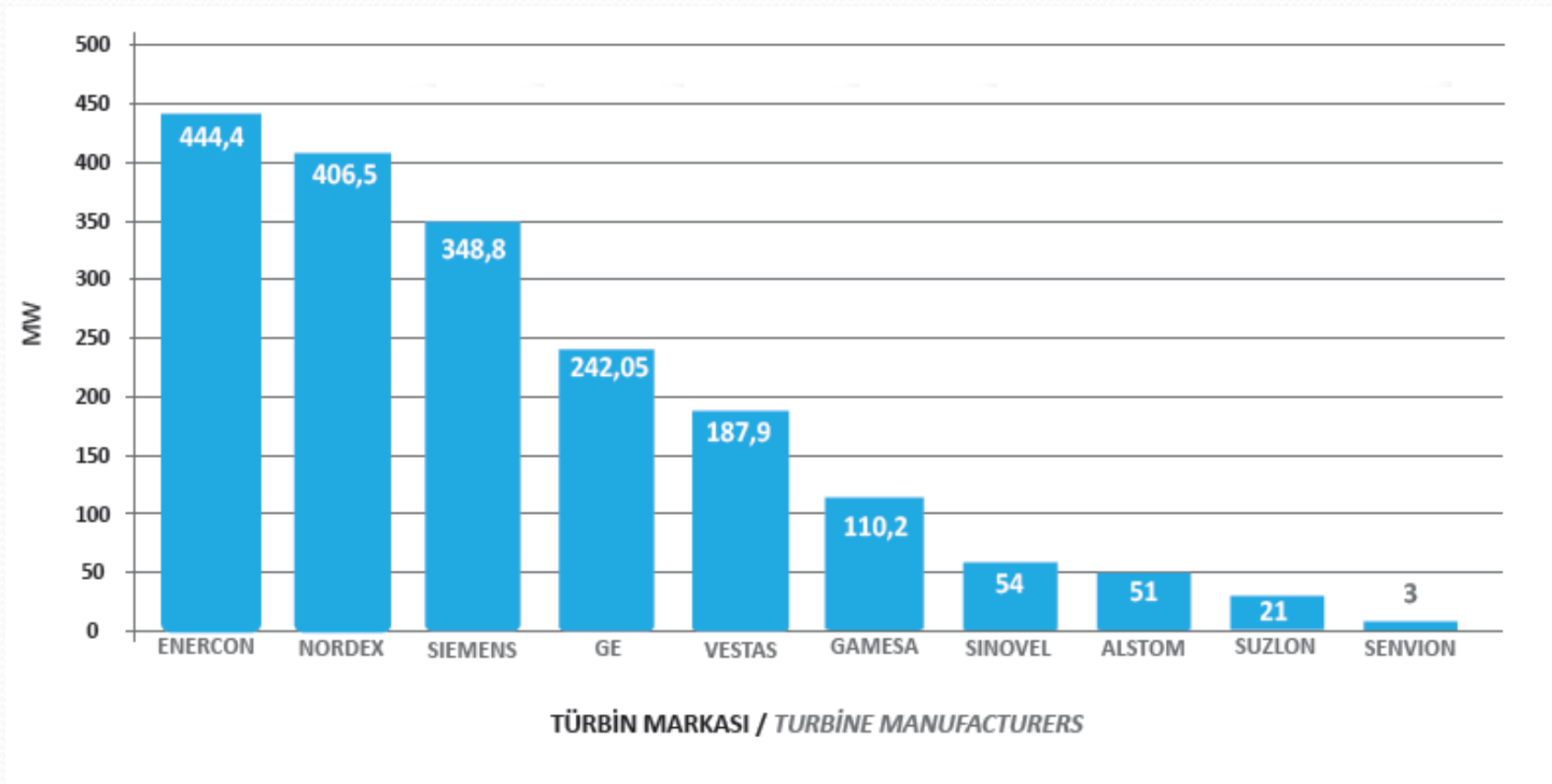
## 3.1.2. Investors According to capacity for WPPs UnderConstruction (MW)



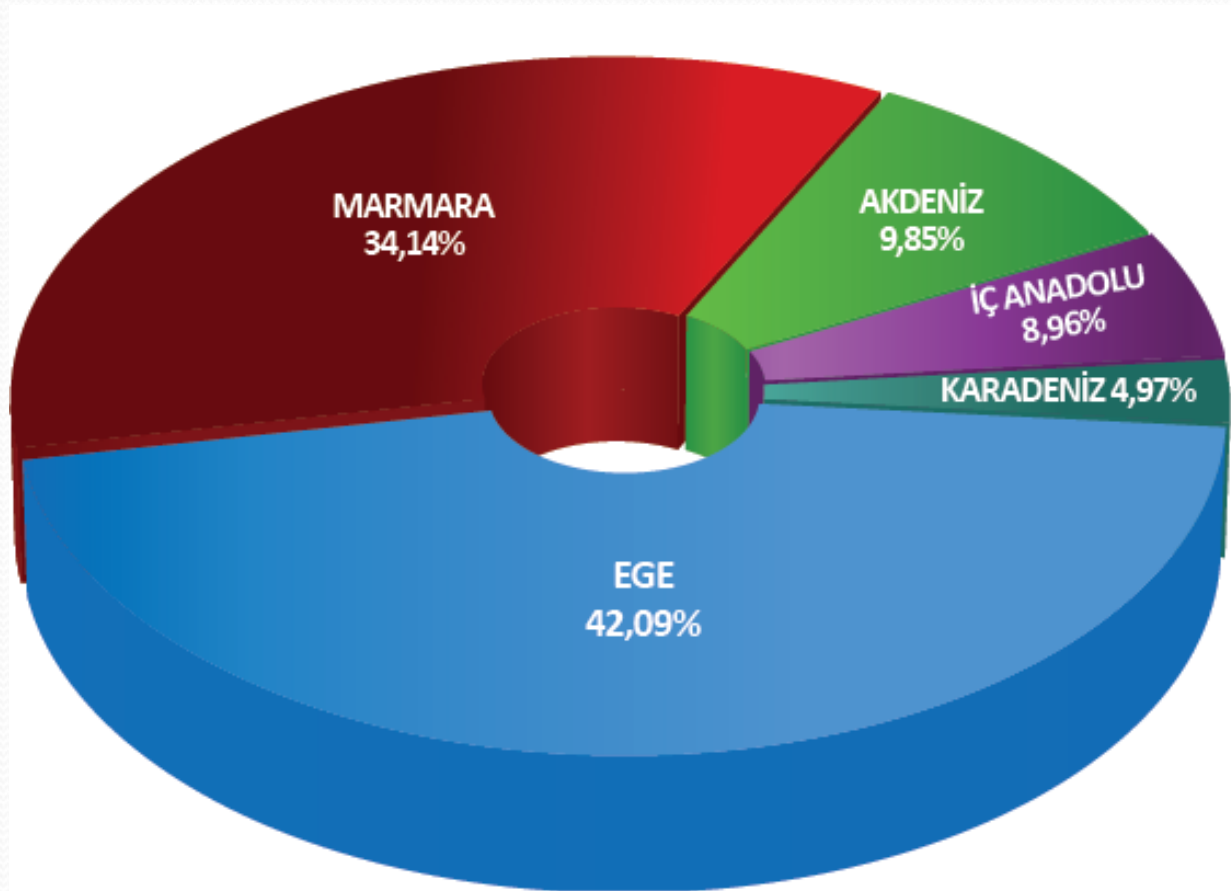
### 3.2.1. Turbine Manufacturers According to capacity for WPPs Under Construction (%)



