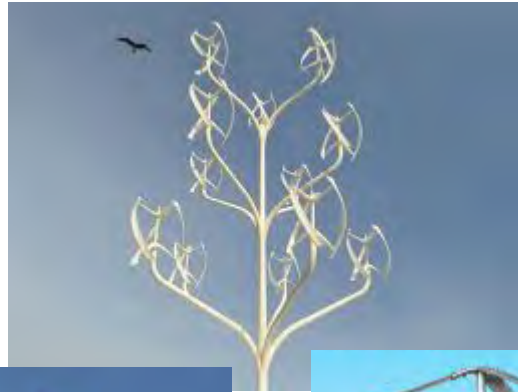


EŞLİ OLARAK ÇALIŞAN DÜŞEY EKSENLİ RÜZGAR TÜRBİNLERİ ÜNİVERSİTE SANAYİ İŞBİRLİĞİ ÖRNEĞİ

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**Doç. Dr. Alpaslan Turgut, Dr. Sercan Acarer, Yük. Müh. İskender
Kökey, Yük. Müh. Ufuk Akgül, Erinç Baytekin, Rıdvan Almaz,
Ferhat Cem Başer, Fatih Tolga Özdemir, Ceren Vatansever**

Düşey Eksenli Rüzgar Türbinleri (DERT)



Yatay Eksenli Rüzgar Türbinleri (YERT)



08.05.2019

Dr. Ziya Haktan Karadeniz

Uygun Saha!



2004

Uygun Saha!

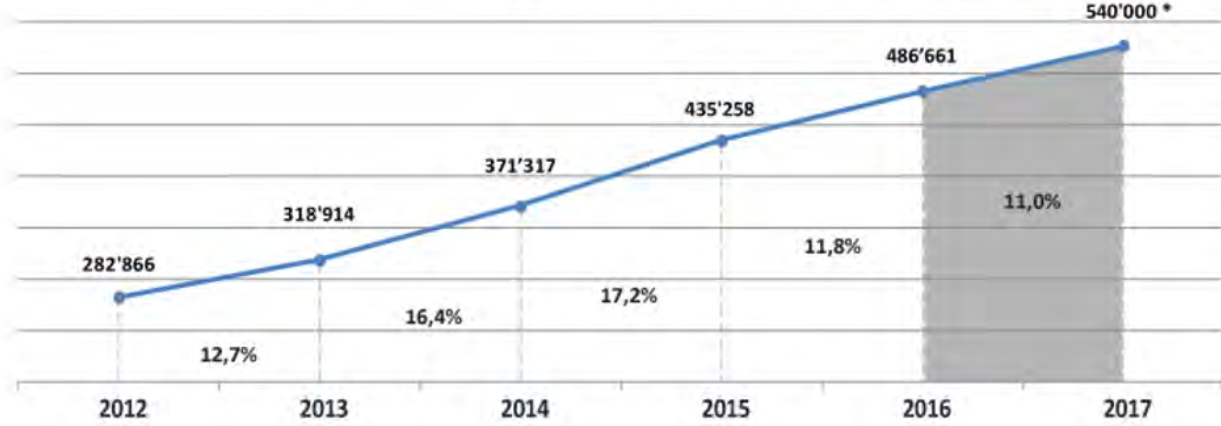


2014

YERT – DERT ?



Total Installed Capacity 2012-2016 [MW]

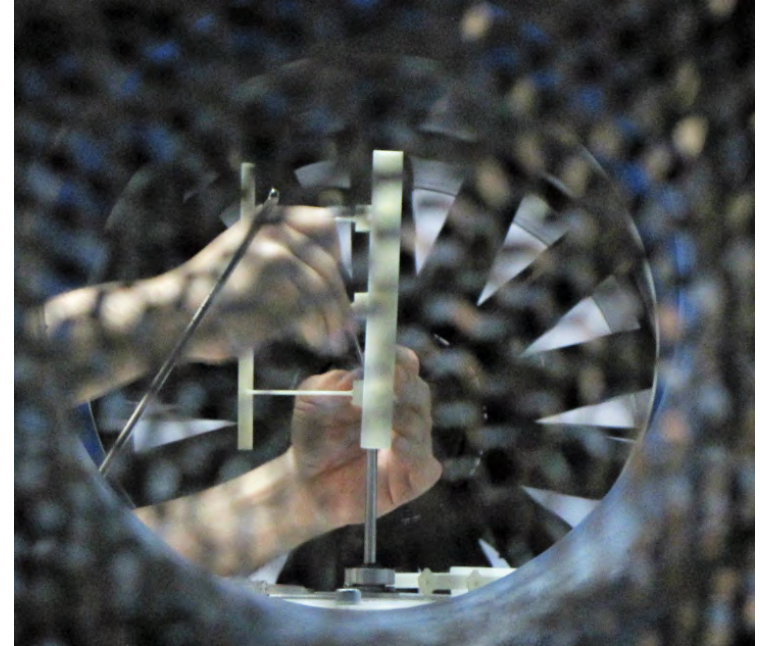
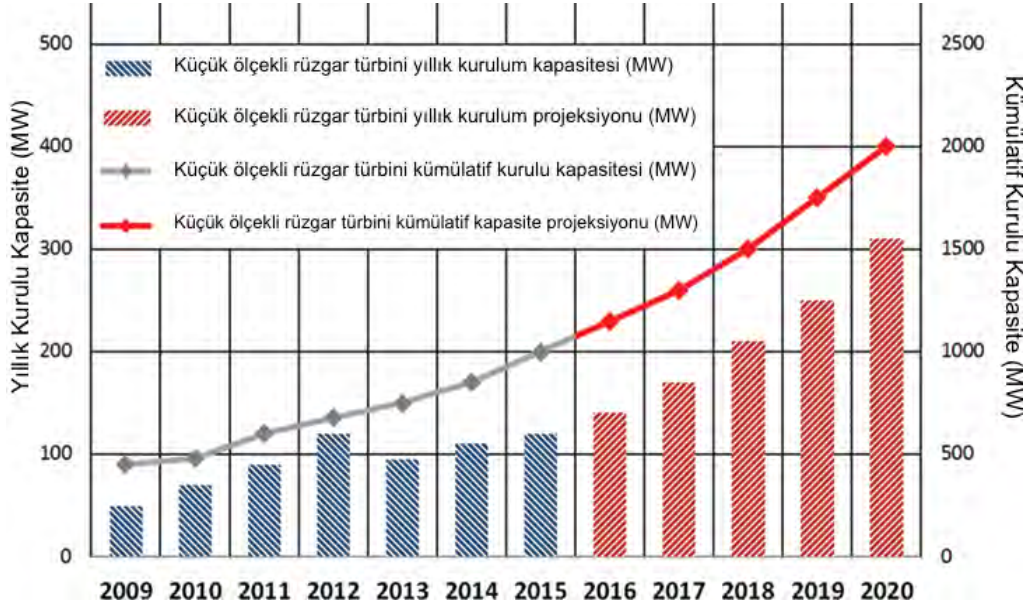


* Prognosis

Total installed capacity: Includes all installed wind capacity, connected and not-connected to the grid.

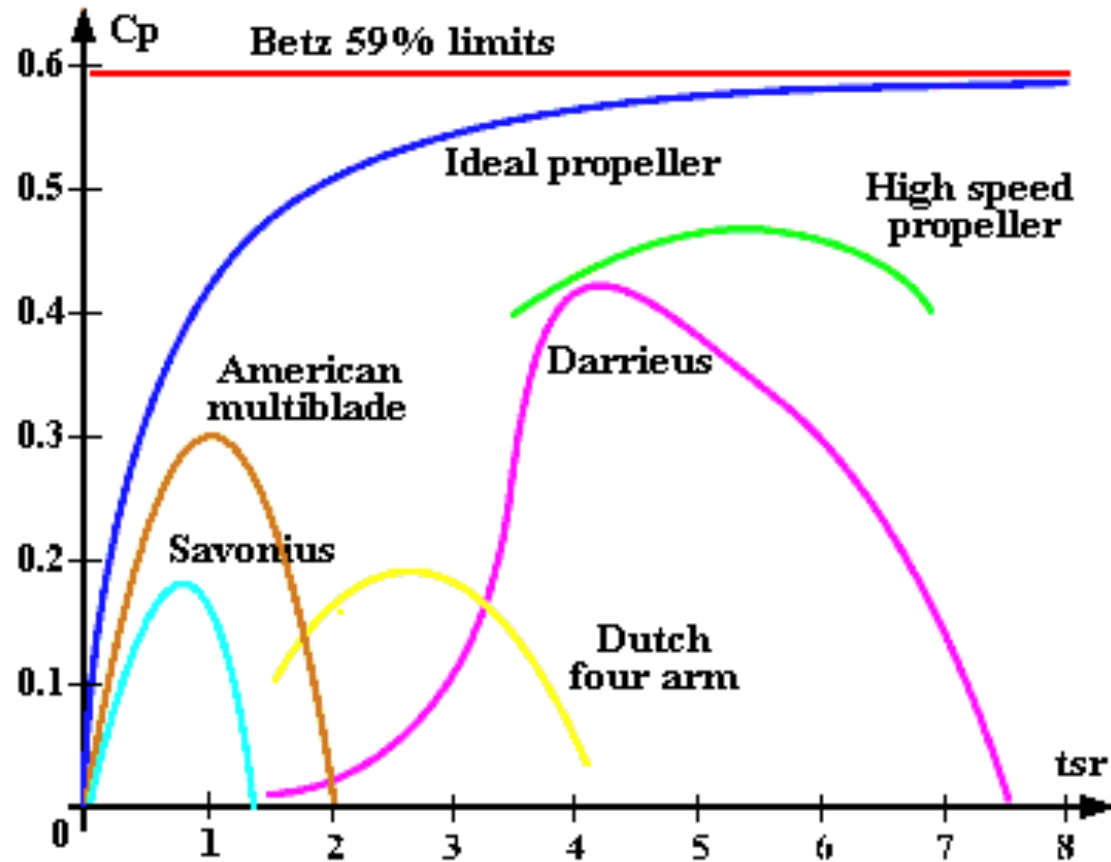
© WWEA

Küçük ölçekli rüzgar türbinleri kurulu güç tahmini



Tekil Türbin Verimi

$$C_p = \frac{P}{\frac{1}{2} \rho A V_{\infty}^3}$$



$$tsr = \frac{\text{Kanat uç hızı}}{\text{Serbest akış hızı}} = \frac{\omega r}{V_{\infty}}$$

DERT Santralleri

P. R. Schatzle, P. C. Klimas and H. R. Spahr, "Aerodynamic Interference Between Two Darrieus Wind Turbines," Journal of Energy, vol. 5, no. 2, pp. 84-88, **1981**.

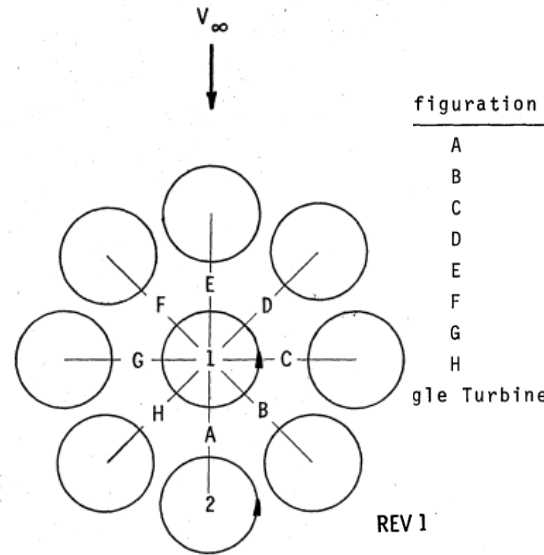
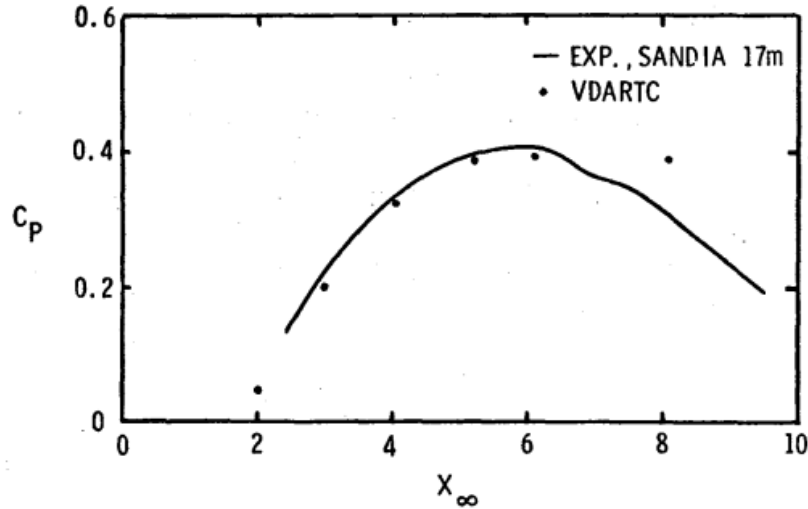


TABLE 1
Predicted Power Coefficients for
Different Configurations, $X_\infty = 3$

figuration	Turbine 1	Turbine 2
A	.200	.160
B	.199	.197
C	.199	.199
D	.199	.200
E	.160	.200
F	.197	.199
G	.199	.199
H	.200	.199
gle Turbine	.199	

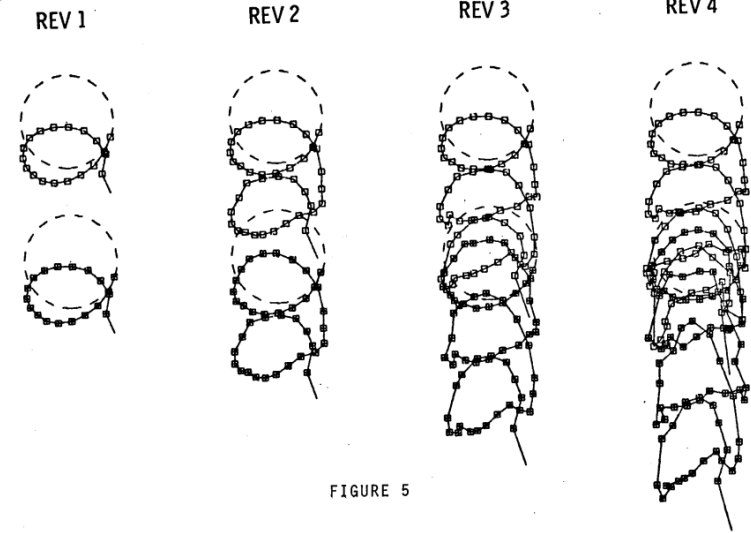
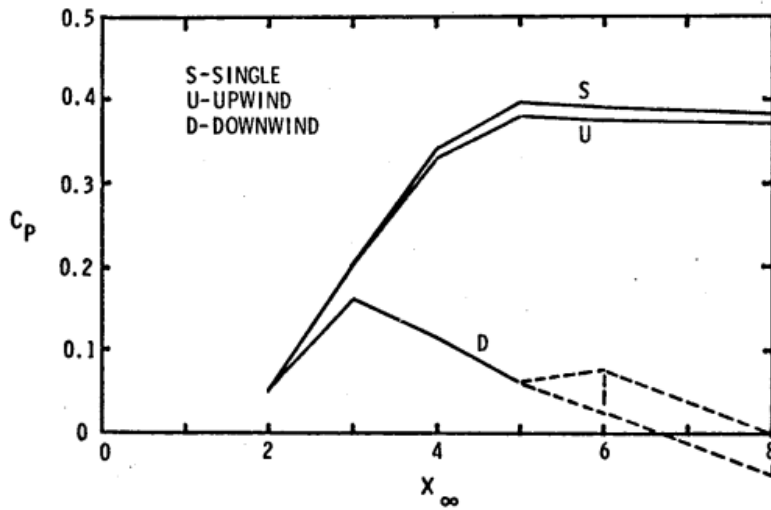
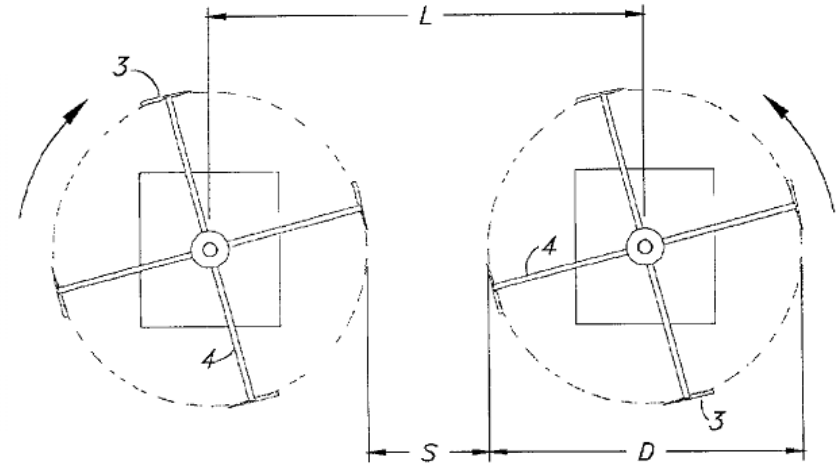
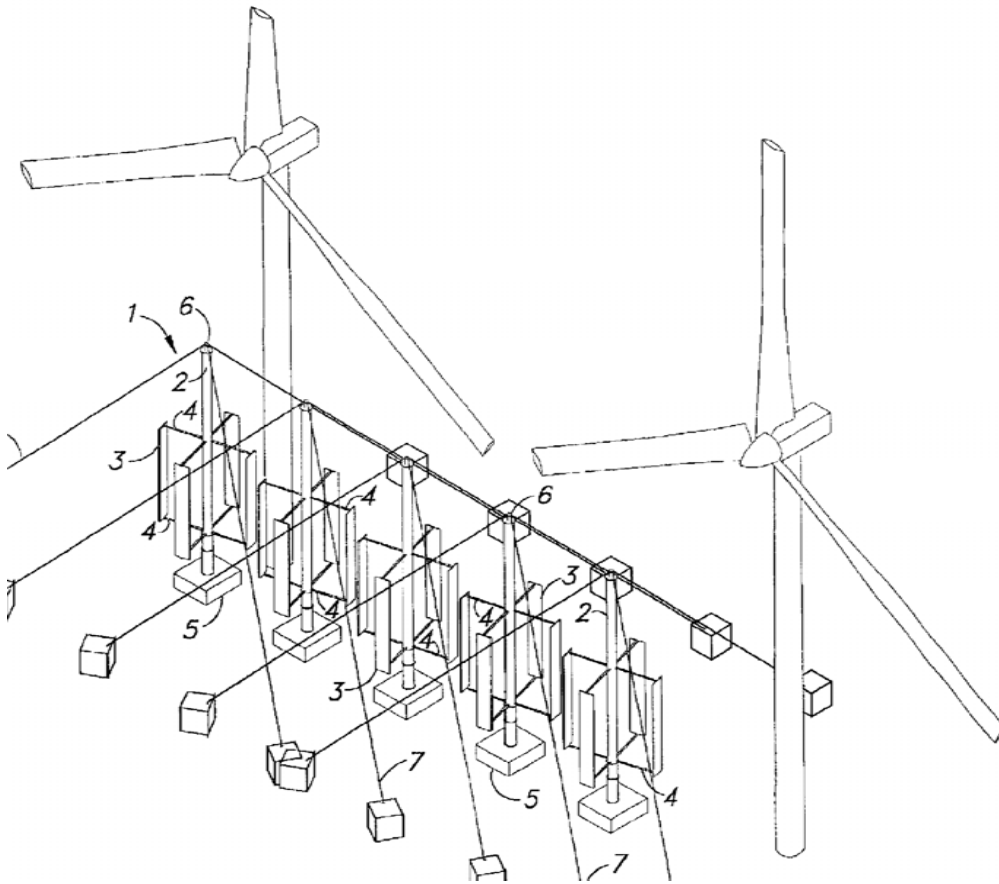