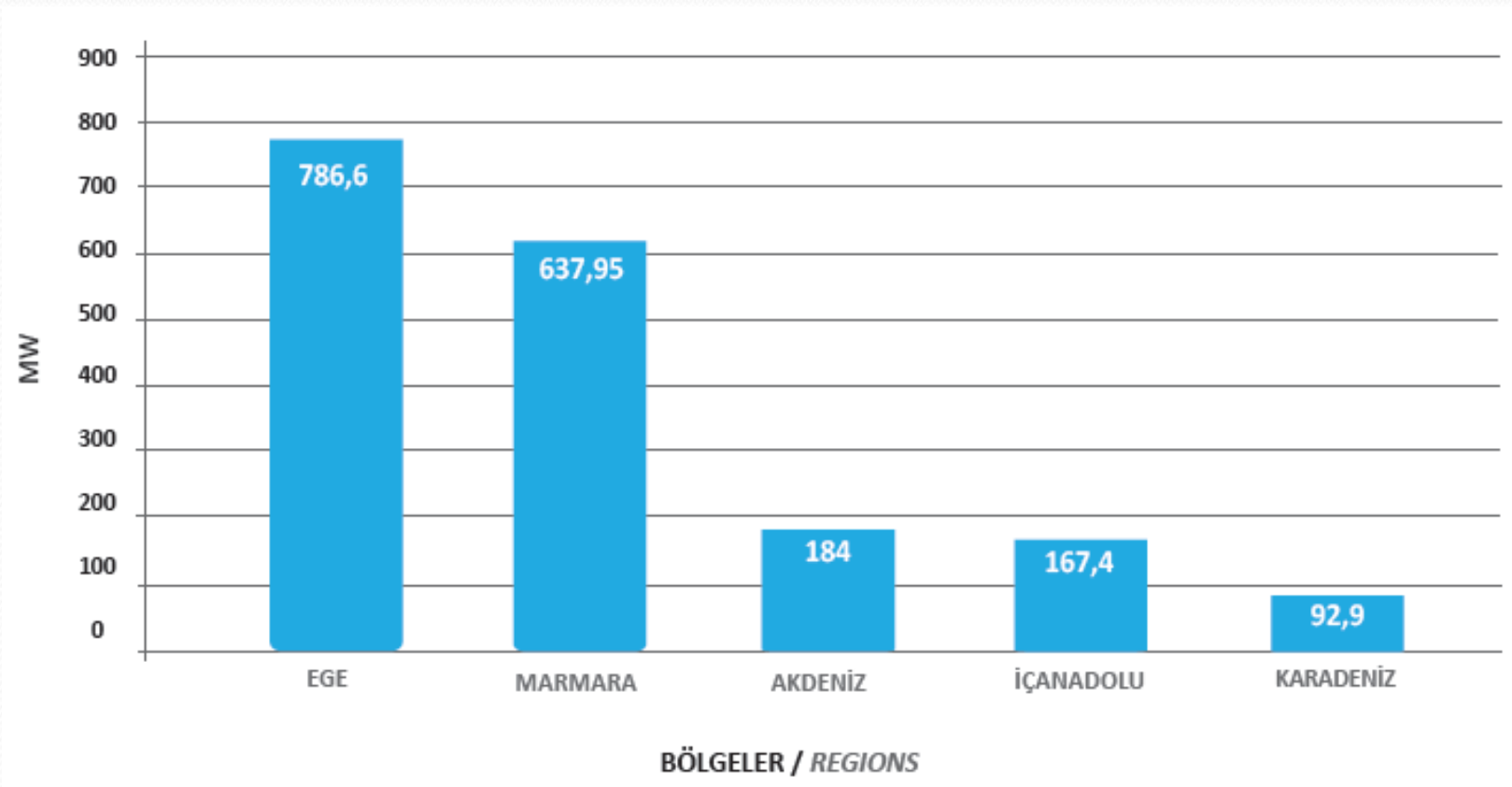
### 3.2.2. Turbine Manufacturers According to capacity for WPPs Under Construction (MW)