FIGURE 5

DERT çifti ya da Eşli Çalışan DERTler

R. N. Thomas, "Coupled vortex vertical axis wind turbine". US Patent Patent 6,784,566, **2004**.



Three 530G VAVTs in Palm Springs, Calif. provide the data needed to secure the Coupled Vortex Patent.

DERT çifti ya da Eşli Çalışan DERTler

WindHarvest
INTERNATIONAL

By 2030, 100,000 MWs of VAWTs around the world

2018



California's San Geronio Pass <https://windharvest.com/vawts-with-hawts/>

08.05.2019

Dr. Ziya Haktan Karadeniz

Toplam Verim - Saha Verimi

R. W. Whittlesey, S. Liska and **J. O. Dabiri**, "Fish schooling as a basis for vertical axis wind turbine farm design," *Bioinspiration & Biomimetics*, vol. 5, pp. 1-6, **2010**.

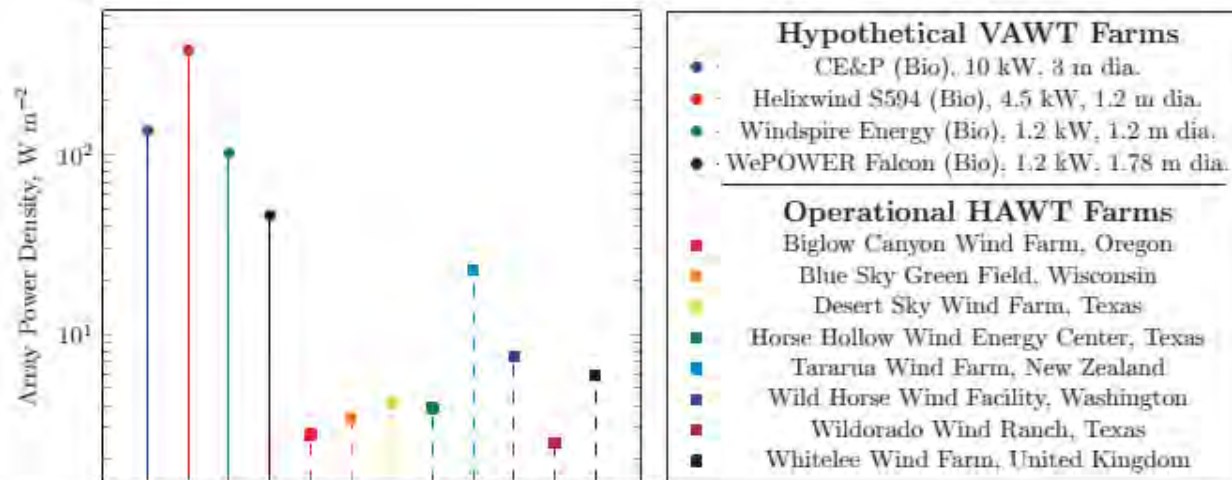
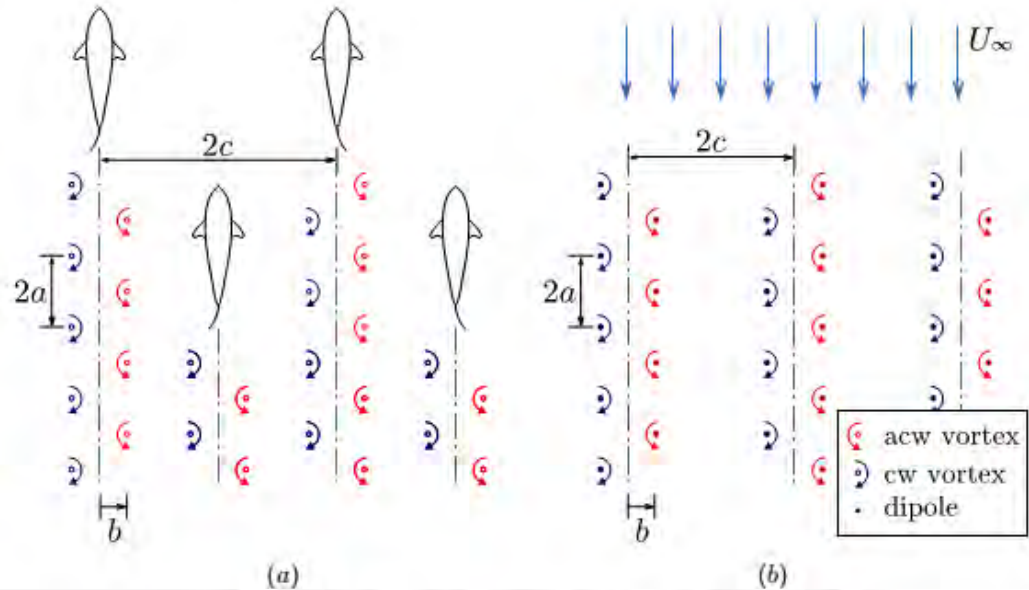
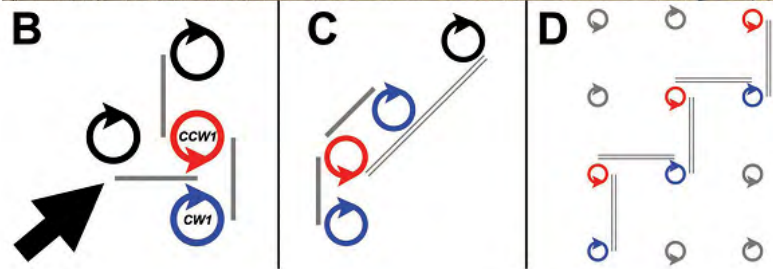
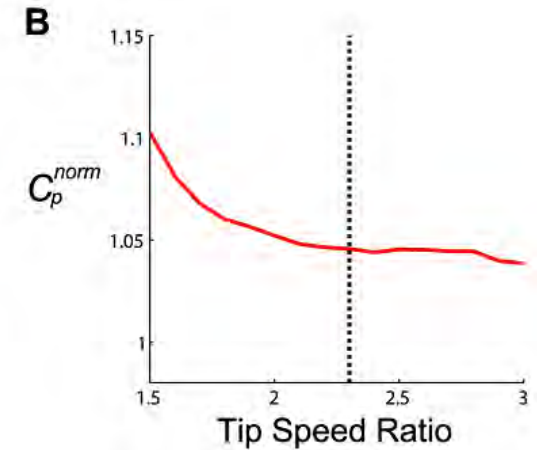
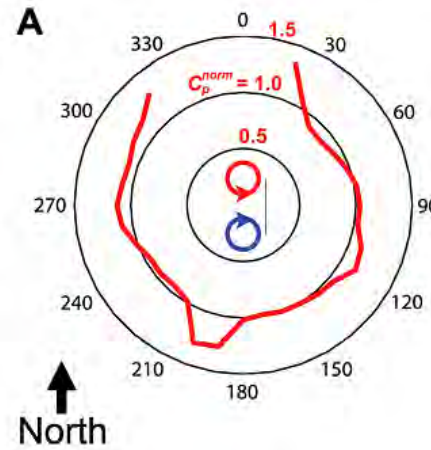
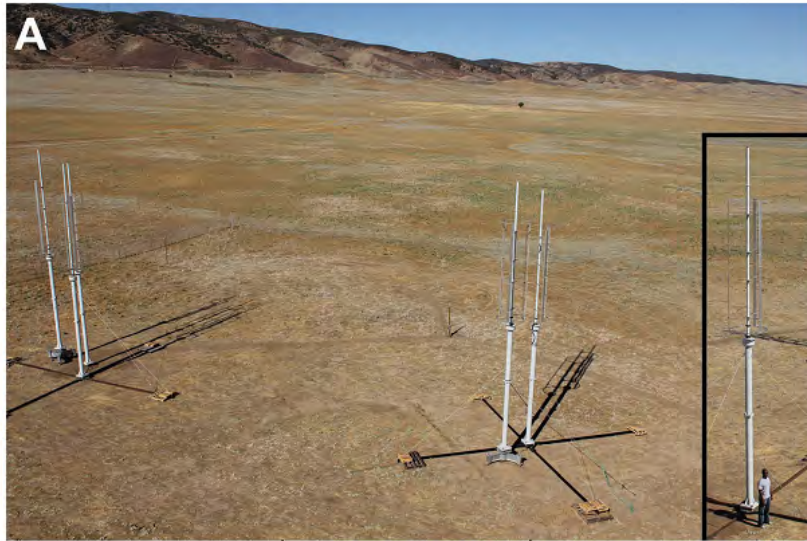


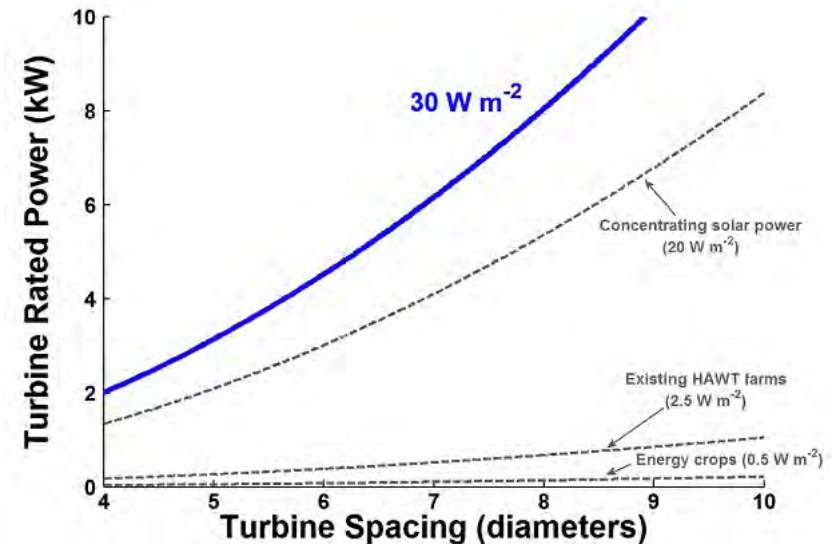
Figure 4. Log plot showing the expected array power density, total array power output over array area, of VAWT and HAWT wind farms. Hypothetical VAWT wind farms using geometry based on fish schooling ($a = 1.2D$, $b = 0.4D$, $c = 2D$, $C_{AP} = 0.61$) are shown as the circles with solid lines. Geometry chosen based on high C_{PD} . A sampling of operational HAWT wind farms is shown as squares with dashed lines. There is a significant increase of over one order of magnitude in the array power density for VAWTs compared to HAWTs.

Toplam Verim - Saha Verimi

J. O. Dabiri, "2011-Potential order-of-magnitude enhancement of wind farm power density via counter-rotating vertical-axis wind turbine arrays," *Journal of Renewable and Sustainable Energy*, no. 43104, pp. 1-12, **2011**.

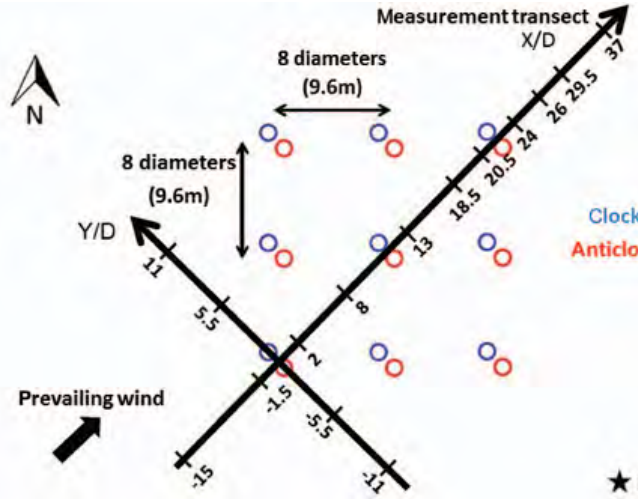


1.2-m türbin çapı,
30% kapasite faktörü



Eşli Çalışan DERTler

M. Kinzel, Q. Mulligan and J. O. Dabiri, "Energy exchange in an array of vertical-axis wind turbines," Journal of Turbulence, vol. 13, no. 38, pp. 1-13, **2012**.



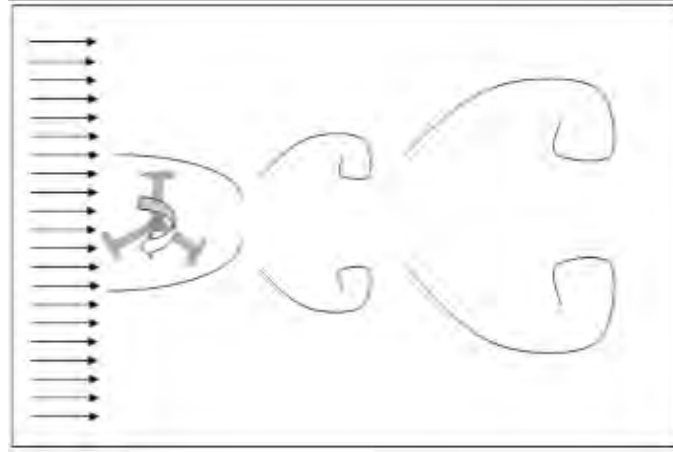
Rüzgar hızının serbest rüzgar hızının %95'i seviyesine ulaşabilmesi için gereken mesafenin 6 türbin çapı olduğu belirtilmiştir. Bu değer modern YERT'ler için gereken mesafenin yarısı kadardır. Ancak, yapılan noktasal ve eş zamanlı olmayan ölçümler, ayrıntılı analizler yapılabilmesi için gerekli çözünürlükte ve yeterlikte değildir. Sunulan çalışmanın, türbinler arası mesafe ile kanat ucu hızı oranı, rotor katılığı (solidity), moment katsayısı vb. özellikler açısından incelenmesi gerektiği vurgulanmıştır.

6,1 m yüksekliğinde 1,2 m çapındaki rotorlar (kuleler ile birlikte toplam yükseklik 9,1 m

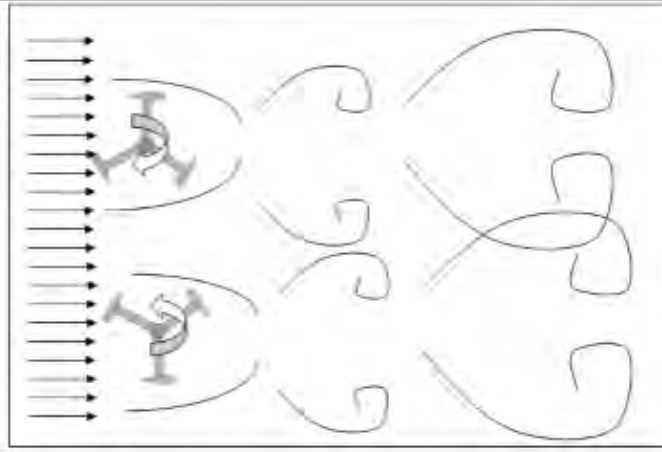
Table 3. Roughness lengths and vertical energy flux for VAWT and HAWT [4, 8] arrays.

	$\langle u_{hor} \rangle$ [ms ⁻¹]	u_{hor}' [ms ⁻¹]	z_0 [m]	$z_{0, Lett}$ [m]	$z_{0, Fran}$ [m]	P_{z_0} [Wm ⁻²]	$P_{z_0, Lett}/from$ LES [Wm ⁻²]	$P_{z_0, Fran}$ [Wm ⁻²]	$P_{measured}$ [Wm ⁻²]
VAWT array	8.05	2.1	0.91	0.72	0.13	42	29	6	24
HAWT array	8.4		10	1.5	3.2	71	21	37	2.5

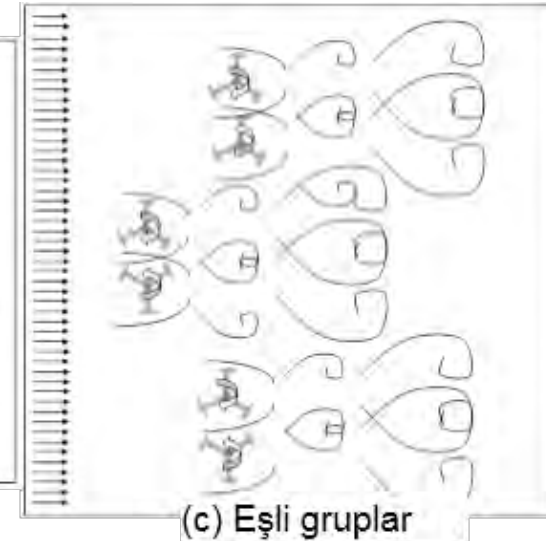
Saha Verimi



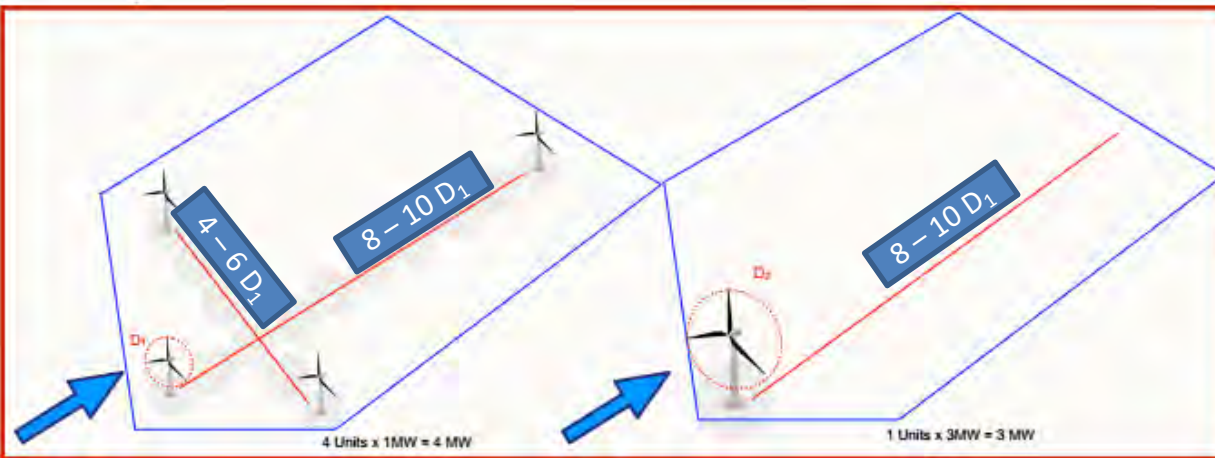
a) Tekil



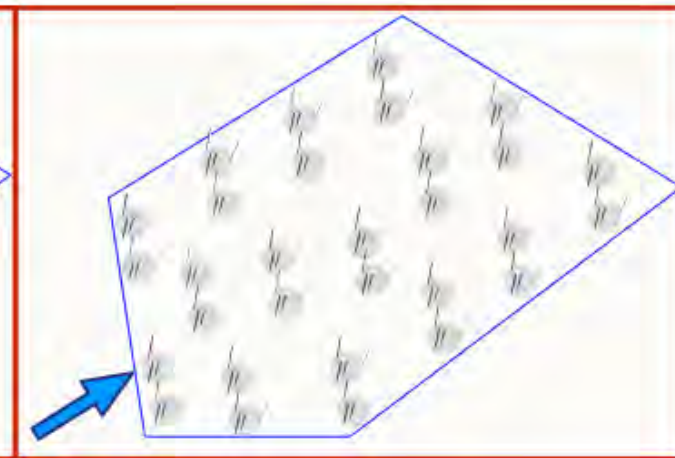
b) Eşli



(c) Eşli gruplar



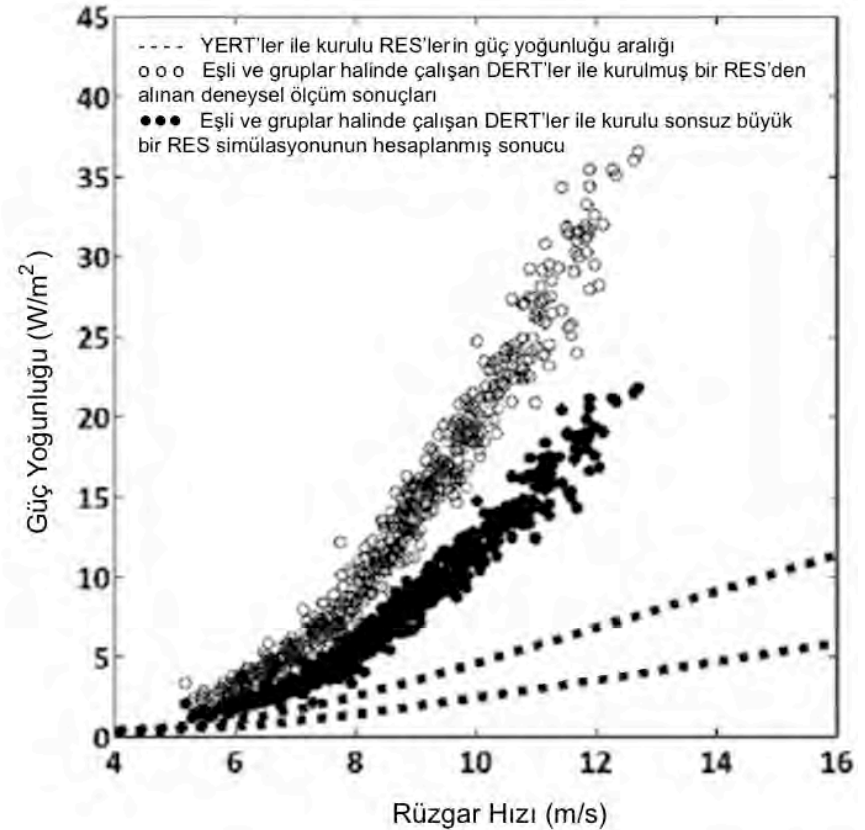
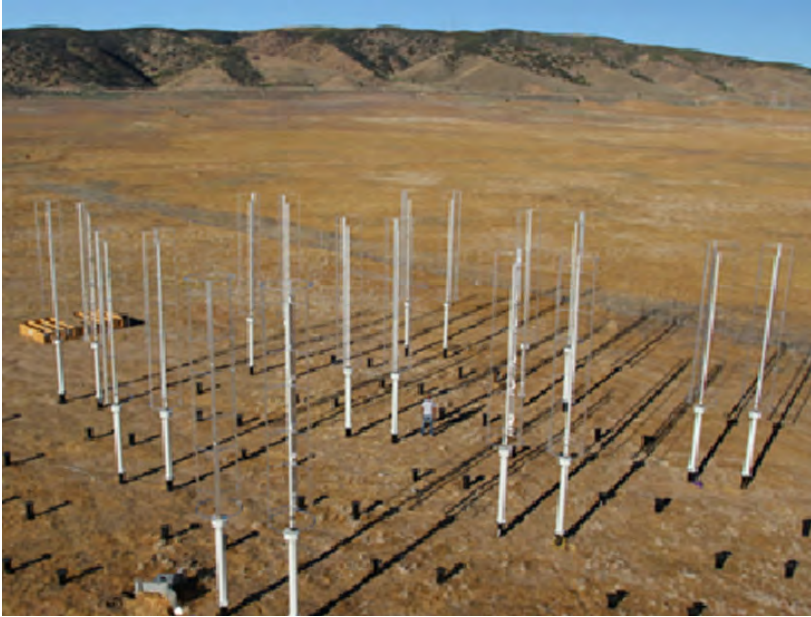
Footprint Power Density of WPPs includes
HAWTs = 3 - 5 W/m² [1][2]



Footprint Power Density of WPPs Includes
Closely Located VAWTs = 15 - 20 W/m² [1][2]

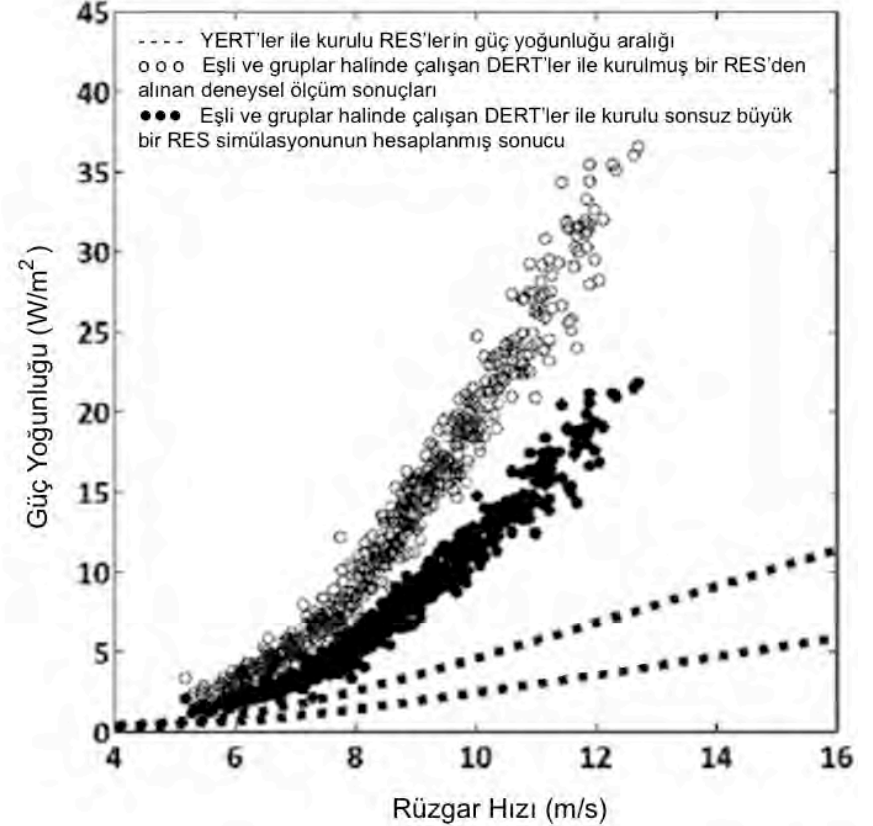
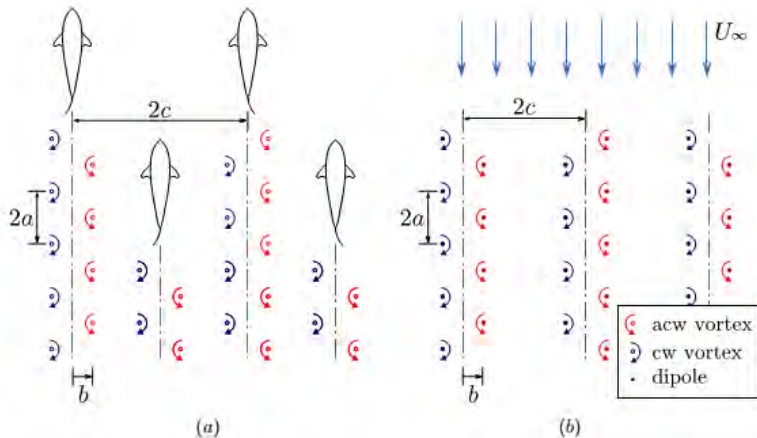
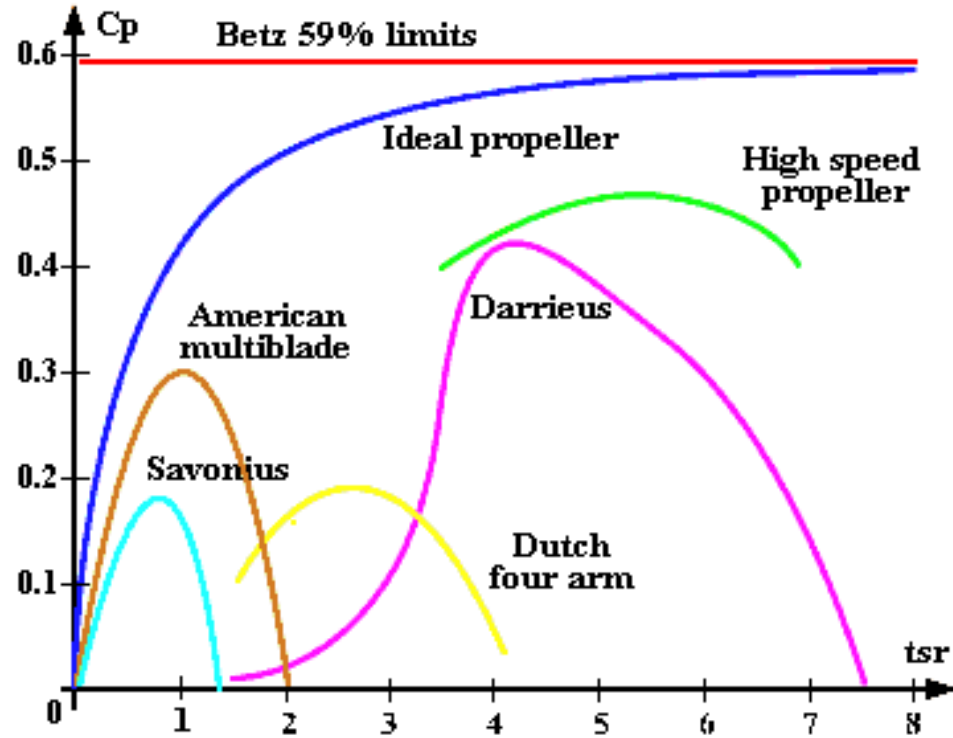
Saha Verimi

J. O. Dabiri, J. R. Greer, J. R. Koseff, P. Moin and J. Peng, "A new approach to wind energy: Opportunities and challenges," in Physics of Sustainable Energy III (PSE III), Berkeley, **2014**.