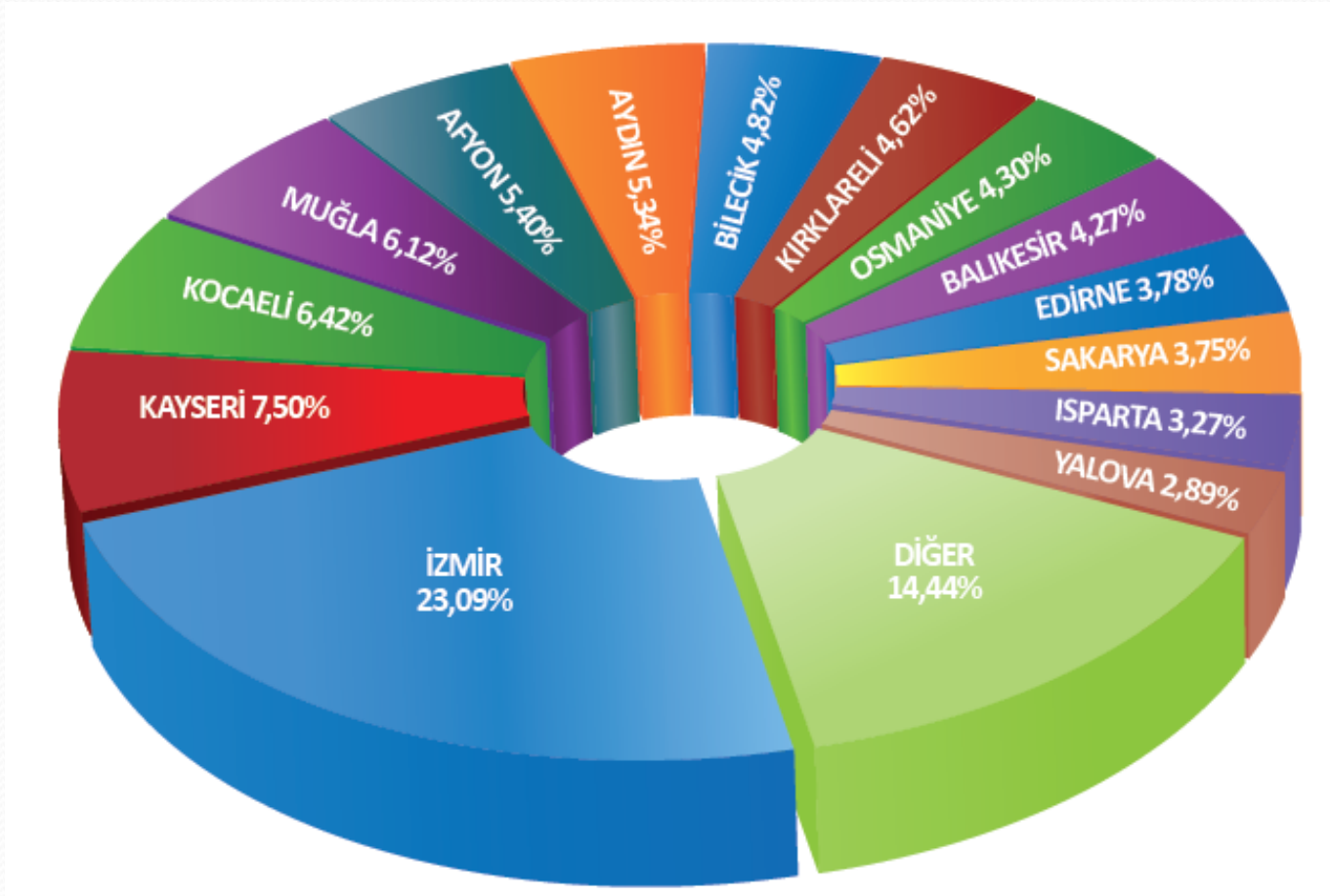
### 3.3.1.Regions According to the Installed Capacity for WPPs Under Construction(%)



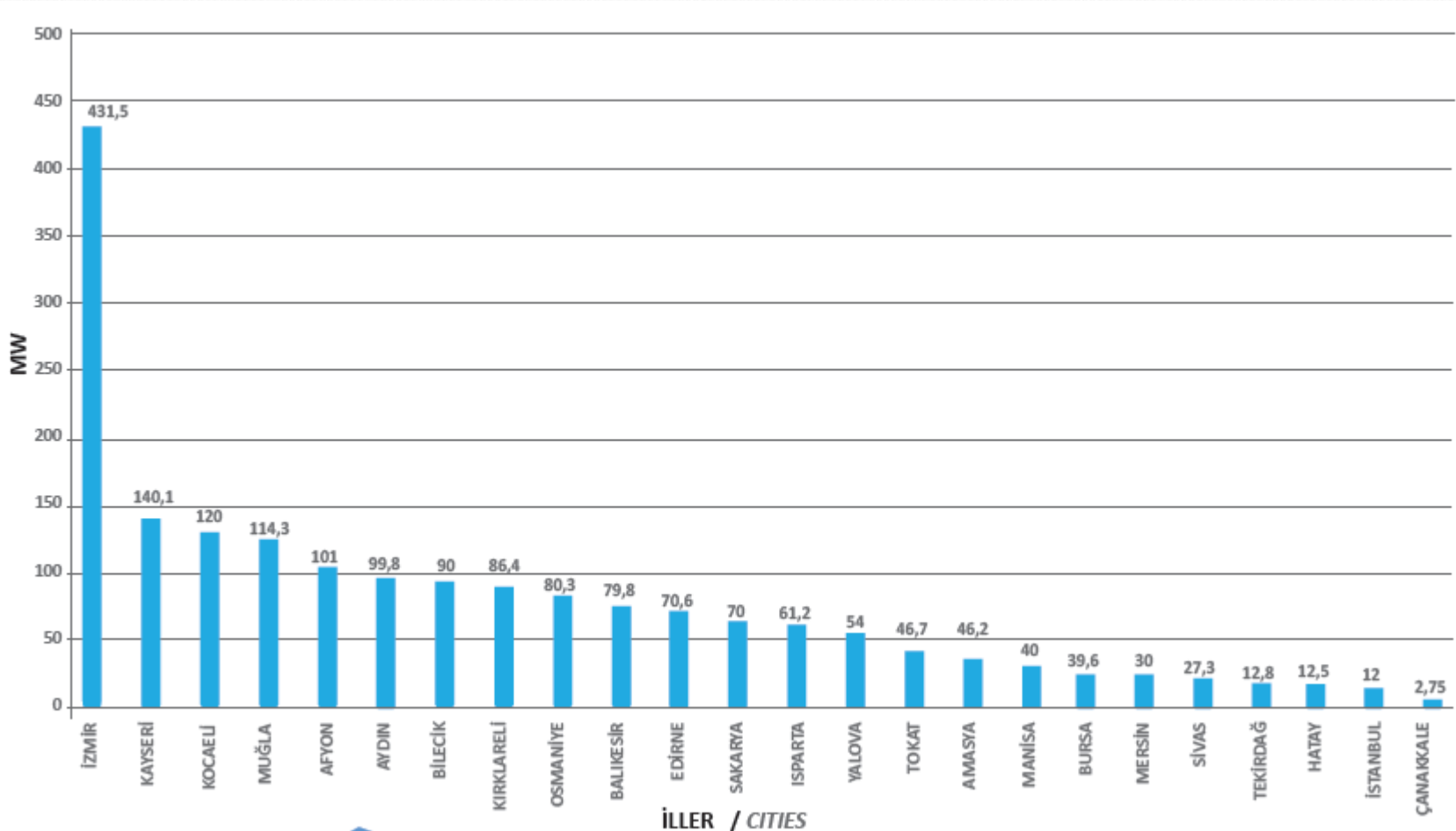
### 3.3.2.Regions According to the Installed Capacity for WPPs Under Construction(MW)



### 3.4.1. Cities According to Capacity for WPPs Under Construction(%)



## 3.4.2. Cities According to Capacity for WPPs Under Construction(MW)



Source: Turkish Wind Energy Association, Turkey Wind Energy Statistics Report, January 2016



# 4. Classification of Wind Turbines in Turkey

The outcoming wind turbine manufacturers in Turkey are :

- ENERCON
- SIEMENS
- NORDEX
- VESTAS

## 4.1.1. ENERCON PRODUCTS in TURKEY

Here, the mostly used wind turbine products of ENERCON series in Turkey have been classified and a comparison has been made out.