Eşler halinde çalışan ve grup olarak yerleştirilmiş Darrieus tipi rüzgar türbinleri üzerinde yapılan çalışmalar bu değerın 2 – 4 kata kadar azaltılabileceğini, 10 m/s rüzgar hızı için taban alanı başına güç yoğunluğunun 20 W/m² değerine kadar yükseltilebileceğini göstermektedir

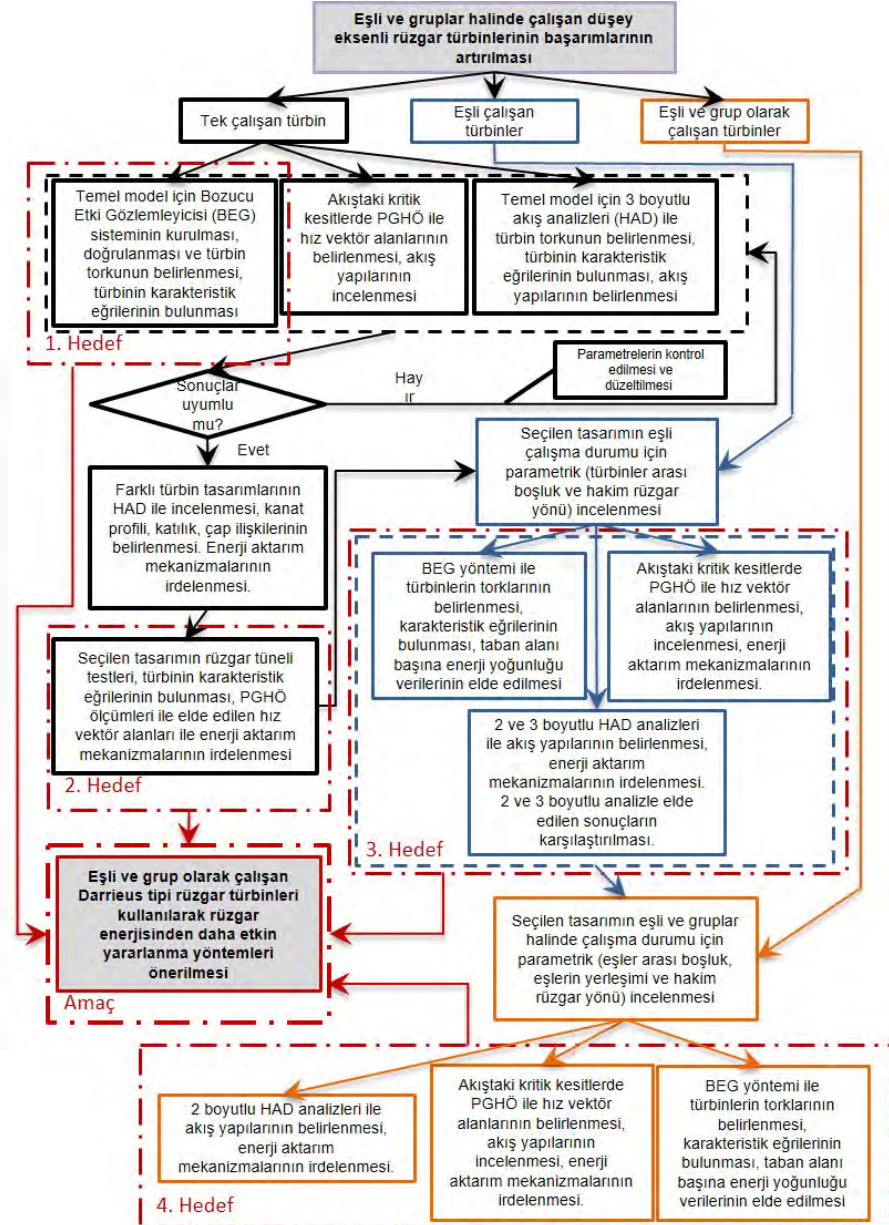
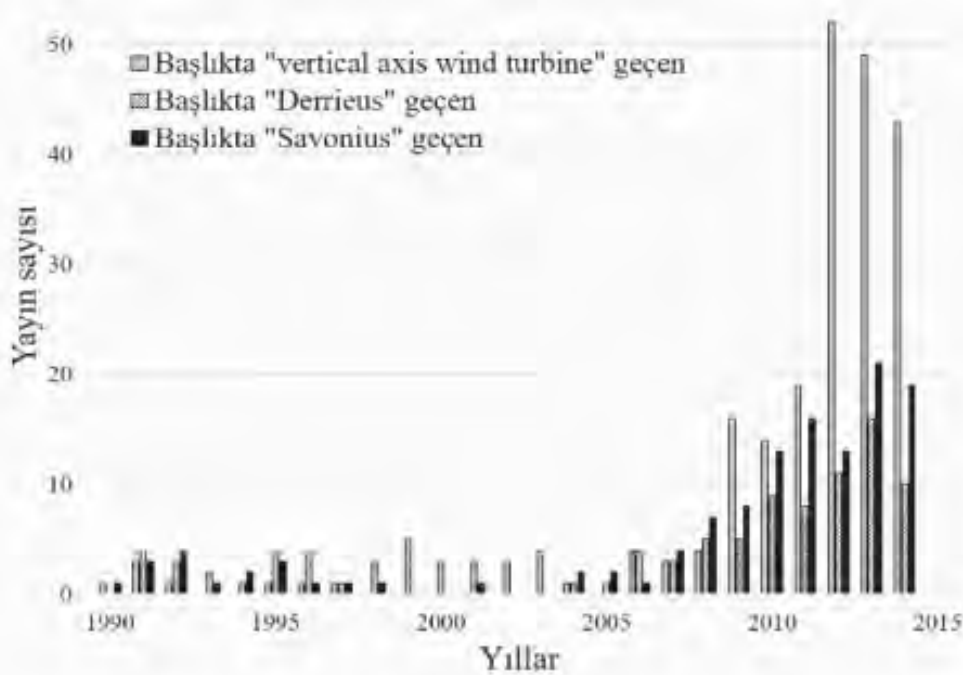
Saha Verimi



J. O. Dabiri, J. R. Greer, J. R. Koseff, P. Moin and J. Peng, "A new approach to wind energy: Opportunities and challenges," in Physics of Sustainable Energy III (PSE III), Berkeley, 2014.

Ar-Ge süreci

Karadeniz Z.H., Düşey eksenli rüzgar türbini araştırmalarında son gelişmeler, 8. Yenilenebilir Enerji Kaynakları Sempozyumu, Adana, 2015



Ar-Ge Süreci – Temel tasarım

DOWNSTREAM ZONE

UPSTREAM ZONE

Türbin çalışma prensibini anlama

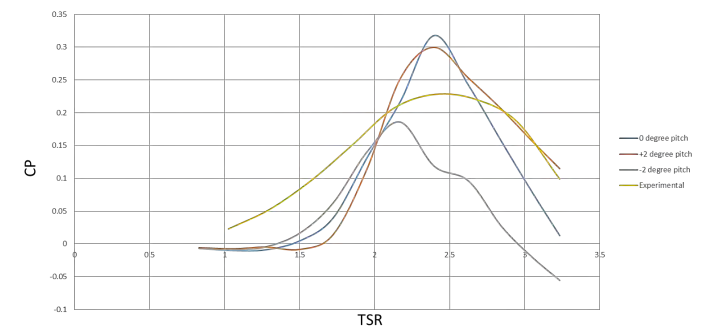
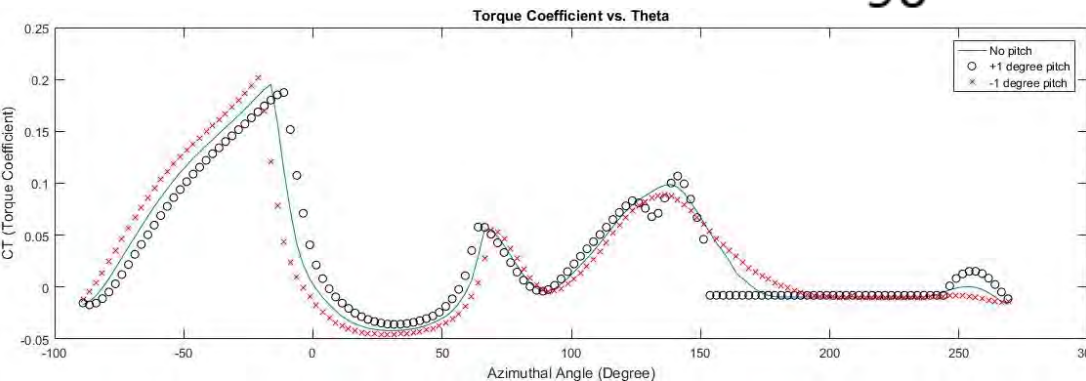
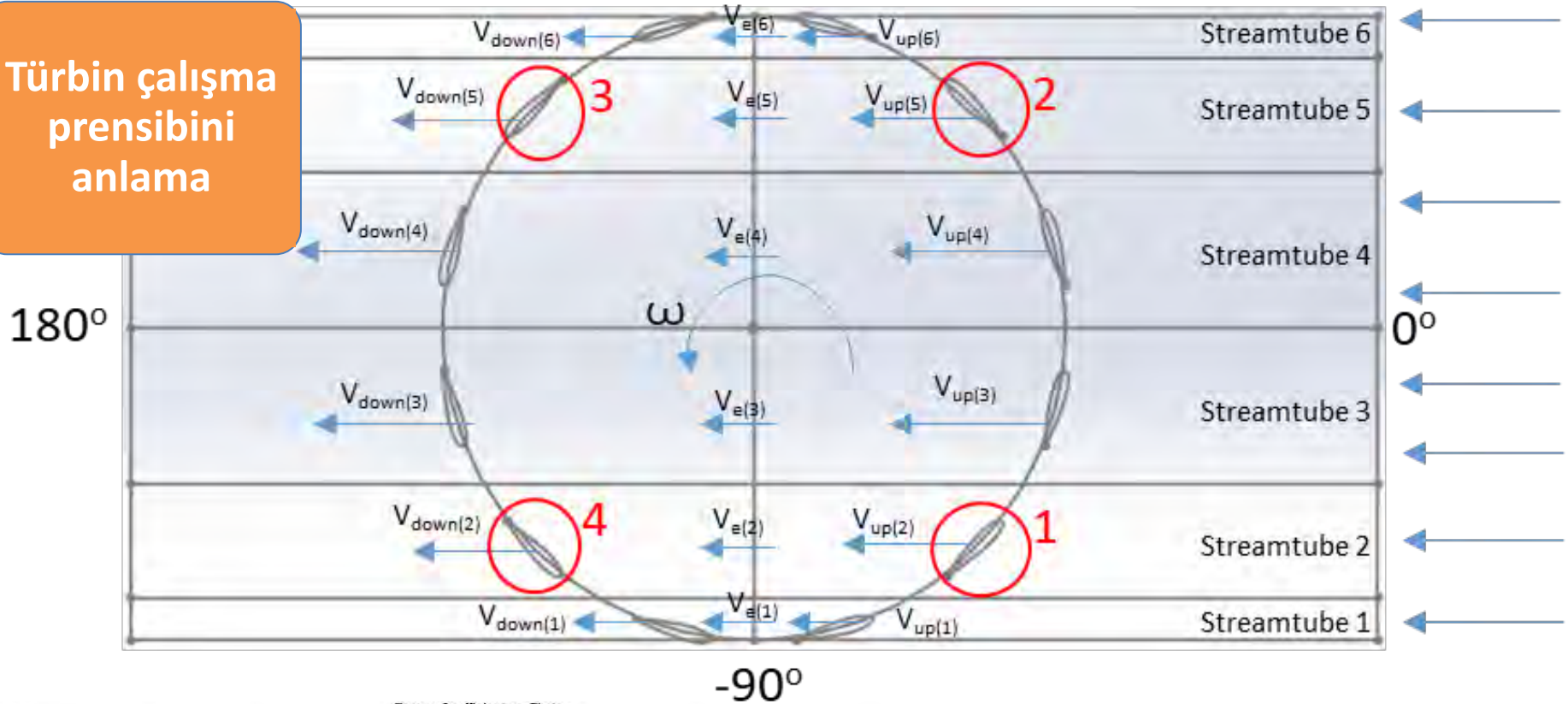
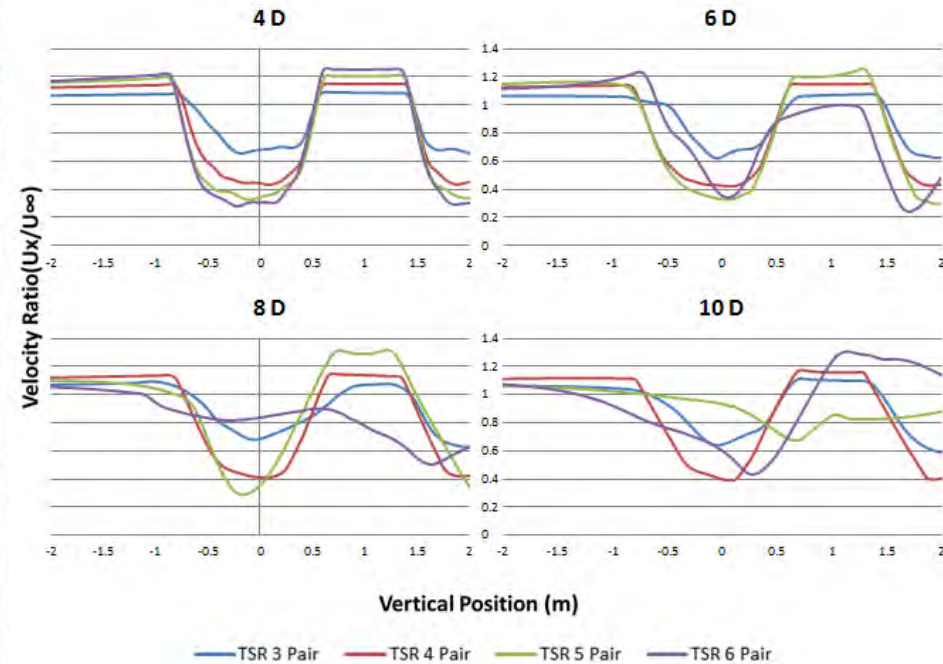
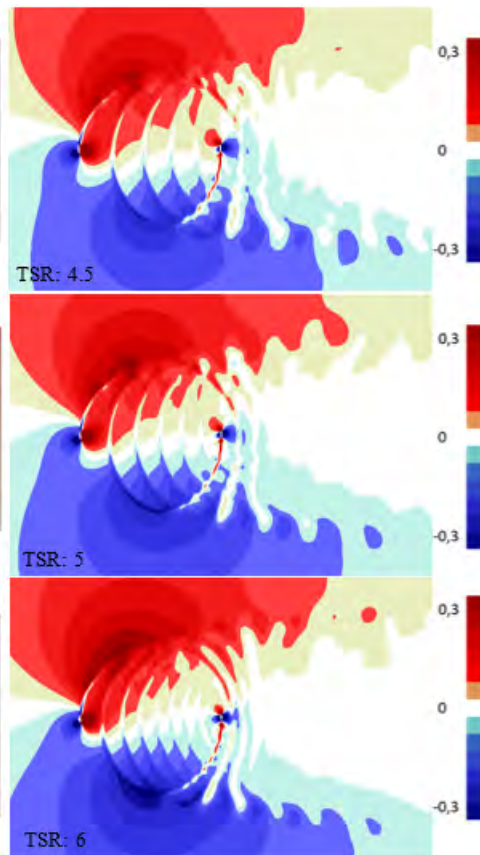
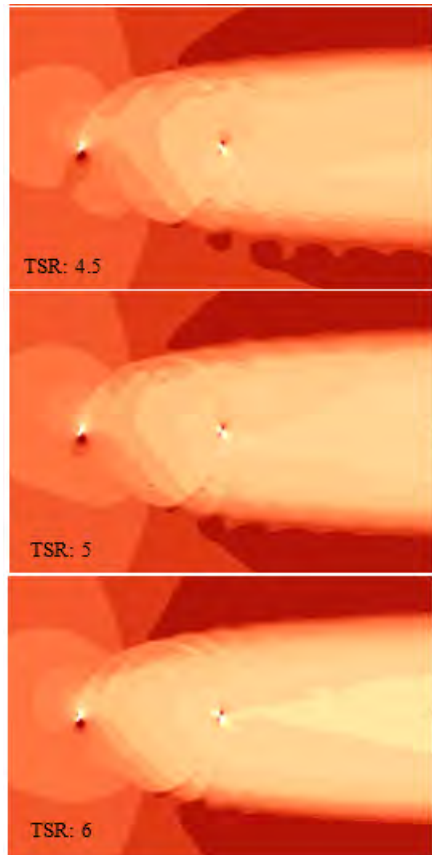
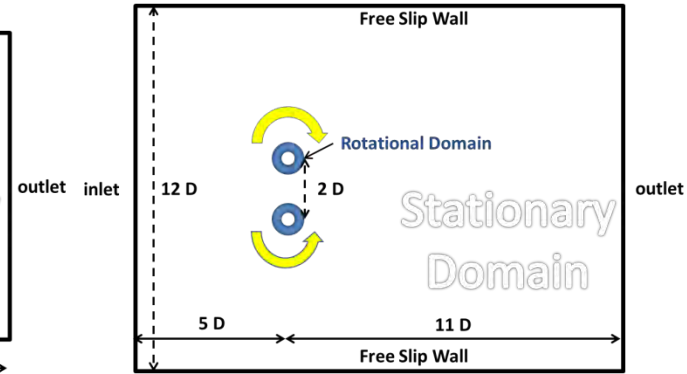
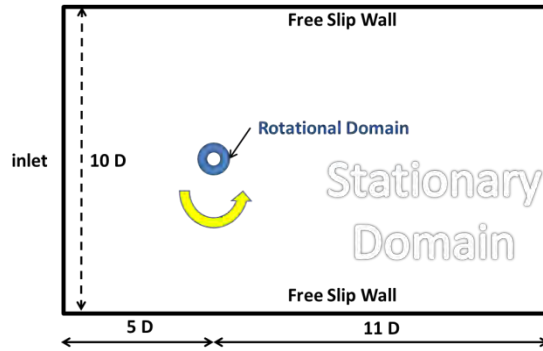


Figure 22. Illustration of Pitch Angle Effects on Turbine Performance

Ar-Ge Süreci – Bilgisayar benzetimleri

Tekil Türbin Davranışı



Ar-Ge Süreci – Bilgisayar benzetimleri

Tekil Türbin Davranışı

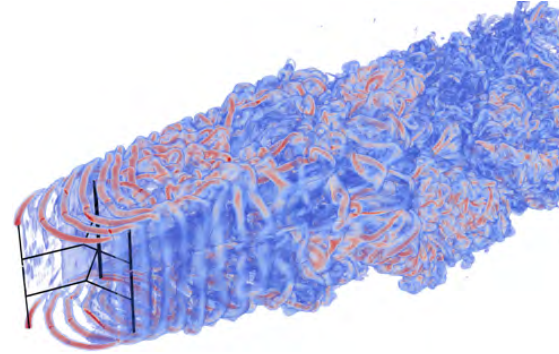
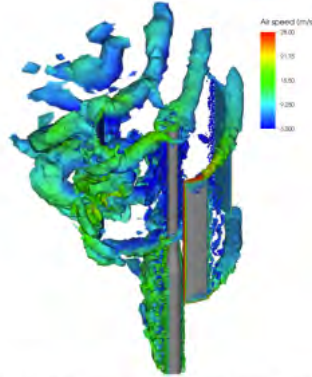
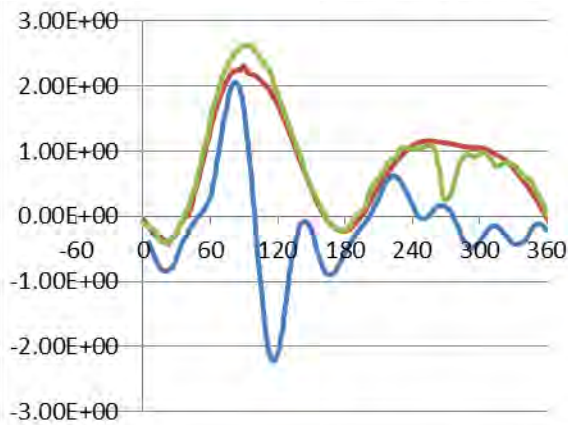
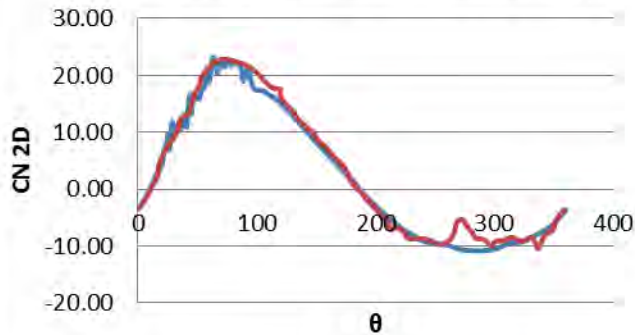


Fig. 4 Vorticity isosurfaces at a time instant colored by velocity magnitude

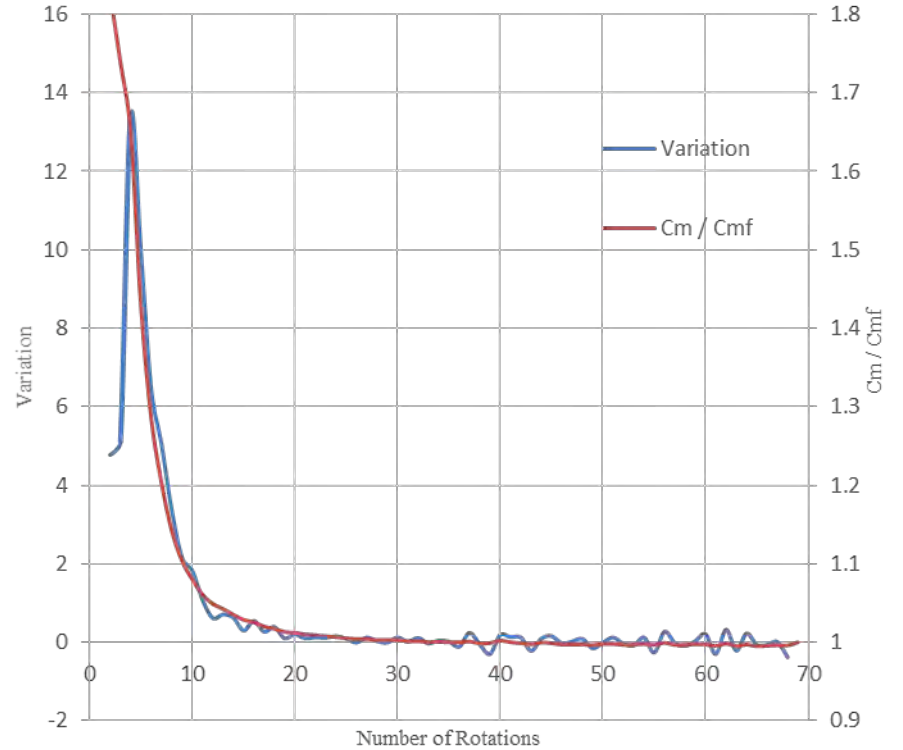


— Bizim analizler
— Study of wake... makalesi
— Deneysel veri

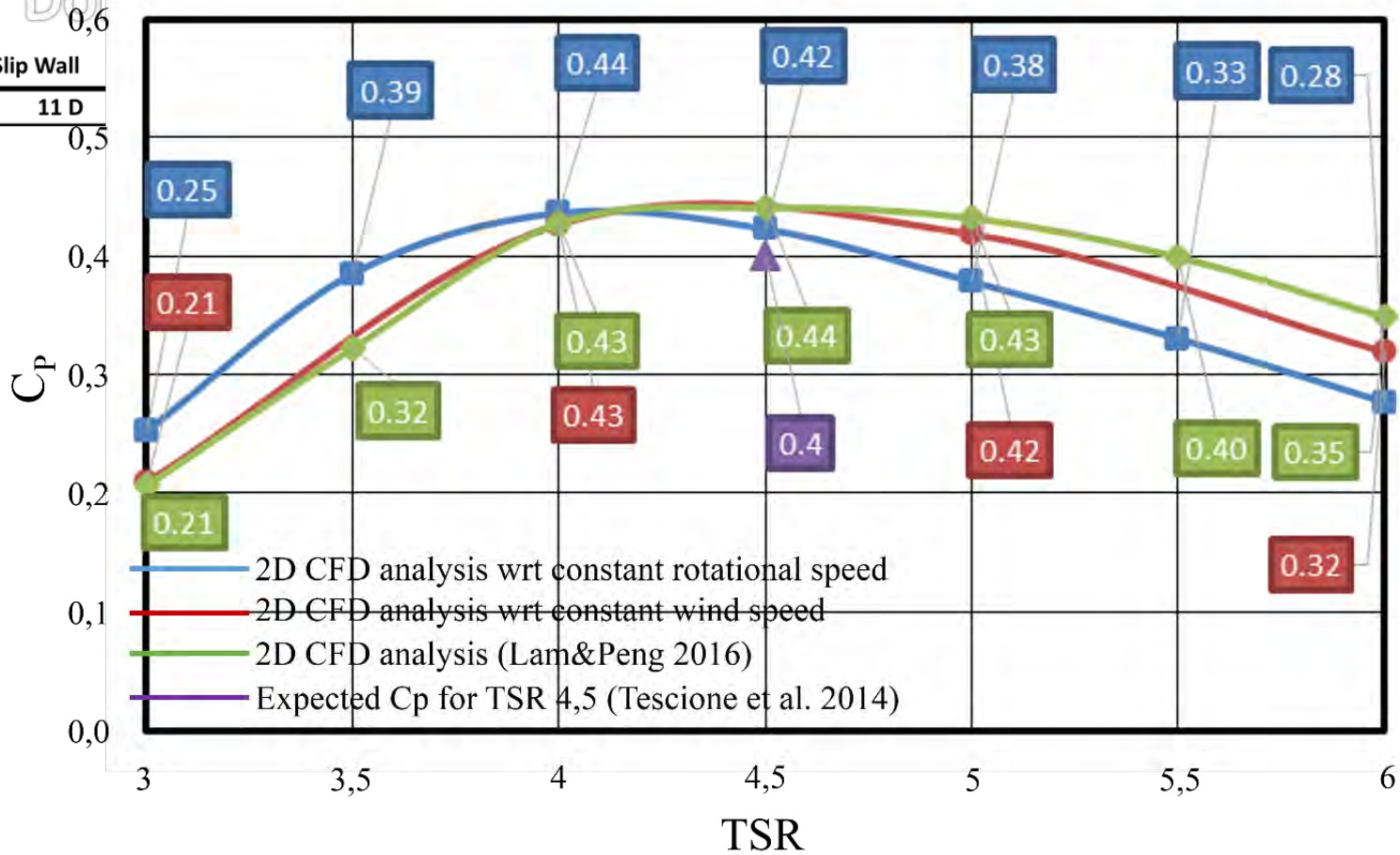
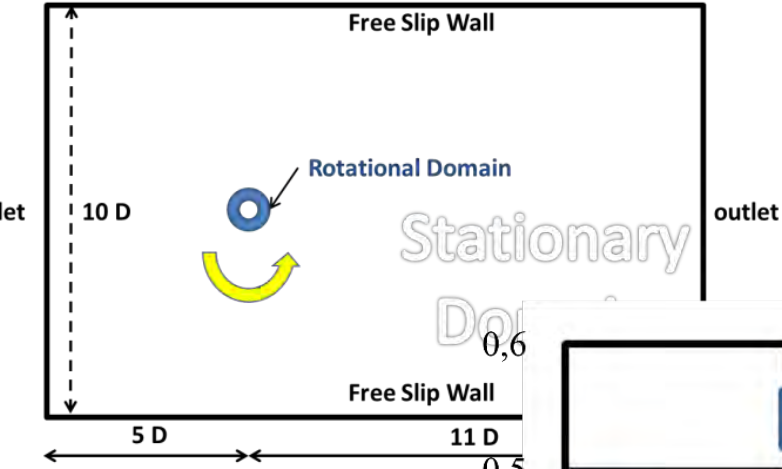
Cn vs. Azimuthal Angle



— Cn1
— Taiwan



Ar-Ge Süreci – Bilgisayar benzetimleri



Tekil Türbin
Davranışı

Eşli Çalışan DERTler – Bilgisayar benzetimleri

Ahmadi-Baloutaki, M., Carriveau, R., Ting, D. S-K. 2016. "A wind tunnel study on the aerodynamic interaction of vertical axis wind turbines in array configurations". Renewable Energy 96, 904-913.

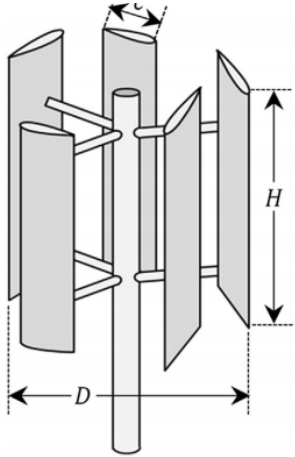


Fig. 1. A schematic of a SB-VAWT.

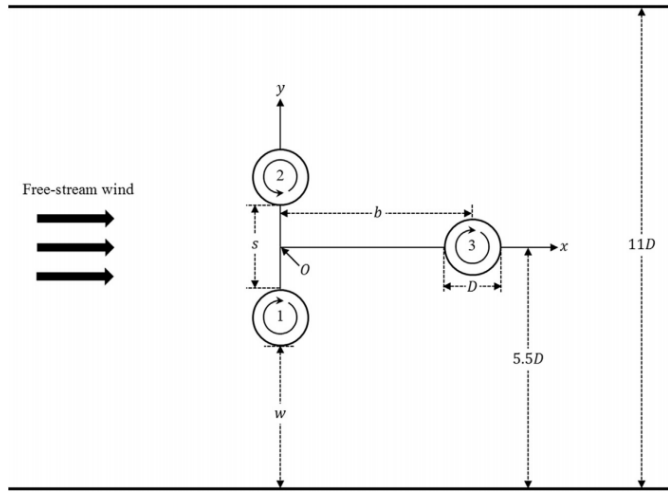
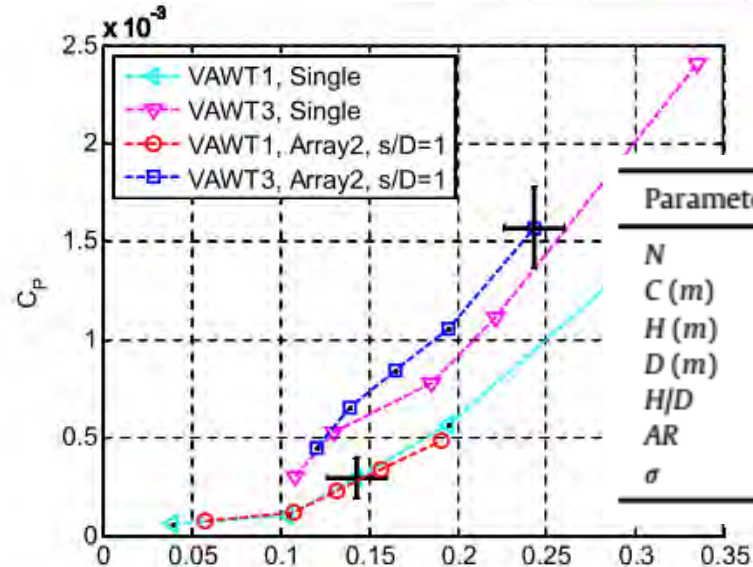
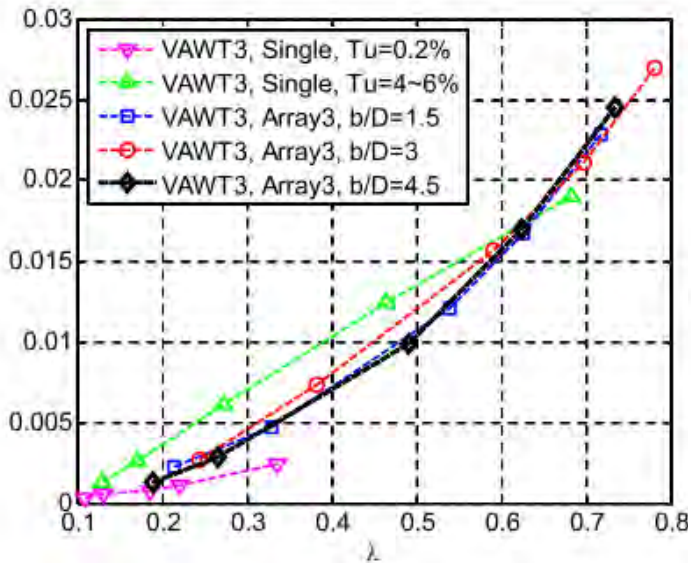
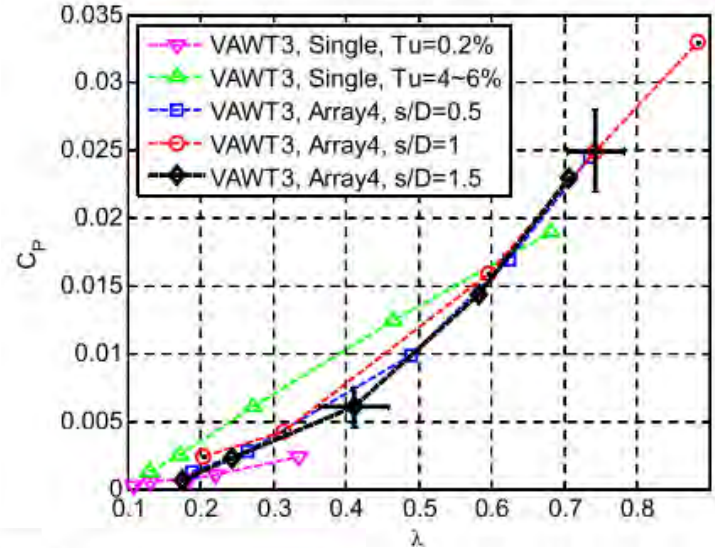


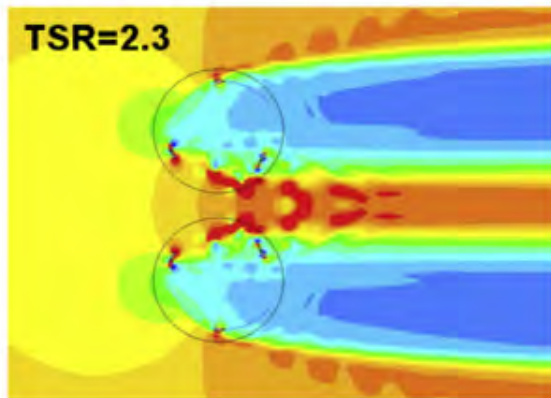
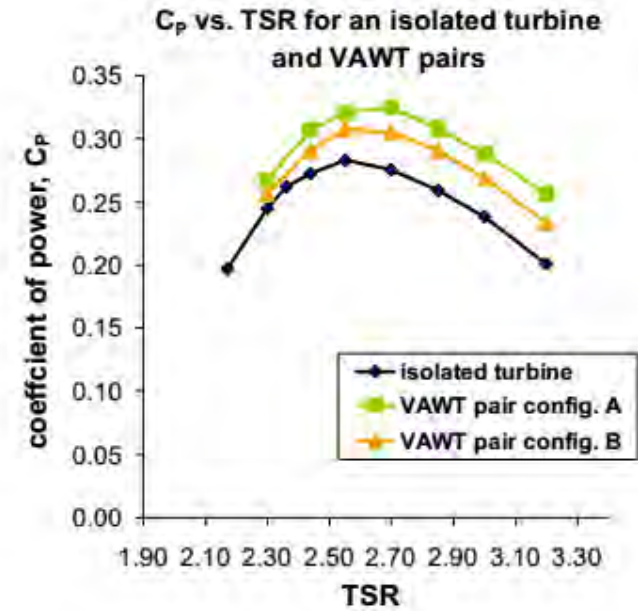
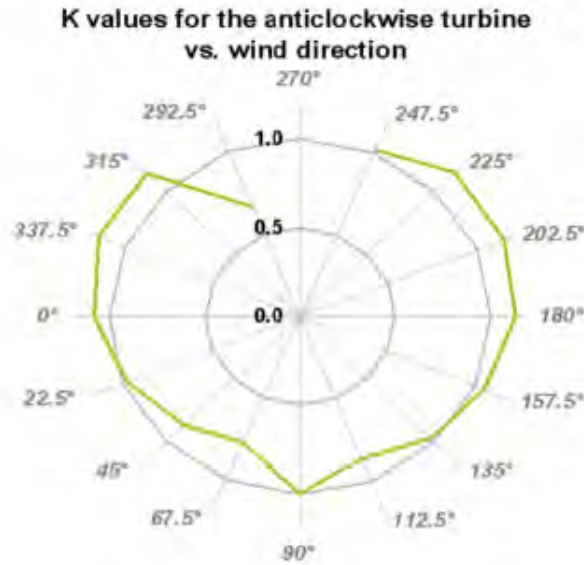
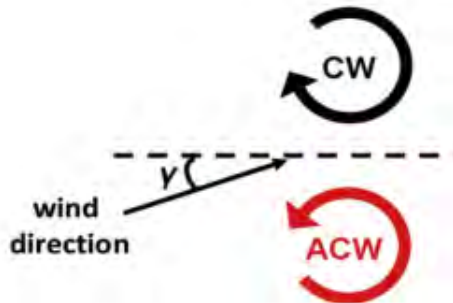
Fig. 2. Top-view schematic of the wind tunnel test section showing a three-VAWT array in a triangular configuration.