- The turbines mainly show difference for their;
- Rated power(kW),
- Rotor diameter(m),
- Rotational speed(rpm)
- Capacity factor(%)



## 4.1.2. ENERCON Wind Turbines Used in Turkey

The mostly used products of Enercon in Turkey are;

- E-44(900 KW)
- E-70(2300 KW)
- E-82(2000 KW)
- E-82(3000 KW)

Source: ENERCON



## 4.1.3. Comparison of Enercon Wind Turbines Used in Turkey

Annual wind energy yield of the mast measurements for different wind turbines of Enercon.

	E82	E101	E115
Rated power (kW)	3000	3050	2500
Rotor diameter (m)	82	101	115
Swept area (m <sup>2</sup> )	5281	8012	10,387
Rotational speed (rpm)	6–18	4–14.5	3–12.8
Gross yield (MWh/year)	4662	6776	7460
Capacity factor (%)	17.6	25.4	34.1

## 4.2.1.SIEMENS PRODUCTS IN TURKEY



Here, the mostly used wind turbine products of SIEMENS series in Turkey have been classified.

The mostly used products are;

- SWT-101/ 2.300KW
- SWT-108/2.300KW
- SWT-113/3.200KW

## 4.2.2.SIEMENS Wind Projects in Turkey

<b>Project Name</b>	<b>Turbine Type</b>	<b>Number of WTG</b>	<b>Total Capacity</b>	<b>Scope</b>	<b>Status</b>
Mahmudiye	SWT-2.3-101	13	29.9MW	WTG+E-BoP Supply	In operation
Dagpazari	SWT-3.0-101	13	39.0MW	WTG+E-BoP Supply	In operation
Dinar	SWT-2.3-108	22	50.6MW	WTG+E-BoP Supply	In operation
Dinar-2	SWT-2.3-108	12	27.6MW	WTG+E-BoP Supply	In operation
Balabanli	SWT-2.3-108	22	50.6MW	WTG+E-BoP Supply	In operation
Dinar-3	SWT-2.3-108	16	36.8MW	WTG+E-BoP Supply	In operation
Zeliha	SWT-3.0-113	8	24.0MW	WTG+E-BoP Supply	Sold/In execution
Kanije	SWT-3.2-113	20	64.0MW	WTG+E-BoP Supply	Sold/In execution
Fatma	SWT-3.0&3.2-113	25	77.4MW	WTG+E-BoP Supply	Sold/In execution
Kinik	SWT-3.2-108	17	54.4MW	WTG+E-BoP Supply	Sold/In execution
Bereketli	SWT-3.2-113	10	32.0MW	WTG	Sold/In execution

## 4.3.1. NORDEX PRODUCTS IN TURKEY

- Here, the mostly used wind turbine products of NORDEX series in Turkey have been classified.

The mostly used products are;

- N90/2500 KW
- N100/3300KW
- N117/3000KW

Source: NORDEX



# A Case Study in Turkey



Source: NORDEX

Project name:	Yuntdag
Owner:	Innores Enerji Üretim Sanayi ve Ticaret A.Ş.
Contractors:	Innores Enerji Üretim Sanayi ve Ticaret A.Ş.
Power utility:	Teias
Installed capacity:	42,5 MW
Wind turbine type:	N90/2500 kW high-speed
Tower height and type:	80 m, steel tube tower
Number of wind turbines:	17
Wind speed:	8,5 to 9,5 m/s
Site:	The site is located in the West of Turkey, some 18 kilometres South of Bergamo, the ancient city of Pergamon.
Site description:	The turbines stand in a relatively harsh landscape which is only used a little for agricultural purposes and is sparsely populated. The nearest villages are Koyuneli (600 metres as the crow flies) and Yuntdag (2.5 kilometres).
Wind turbine siting:	The turbines were erected on two contour lines running in a North-South direction. There are twelve turbines on the eastern side and five on the western side.
Building period:	November to April 2008
Grid connection:	February 2008
Extent of delivery:	Nordex was responsible for supplying and installing the turbines.
Calculated annual power output:	160,000 MWh
Maintenance:	Nordex Energy GmbH
Warranty period:	5 years





## 4.4.1. VESTAS PRODUCTS IN TURKEY

- Here, the mostly used wind turbine products of VESTAS series in Turkey have been classified.

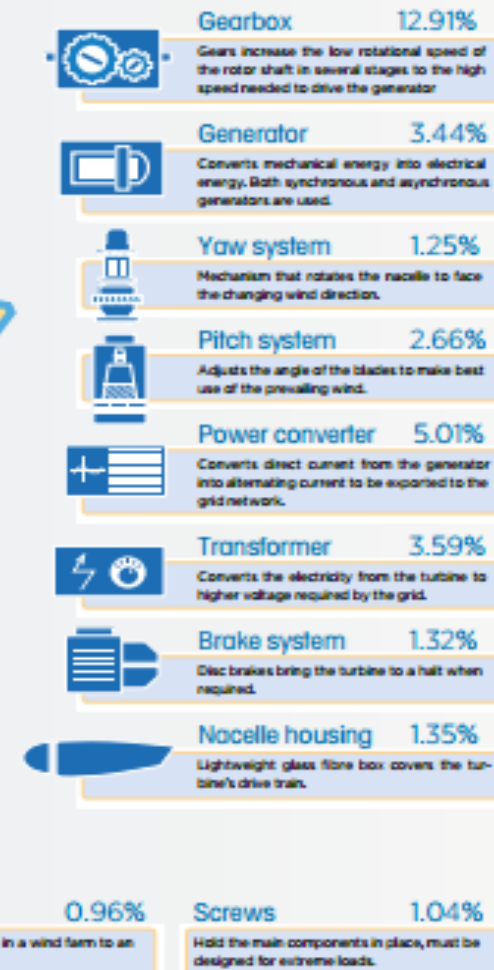
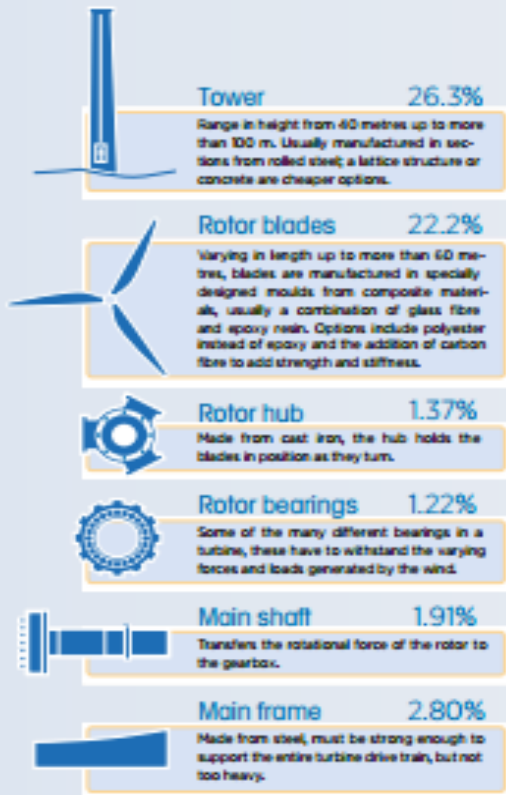
The mostly used products are;