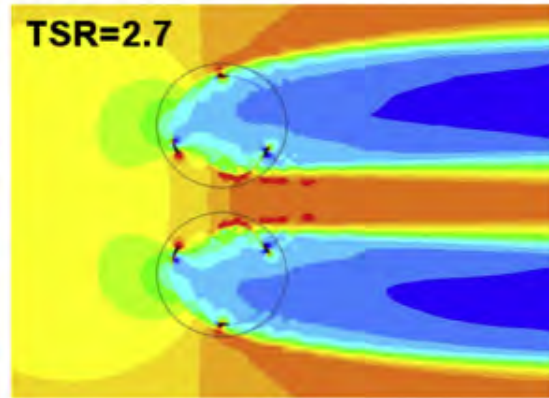
Parameter	Current SB-VAWT
N	5
C (m)	0.045
H (m)	0.3
D (m)	0.3
H/D	1
AR	6.6
σ	1.5

Eşli Çalışan DERTler– Bilgisayar benzetimleri

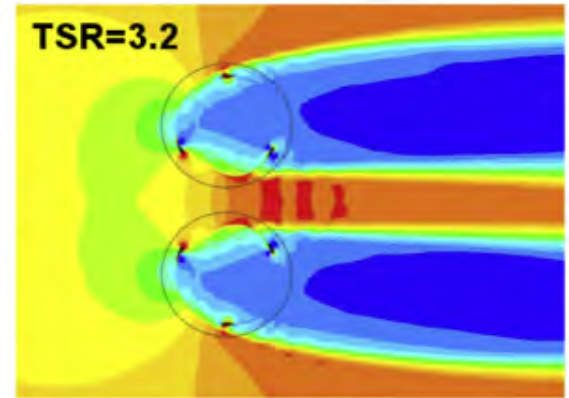
Zanforlin, S., Nishino, T. 2016. "Fluid dynamic mechanisms of enhanced power generation by closely spaced vertical axis wind turbines", Renewable Energy, 99, 1213-1216.



a



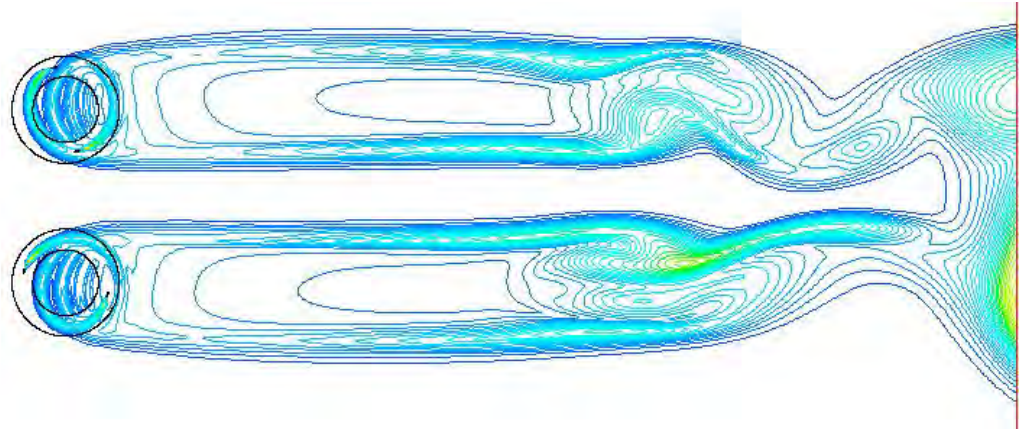
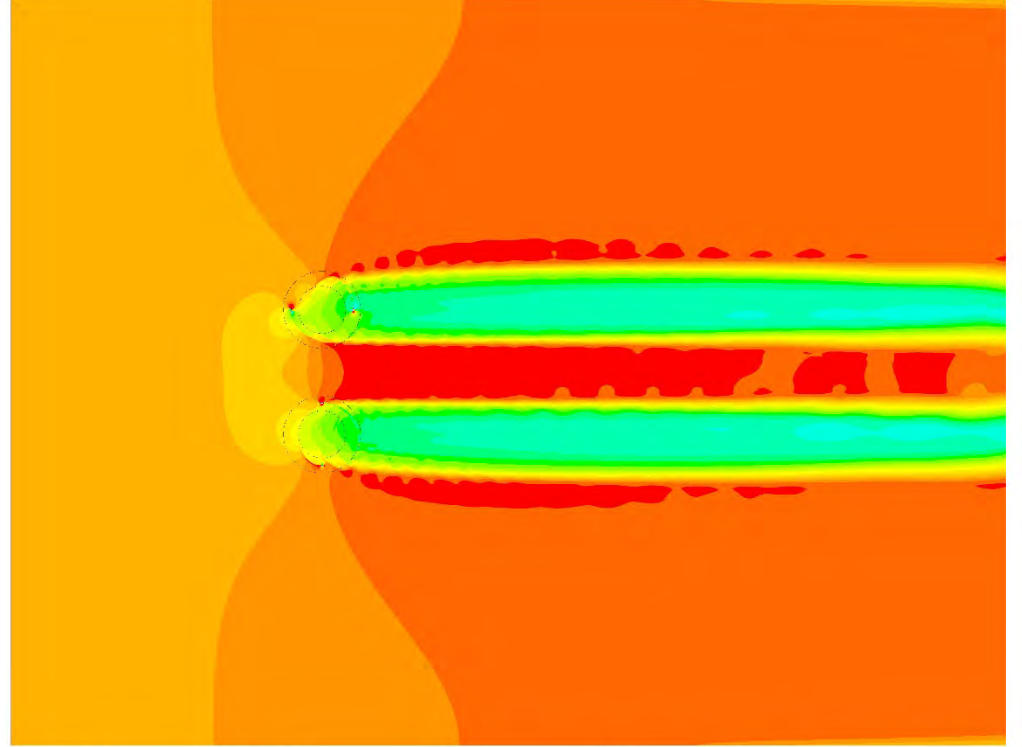
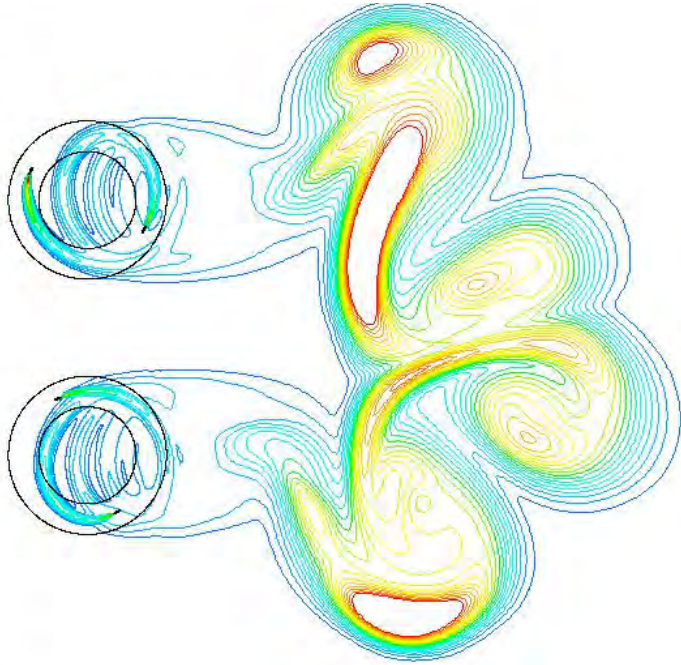
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c

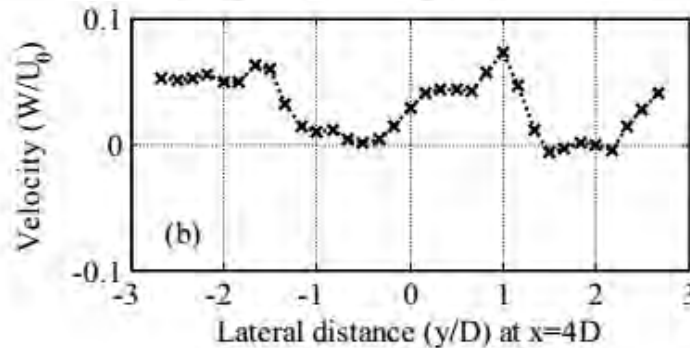
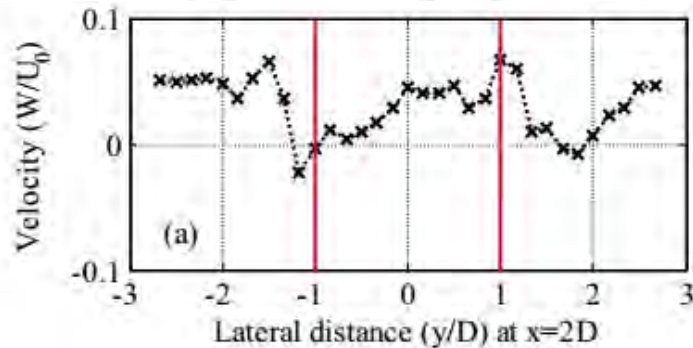
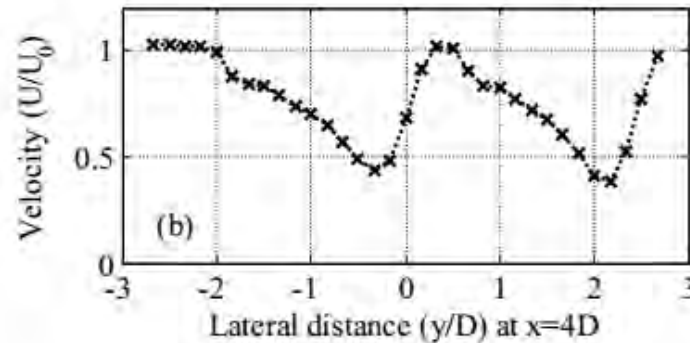
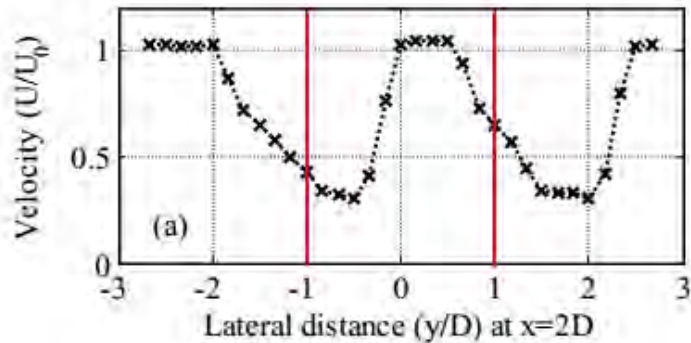
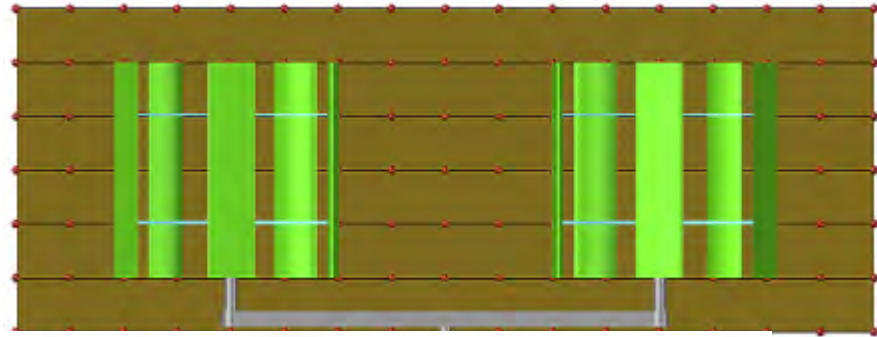
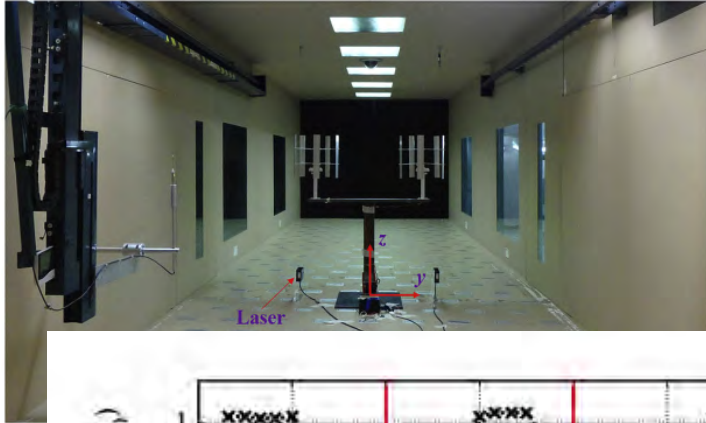
Ar-Ge Süreci – Bilgisayar benzetimleri

Çoklu Türbin
Davranışı

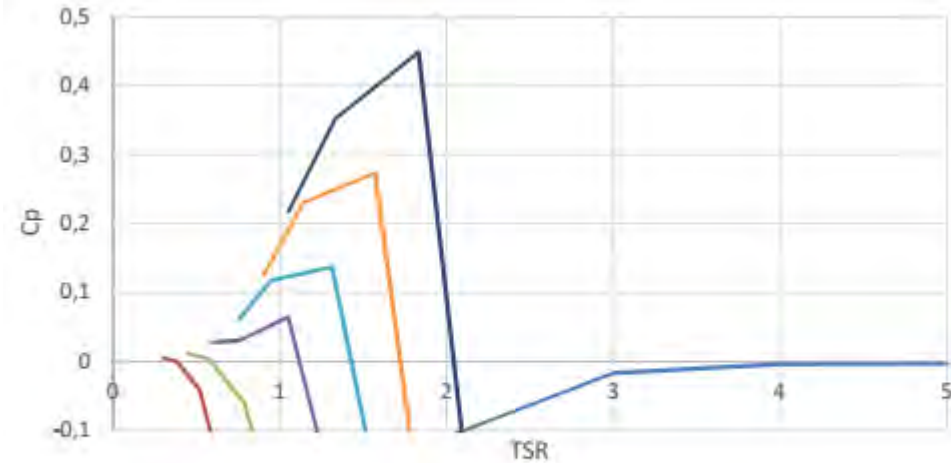
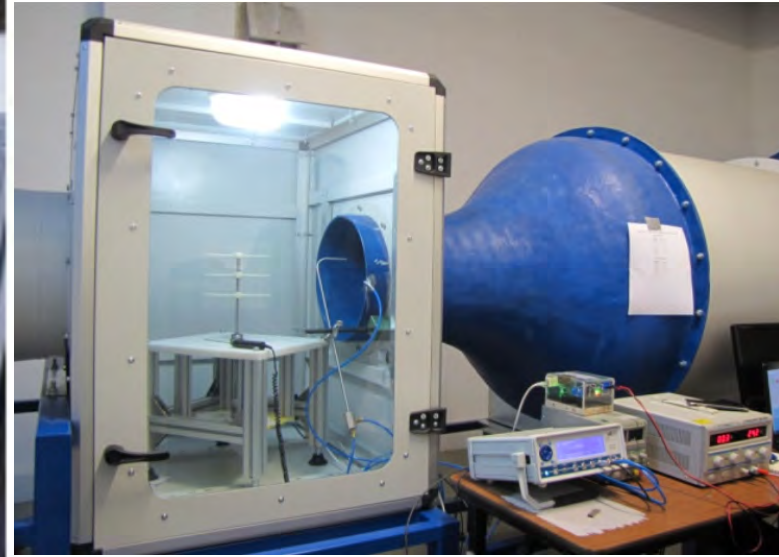
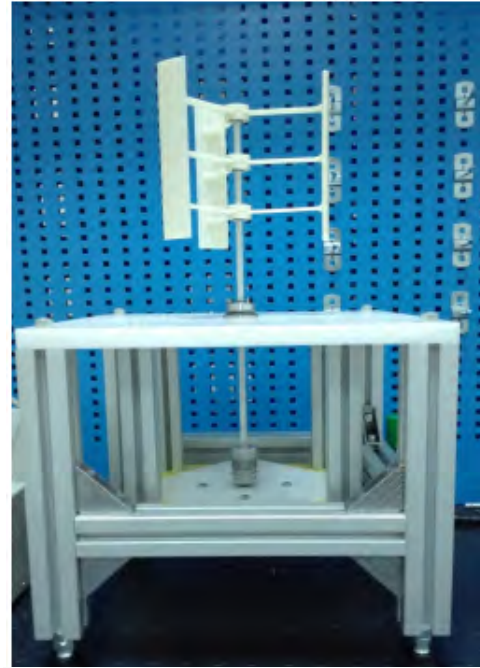