- V90/2000 KW
- V100/2000 KW
- V112/3300KW

# 4.5.1.Wind Turbine Components

## How a wind turbine comes together

A typical wind turbine will contain up to 8000 different components. This guide shows the main parts and their contribution in percentage terms to the overall cost. Figures are based on a REpower M992 turbine with 45.5 metre length blades and a 100 metre tower.



## 4.5.2. Wind Turbine Components

- A 1.5 MW wind turbine of a has a tower 80 meters high.
- The rotor assembly (blades and hub) weighs 48,000 pounds (22,000 kg).
- The nacelle, which contains the generator component, weighs 115,000 pounds (52,000 kg).
- The concrete base for the tower is constructed using 58,000 pounds (26,000 kg) of reinforcing steel and contains 250 cubic yards of concrete.
- The base is 50 feet (15 m) in diameter and 8 feet (2.4 m) thick near the center.

## 4.6.CBA of Wind Turbines

- CBA applied to energy is the consideration of all the costs and benefits of an energy Project taking account of present and future work.
- CBA takes account of both financial and social analysis



## 4.6.CBA of Wind Turbines

There is mainly four ways of evaluating CBA;

- Benefit/Cost ratio
- Net present value(NPV)
- Internal rate of return (IRR)

# Benefits/Cost Ratio

- As the name suggest, Benefit-cost ration method of analysis is based on the ratio of the benefits to cost associated with a particular project
- The basic need to calculate all the cost and benefit separately.
- B-C ratio method has frequently used by government agencies whose benefit are reaped by the public and cost are incurred by government
- Let B= Present Value of cash inflows (benefits)  
C=Present Value of cash outflows (costs)

$$B = \sum_{j=0}^n \frac{B_j}{(1+i)^j}$$

$$C = \sum_{j=0}^n \frac{C_j}{(1+i)^j}$$

Where **i** is the interest rate and **j** is the part of time period

- The equivalent present value cost  $C$  may consist two part:
  1. The initial capital expenditure  $C_o$
  2. The annual cost accrued in each successive period  $C'$
- Let for any project, there is initial  $m$  period for installation and ones the plant is ready to operate, there is fixed maintenance cost per year from  $m+1$  period to life cycle of project ( $n$ ).

$$C_o = \sum_{j=0}^m \frac{C_j}{(1+i)^j}$$

$$C' = \sum_{j=m+1}^n \frac{C_j}{(1+i)^j}$$

And  $C = C_o + C'$

# Renewable Energy Parameters for C/B Analysis

- The type of parameter for C/B analysis is depend upon the type of renewable technology
- Here the list which affect the analysis of RET
  1. Location of plant
  2. Type of renewable energy
  3. Technology status
  4. Government involvement
  5. Availability of technical staff
  6. Economical consideration of society
  7. Overall objective of installation
  8. Climate condition
  9. Risk of natural disaster



# Basic cost of wind energy

- Approximately 75% of the total cost of energy for a wind turbine is related to upfront costs such as
- **the cost of the turbine,**
- **foundation,**
- **electrical equipment,**
- **grid-connection**

Source: THE ECONOMICS OF WIND ENERGY EWEA

# CBA parameters for Renewable Energy

- CBA parameter can be categories on the basis of cost inflow and outflow

Cost Outflow	Cost Inflow
<ol style="list-style-type: none"><li>1. Capital cost of plant</li><li>2. Annual maintenance cost</li><li>3. Unwanted investment due to technology failure</li><li>4. Extra investment due to change in incentive policy of govt.</li></ol>	<ol style="list-style-type: none"><li>1. Benefit by selling energy</li><li>2. Social benefit by supplying electricity in rural area</li><li>3. Carbon credit</li><li>4. Commitment to ward green development</li><li>5. High rate of return to support renewable energy (incentive from govt)</li></ol>

# Implementation of CBA for wind Energy

- Cost of the system:
  1. Land lease cost
  2. Turbine installation cost
  3. Electrical network up gradation cost
  4. Cost of additional reserve requirement
  5. Component life maintaining cost
  6. Operating cost
- Benefits of the system
  1. Capacity benefit
  2. Carbon credit benefit
  3. Fuel saving benefit
  4. Social empowerment benefit in remote area
  5. With proper design, multi function land utilization

# 4.6.1.A typical 2 MW Wind Turbine Costs

	<b>INVESTMENT (€1,000/MW)</b>	<b>SHARE OF TOTAL COST %</b>
Turbine (ex works)	928	75.6
Grid connection	109	8.9
Foundation	80	6.5
Land rent	48	3.9
Electric installation	18	1.5
Consultancy	15	1.2
Financial costs	15	1.2
Road construction	11	0.9
Control systems	4	0.3
<b>TOTAL</b>	<b>1,227</b>	<b>100</b>