Ar-Ge Süreci – Laboratuvar çalışmaları

Lam, H.F., Peng, H.Y. 2017. "Measurements of the wake characteristics of co- and counter-rotating twin H-rotor vertical axis wind turbines." Energy 131, 13-26



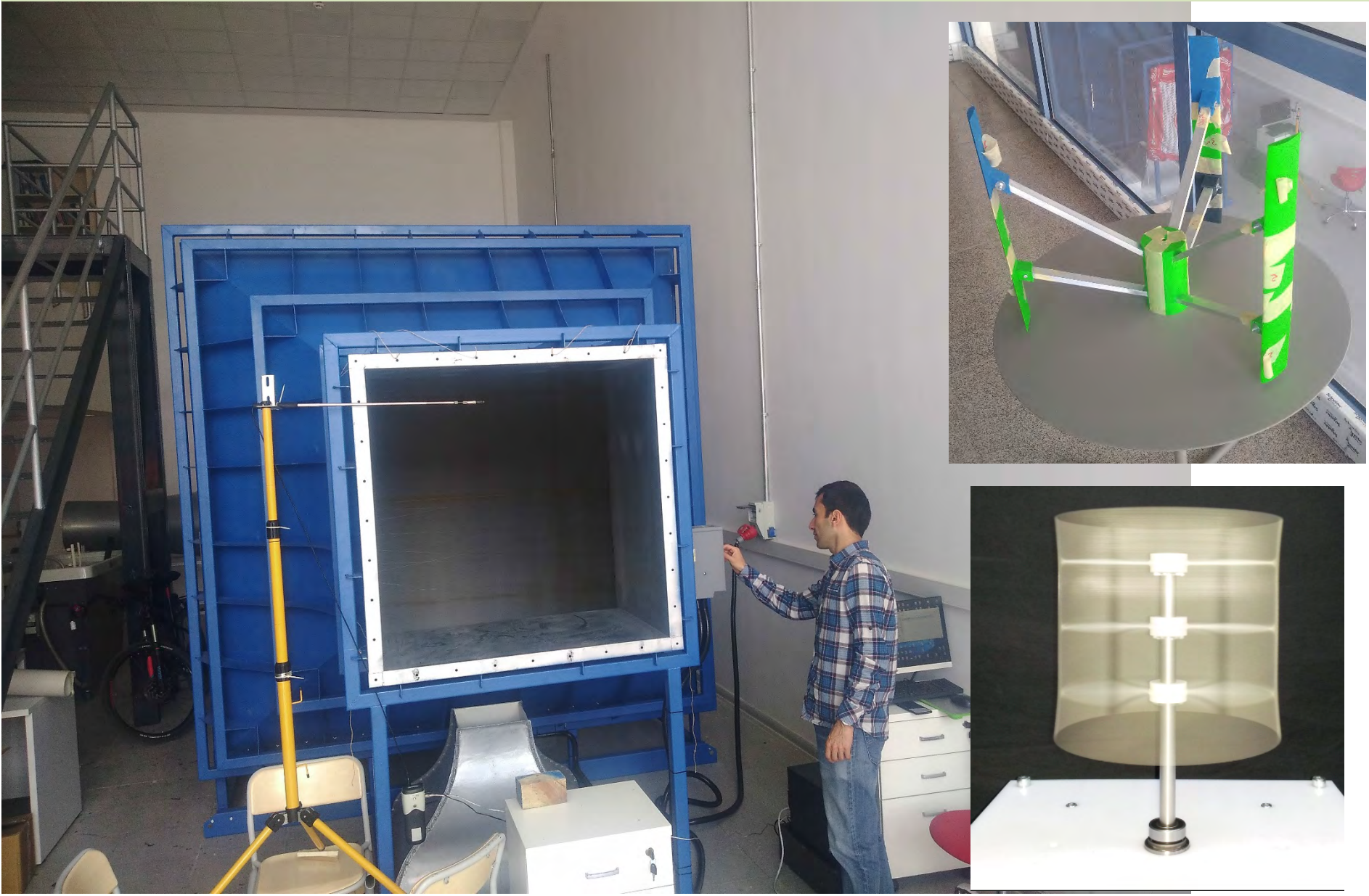
Ar-Ge Süreci – Laboratuvar çalışmaları



— Re 5434 — Re 10869 — Re 16329 — Re 21764
— Re 27198 — Re 32659 — Re 38093



Ar-Ge Süreci – Laboratuvar alıřmaları

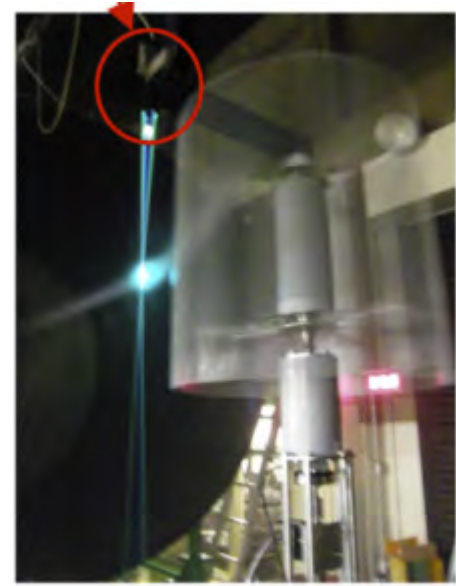
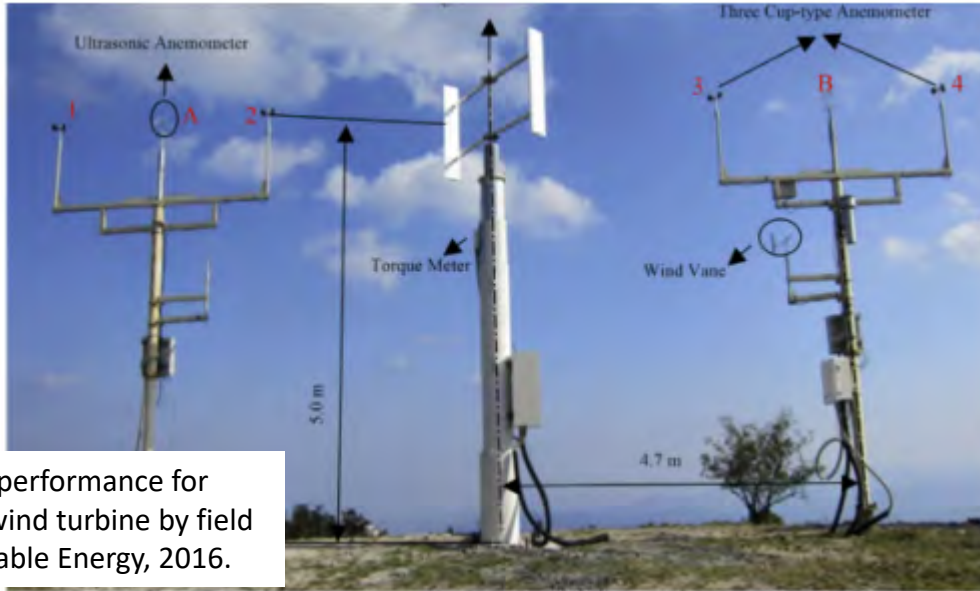


08.05.2019

Dr. Ziya Haktan Karadeniz

Ar-Ge Süreci – Saha çalışmaları

Saha koşullarında türbin performansı



(a) Wind tunnel and wind turbine.

Li, Q., et. al, Study on power performance for straight-bladed vertical axis wind turbine by field and wind tunnel test. Renewable Energy, 2016.

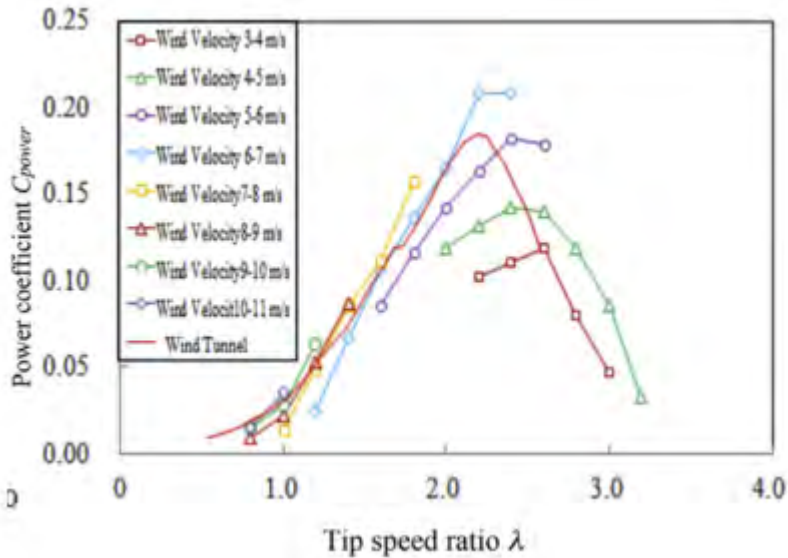
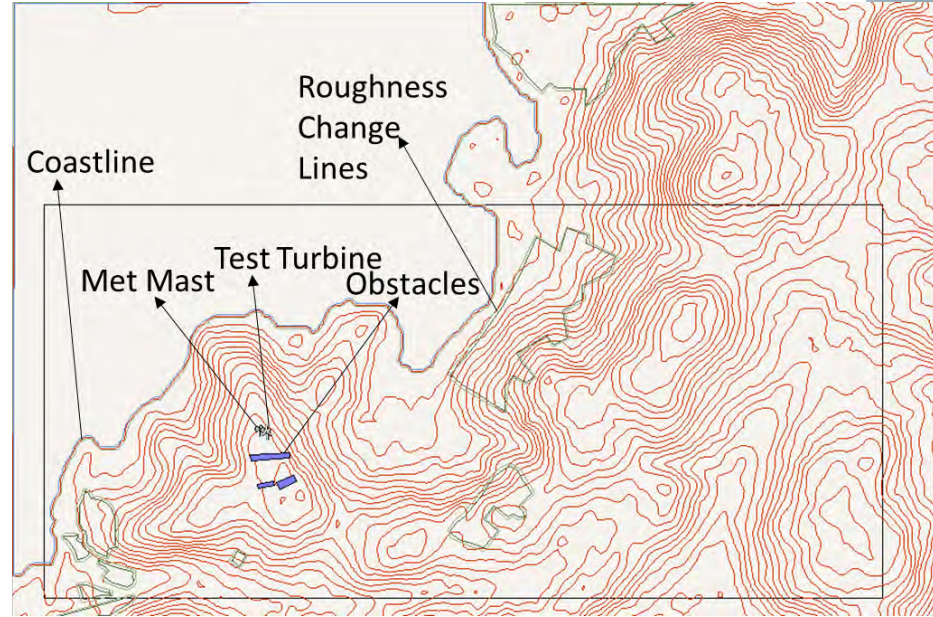


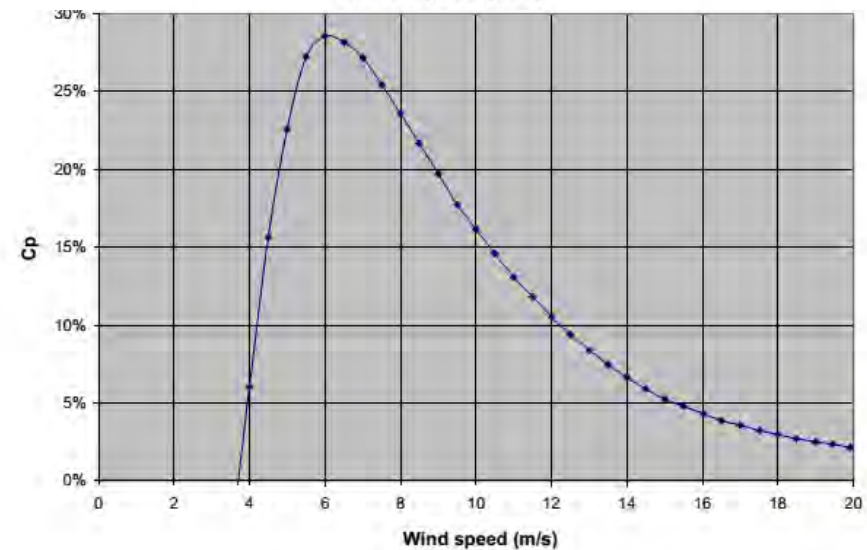
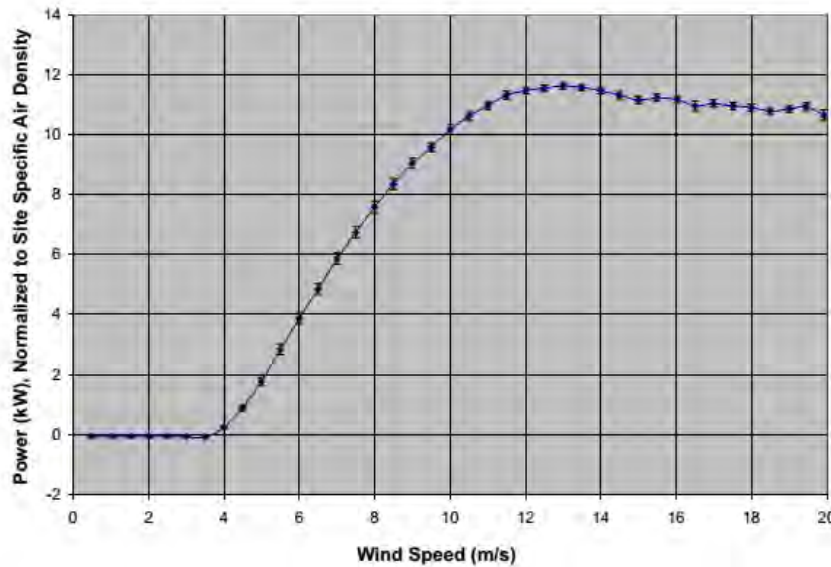
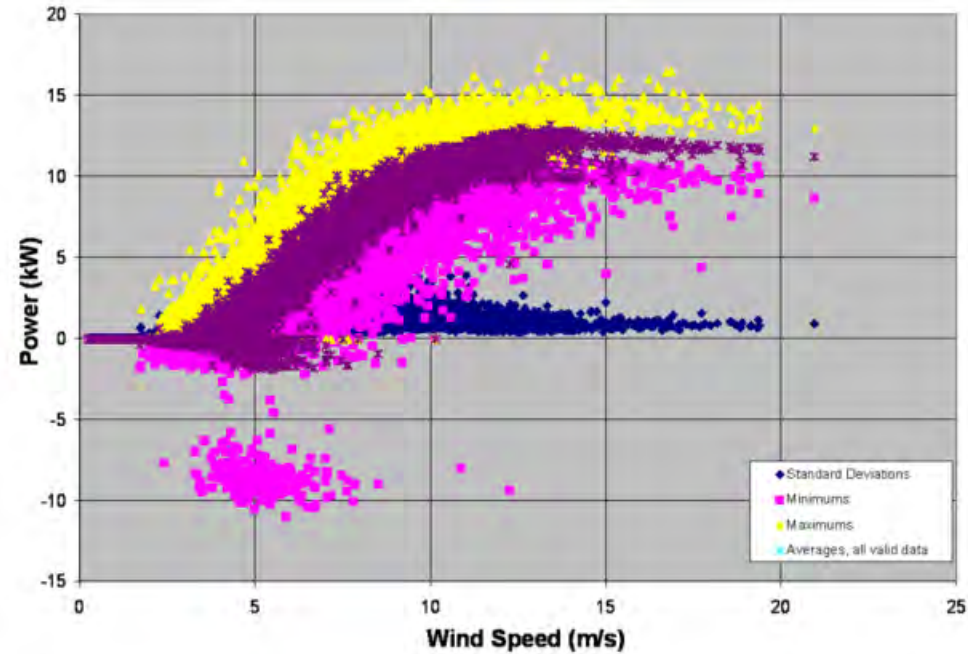
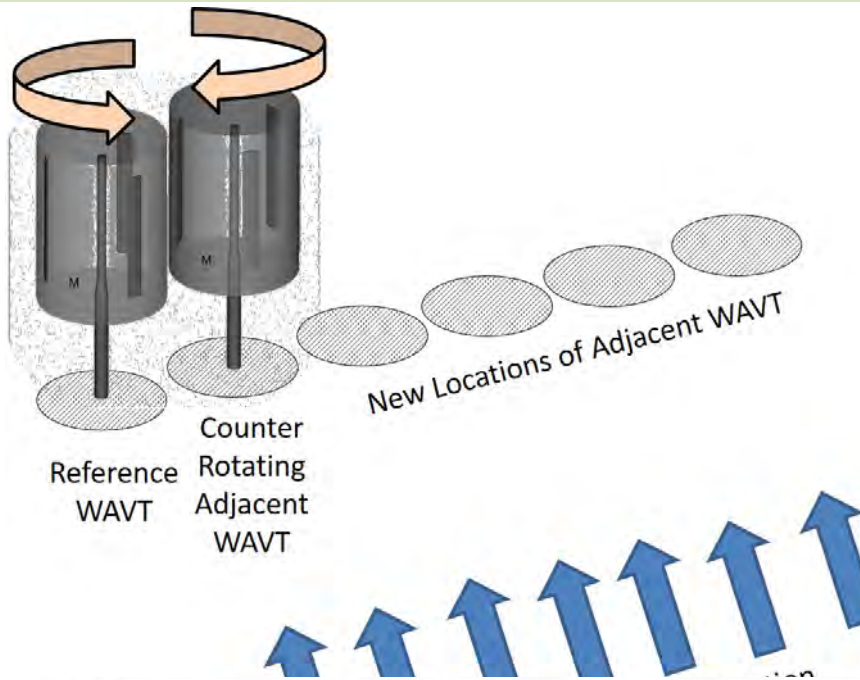
Figure 32. Soap film visualization of a clockwise rotating vertical axis wind turbine

Araya, D. B., & Dabiri, J. O., Vertical axis wind turbine in a falling soap film. Physics of Fluids, 2015.

Ar-Ge Süreci – Saha çalışmaları

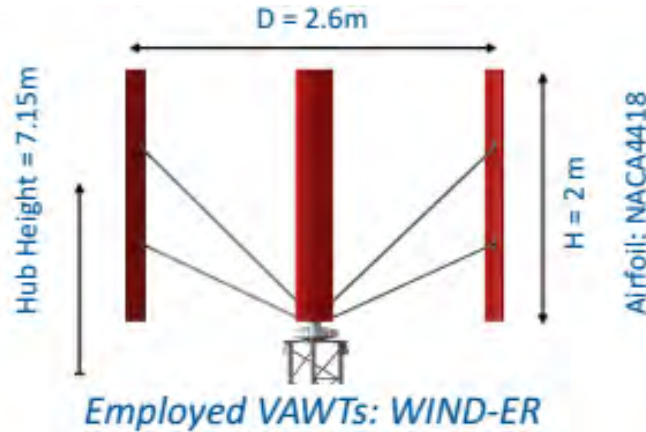


Conclusion – What is next? – On-site

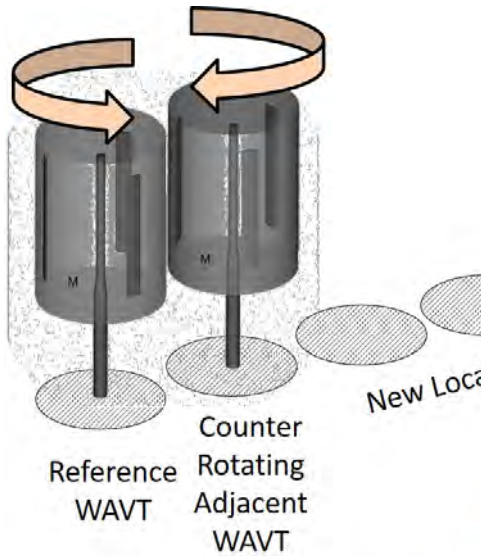


Ar-Ge Süreci – Saha çalışmaları

Kökey İ., Karadeniz Z.H., Acarer S., Turgut A., Energy Interaction of Vertical Axis Wind Turbines Working In Pairs: A Case Study And An Application of IEC61400-12-1:2017, WindEurope 2018 Conference at the Global Wind Summit, 2018

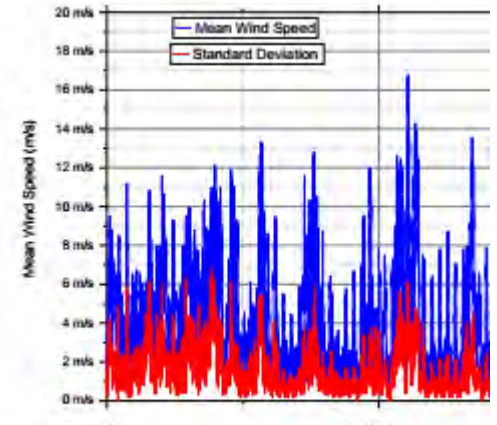
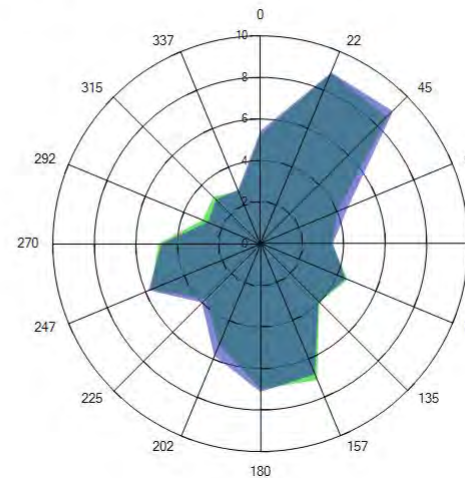


Wind Measurement Station



Mean Value Series	Offset
Anemo1_Windvane1	0
Anemo1_Windvane2	0

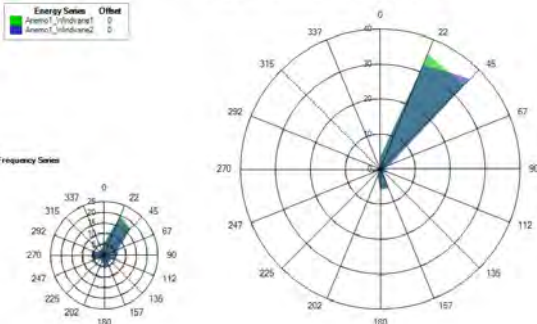
Data from logger: ALIAGA (ID?????) Time Zone: UTC+00:00:00
 Mean Value (Anemo1) by Wind Direction [From 25.07.2012 To 01.11.2013]



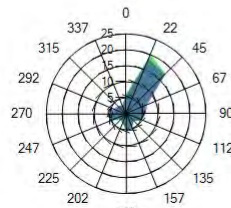
Data from logger: ALIAGA (ID?????) Time Zone: UTC+00:00:00
 % Energy (Anemo1) by Wind Direction [From 25.07.2012 To 01.11.2013]

Energy Series	Offset
Anemo1_Windvane1	0
Anemo1_Windvane2	0

Frequency Series



Frequency Series

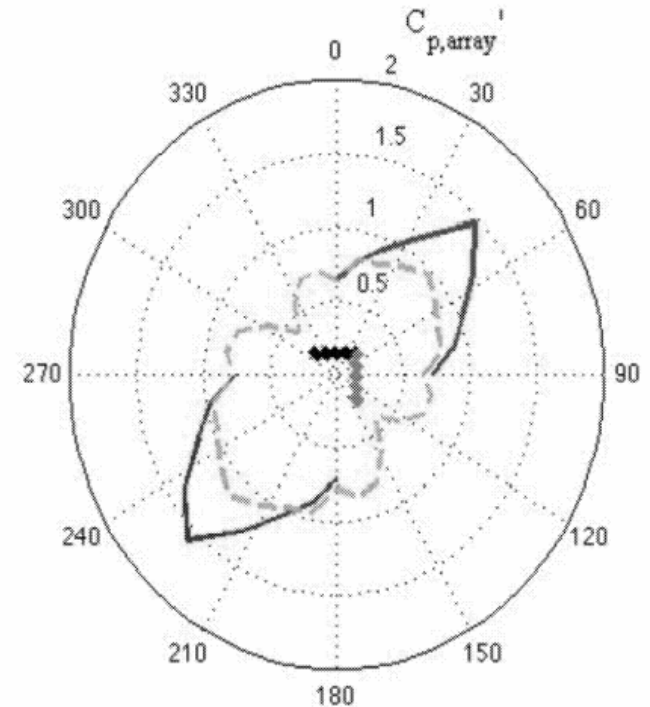
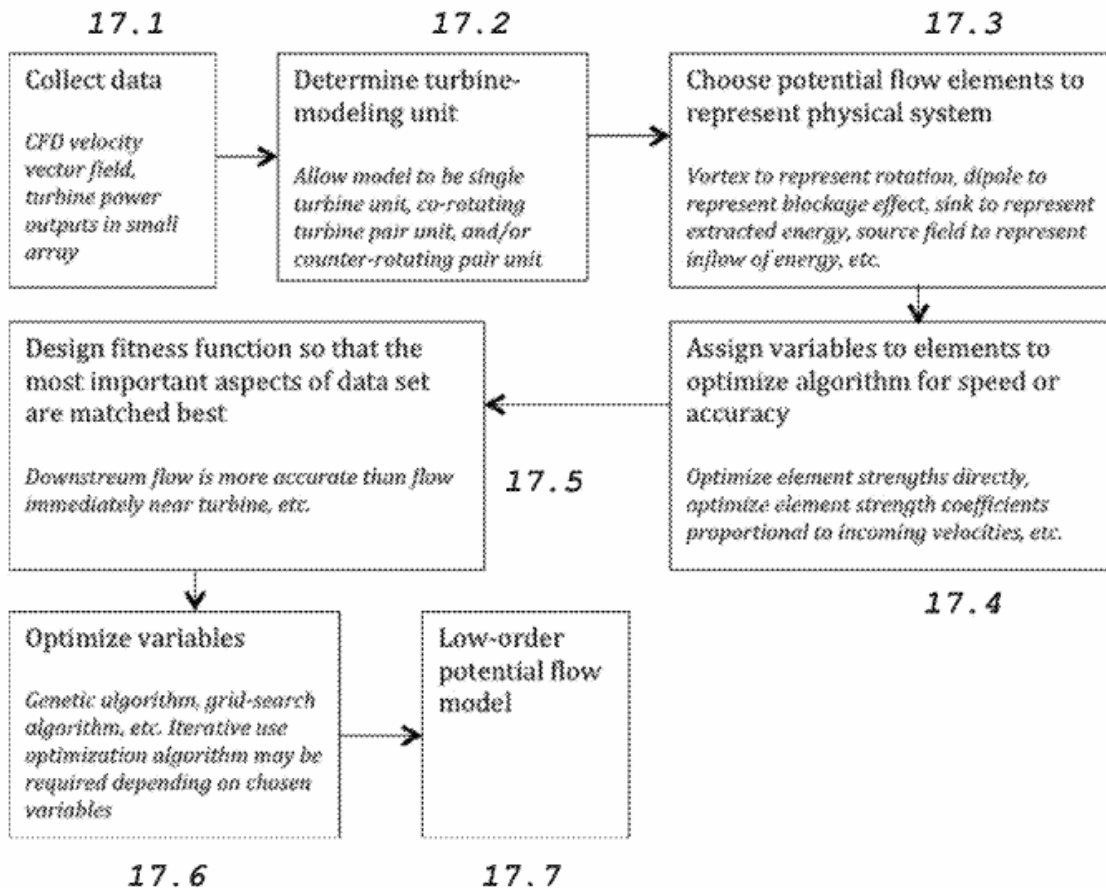
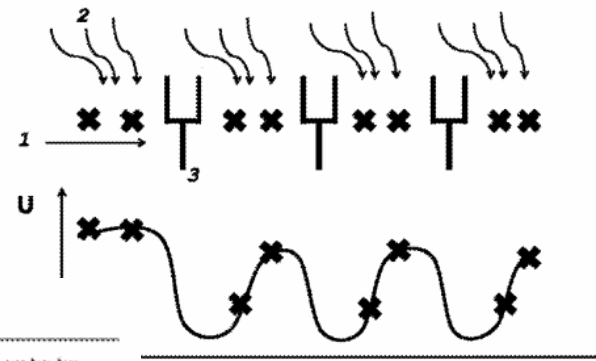


New Loca

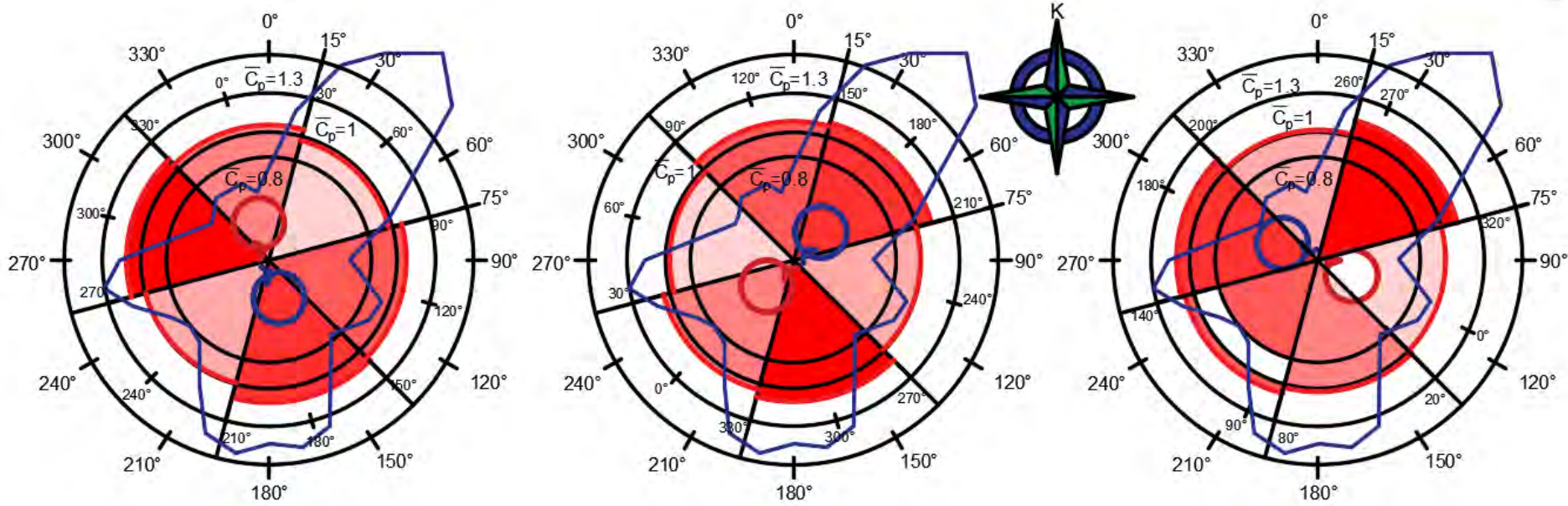
Saha Yerleşimi için Yöntem Önerileri

(54) METHODS AND SYSTEMS FOR COMPARING VERTICAL AXIS TURBINE ARRAYS AND PROVIDING CONFIGURATIONS THEREOF

(75) Inventors: **Anna Craig**, Menlo Park, CA (US);
John Oluseun Dabiri, Pasadena, CA (US)



Saha Yerleşimi için Yöntem Önerileri



Eşli çalışan DERT çifti dizilimlerinin YEÜ'lerinin, ayrıık çalışan iki DERT'in toplam YEÜ'ne göre performans artışı

Dizilim	YEÜ (kWh)	Performans Artışı
Ayrıık Çalışan	2990	-
30°-90°	3059	%2,25
150°-210°	3349	%10,73
260°-320°	3374	%11,37

İlginiz için teşekkür ederiz!

Doç. Dr. Alpaslan Turgut, Dr. Z. Haktan Karadeniz, Dr. Sercan Acarer, Yük. Müh. İskender Kökey, Yük. Müh. Ufuk Akgül, Erinç Baytekin, Rıdvan Almaz, Ferhat Cem Başer, Fatih Tolga Özdemir, Ceren Vatansever



İZMİR
KÂTİP ÇELEBİ
ÜNİVERSİTESİ

2010