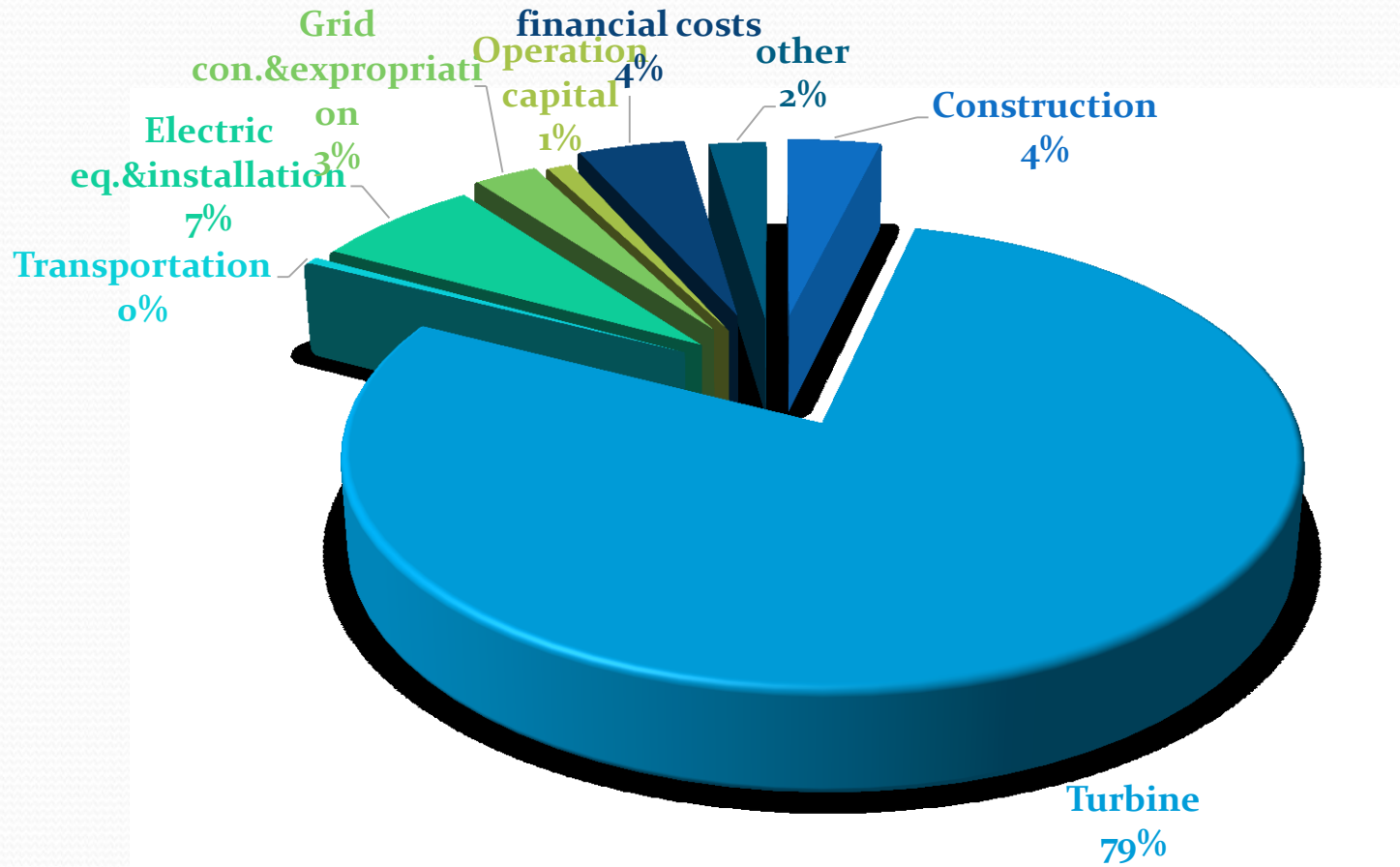
Note: Calculated by the author based on selected data for European wind turbine installations

SOURCE: EWEA, The Economics  
of Wind Energy, 2009

# 4.6.2. Case Study-55 MW Wind Project Costs (Turkey project)

55 MW Wind Project		
Transmission line length		20,7 km
License Capacity		54,9 MW
Turbine Rated Power		2 MW
Turbine Type		Enercon E-82
Hub Height		85 m
Wind Class		Wind Class I
Mean Wind Speed		7,8 m/s
Gross Generation kWh		182.751.120,00
Net Selleable Generation kWh		158.704.920,00
Gross Capacity Factor		38,00 %
Net Capacity Factor		33,00 %
Project Cost without VAT		€ 71.581.155,17
VAT		€ 1.952.707,93
Equity	% 20	€ 15.033.863,10
Loan	% 80	€ 58.500.000,00

# A 55 MW Turbine costs in Turkey (€2011)

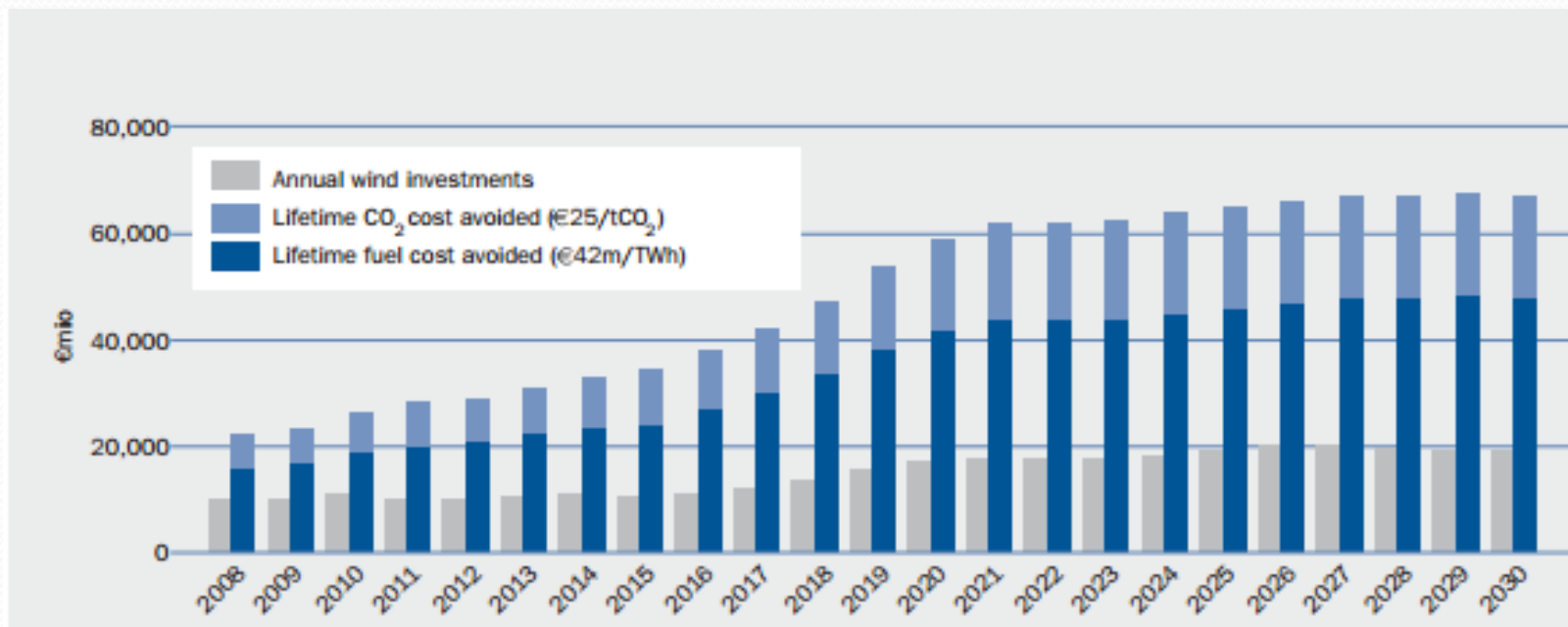


## 4.6.3. Outcomes of the Project

As the 55 MW wind Project is considered:

- the operation time **3000 hours** per year,
- the lifetime of the turbine is **30 years**,
- The power plant generates **155 million kWh** of electricity per year
- meets the annual need of **77.500 people**.
- Also it reduces **98.500 tons of emission** each year

## 4.6.4. Wind investments compared with life time avoided fuel and CO2 costs



Source: THE ECONOMICS OF WIND ENERGY EWEA



(Oil – \$90/barrel; CO<sub>2</sub> – €25/t)

- Figure shows the total CO<sub>2</sub> costs and fuel costs avoided during the lifetime of the wind energy capacity installed for each of the years 2008-2030, assuming a technical lifetime for onshore wind turbines of 20 years and for offshore wind turbines of 25 years.
- Furthermore, it is assumed that wind energy avoids an average of **690g CO<sub>2</sub>/kWh** produced; that the average price of a CO<sub>2</sub> allowance is €25/t CO<sub>2</sub> and that €42 million worth of fuel is avoided for each TWh of wind power produced, equivalent to an oil price throughout the period of \$90 per barrel.

## 4.7. Onshore vs Offshore Wind Energy Costs



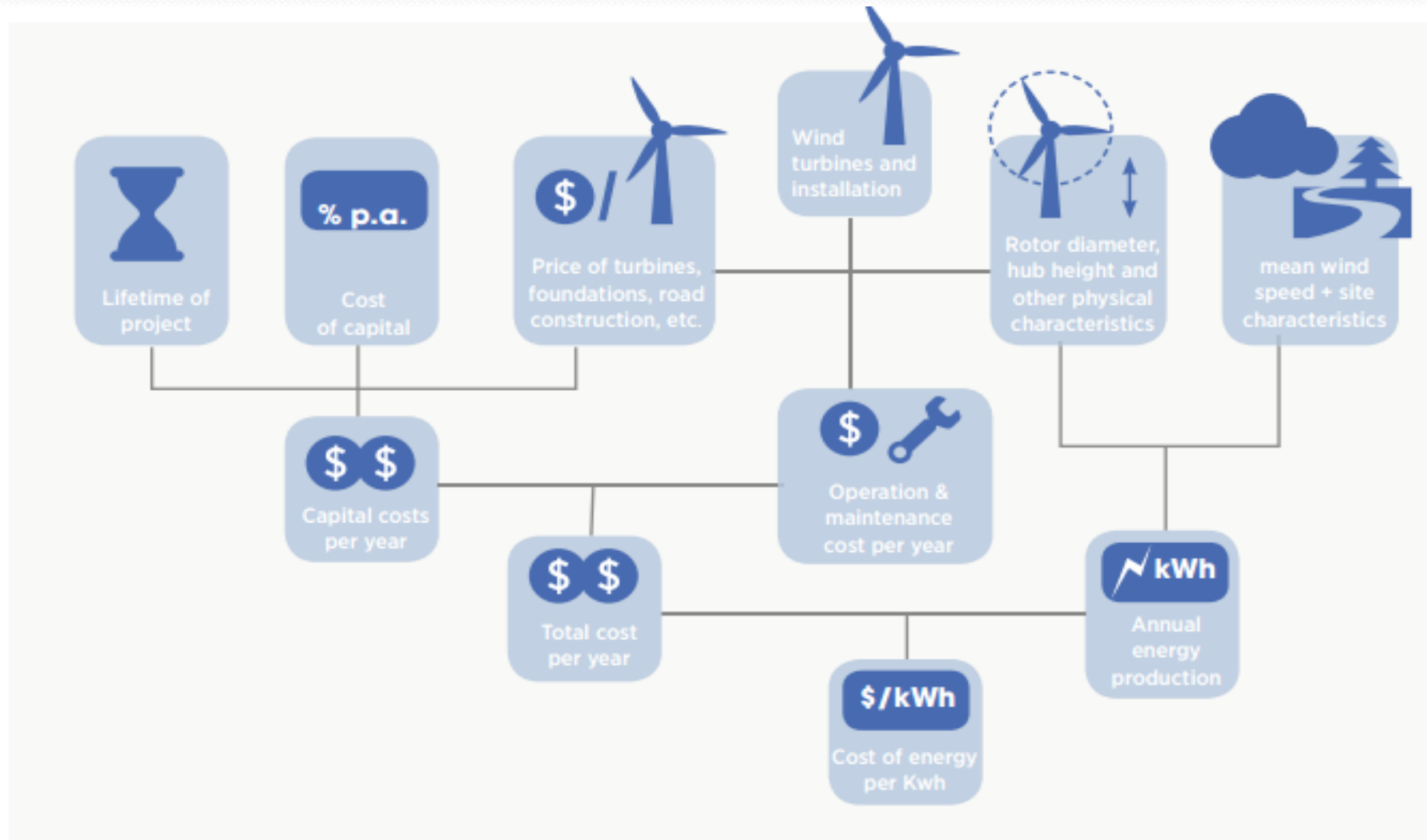
- Onshore wind energy sticks out as being extremely important because it's one of the most cost-effective and mature of all the renewable technologies.
- Although offshore wind is another great source of clean energy, it's not the best investment right now because of its very high costs, immature technologies and development constraints.

# 5. Comparison of Turbines

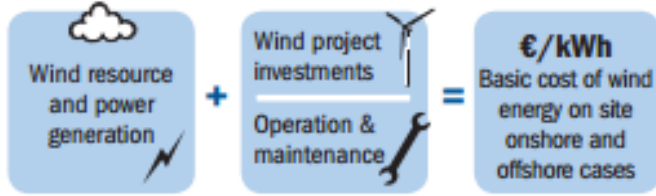
The wind turbines are compared due to the parameters;

1. The produced power
2. Lifetime
3. O&M (Eurocent/kWh)
4. Capital cost (Euro/KW)
5. Interest rate (%)
6. Full hours (per year)
7. Capacity Factor

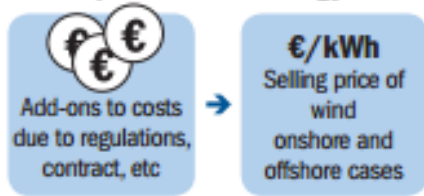
## 5.1.The economics of wind systems



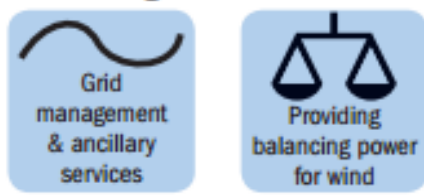
### 1. The cost of wind



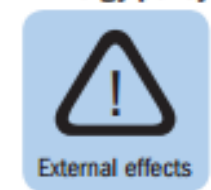
### 2. The price of wind energy



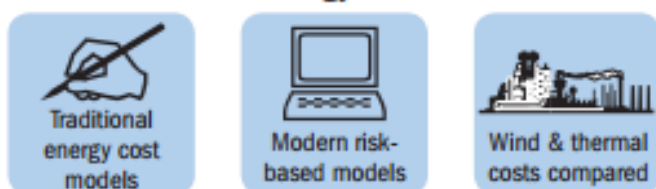
### 3. Grid integration issues



### 4. Energy policy and risk



### 5. The value of wind energy



## Benefits of Wind Energy

- One of the most important economic benefits of wind power is that it reduces the exposure of our economies to fuel price volatility.
- Wind energy will have a large share in most European countries, even if wind were more expensive per kWh than other forms of power generation.
- In a situation where the industrialized world is becoming ever more dependent on importing fuel from politically unstable areas, this aspect merits immediate attention.

# Advantages of Wind Power

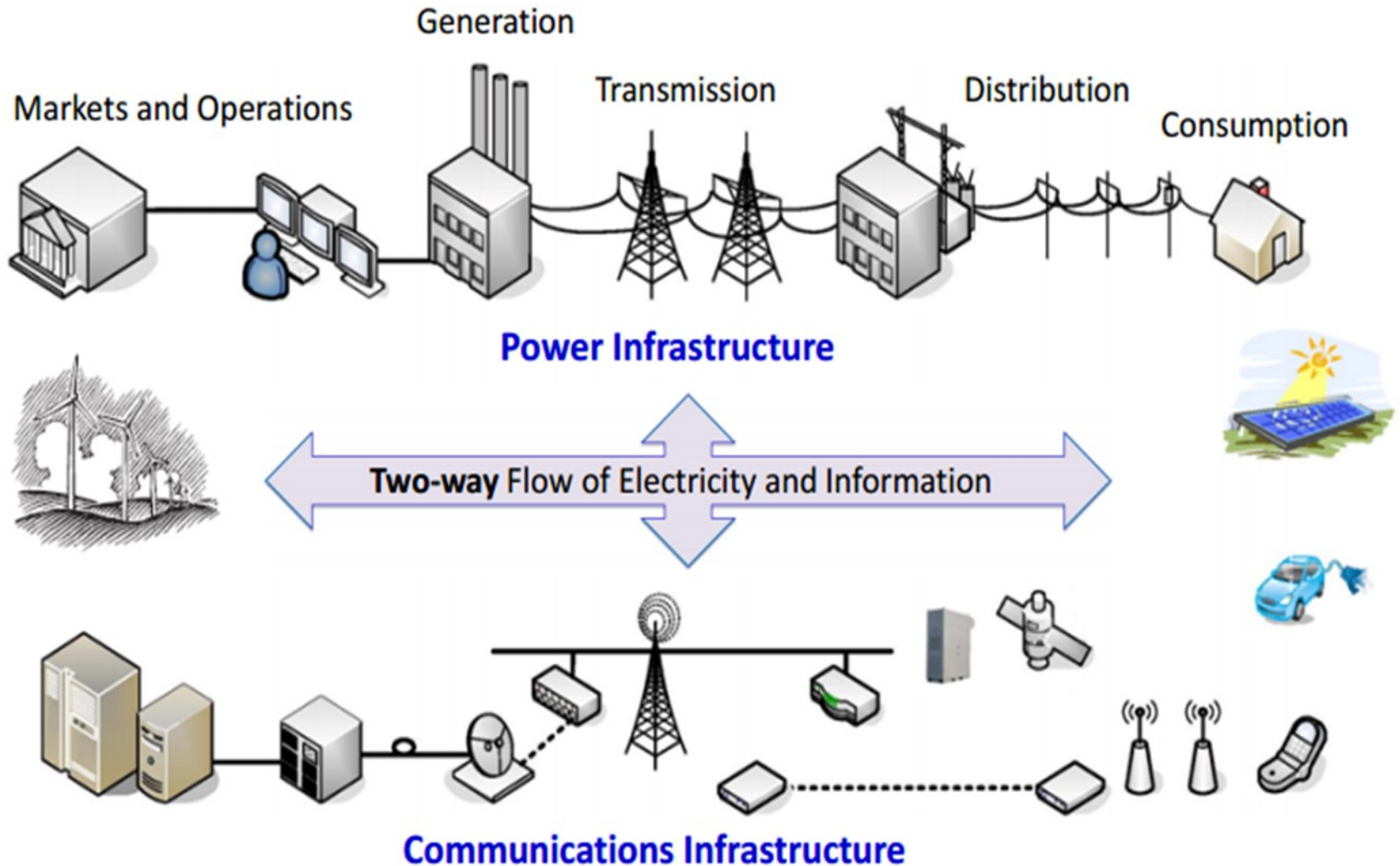
- After installation, only cost is maintenance
- Wind is renewable
- Available everywhere to some extent
- No pollution
- Simple designs
- Supply of wind energy cannot be controlled by anyone (no political maneuvering)
- Wind farms make it profitable

# Disadvantages of Wind Power

- Expensive to set up, custom products
- Wind speed varies a lot
  - Hard to predict
  - Not steady, so unreliable
  - Accurate data absolutely necessary
- Environmental impact from manufacturing
- Turbines can require large areas of land

# What is Smart Grid?

- Future Smart Grid:





## 6.1.The Cost Benefit Analysis in Smart Grid Systems

- Cost Benefit Analysis (CBA) in smart grid system will compensate the energy need in Turkey by providing energy more efficiently and environment friendly. The energy rate produced from wind turbines among renewable energies will take an active role in electric grid in the future.
- Without the knowledge of the cost and benefits of renewables, it is difficult to draw a roadmap for the countries renewable energy technology policies.

# How to integrate to Smart Grid?

## **Benefits**

- Benefits of Smart Meters
- CO<sub>2</sub> Reduction
- Fuel Savings

## **Costs**

- Installing Smart Meters
- Renewables & Integration
- Updating Infrastructure
- Educating the Public

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  - ERASMUS+
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