Malaysia :
Wind Energy Distribution Recent Development

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....(1) INTRODUCTION

- Solar Energy Research Institute (SERI), UKM Malaysia is an institute that responsible in handling research on renewable energy development in Malaysia. It was formed to address the immediate issue of fossil fuels consumption that causing environmental pollution and global warming.

- The rapid depletion of fossil fuels resources has resulted in the increase of it prices. Together with environmental issues and it impacts, making alternative resources such as wind energy are one of the important renewable sources

- Research on wind and its potential in producing energy is carried out by researchers around the world.

- ***(Saidur et al., 2010 and 2011)*** have concluded that wind speed, wind direction, speed swings and wind direction strong relationship

- ***Belu and Koracin (2013 and 2015)*** have concluded that there is a strong linkage between wind speed and direction. So the relationship between wind direction and the potential to increase wind power generation needs to be investigated.

- Detailed knowledge of wind in an area is a key requirement in general assessment of wind energy potential as a whole

- With low average speed throughout the year, small-scale wind energy systems may be more suitable for development in Malaysia. Systems such as wind turbines are more influenced by cut-in speeds than turbine height ***(Akorede et al., 2013).***

..(2) RESEARCH WIND IN MALAYSIA

(a) <u>Wind Speed</u>

- The research trend as can be seen start explode by wind speed research.
- Wind speed has become the most selected parameter to be studied as it much more easier to be conducted.
- There are numerous researches related on wind speed were discussed on the statistical distribution for wind speed. ***Weibull, Gamma and Inverse Gamma*** are among the statistical distribution that being used. The details are shown in Table 1.

Table 1 Details of researches

Researcher(s)	Finding
K.Sopian et.al [1] 1995	• For 1982-1991 data, Mersing and Kuala Terengganu have the highest potential to generate wind energy with a mean power density of 85.61 W/m^2 and 32.5 W/m^2. • The highest mean monthly wind speed was recorded at Mersing (4-5.5m/s).
Shamshad et.al [2] 2007	Revealed that the second order of Markov Chain model has improved the autocorrelation (AR) of synthetic generated wind speed data.
A. Zaharim et.al [3] 2008	Found that the accurate distribution of wind speed was Weibull approximation.

Researcher(s)	Finding
S.K Najid et.al [4] 2009	Revealed that Burr distribution is the most appropriate probability distribution for that data set. (For the year of 2005-2006, Terengganu data)
A. Zaharim et.al [5] 2009	Found that the wind speed data for Terengganu is adequate with the Weibull and Gamma distribution.
Shamsad et.al [6] 2009	Found that maximum likelihood is the best estimator in explaining the Weibull parameters. The maximum wind speed in Peninsular Malaysia is located at Mersing with the average wind speed at 3 m/s.

R.Norhayati [7] 2010	• Introduced the use of FirstLook software in analysing monthly and yearly mean wind speed and attaining the view of wind speed distribution. • Suggested that Kota Belud, Kudat and Langkawi are the most potential location to install wind turbine generator in Malaysia. • Suggested the use of shrouded WTG with wind-lens technology in capturing the low wind speed in Malaysia
K.H Yong et.al [8] and A. Albani et.al [9] 2011	• Discovered the wind speed mapping of Malaysia by using Inverse Distance Weighted Method (IDW). • Found that Kudat and Sandakan is a good wind potential based on its high wind speed all over year.

N. Masseran et.al [10] 2012 and 2013	Revealed that Mersing had the most potential for energy production with the percentage of the time was 18.2%. A good fit for most of the stations in East Malaysia was found using the Gamma and Burr distributions, though there was no clear pattern observed for all regions in East Malaysia.
Islam, M.R et al [11] 2012	Assessing wind energy potentiality for selected sites in Malaysia Mersing, Melaka and Kuantan in 2006-2008. The annual highest values of the Weibull shape parameter (k) and the Weibull scale parameter (c) were 2.18 and 3.11 m/s.

Osamah Basheer Shukur, Muhammad Hisyam Lee [11] 2014	Proposed a hybrid KF-ANN approach (Kalman Filter and Artifical Neural Network) and was proposed to improve the accuracy of wind speed forecasting.

(b) Wind Direction

- Studies on wind direction is not as spread/aggressive as wind speed. But as year to year the number of research increases as shown in Table 2.

Table 2 Details of researches in wind direction

A.G Hussin et.al [12] 1998	• Which used wind direction data in developing a model named the unreplicated complex linear functional relationship model.
A.G Hussin et.al [13] 2006	• Introduced a software named AXIS for analysing Malaysia wind direction. • However this package contains some limitation that needs other software to complement it.

S.Fatimah Hassan et.al [14] 2009	• Introduce the application of ORIANA software to analyse Malaysia wind direction data. • Software is found to be more comprehensive than the previous • A Comparison of Asymptotic and Bootstrapping Approach in Constructing • Confidence Interval of the Concentration Parameter in von Mises Distribution
N.A.B Kamisan et.al [15] 2010 A.M Razali et.al [16] 2012 and A.M Razali et.al [16] 2012	Von Mises distribution was the best circular distribution to describe wind direction in Malaysia
N.Masseran [18] 2015	Using Markov Chain model in describing stochastic behavior of wind direction in Malaysia

(c) Wind Power

- Wind power analysis in this section consists of ***wind turbine*** and ***wind energy estimation***

- Studies of both area were being done either by statistician or engineers.

- For research in wind turbine, recent studies shows that their keen is to cater the low wind speed in Malaysia and optimize the energy.
  - Details shown in Table 3.

Table 3 Details of researches in wind turbine

W.T Chong et al. [1] 2013	• Positioned a vertical axis wind turbine (VAWT) above a cooling tower to harness the wind energy. • It was observed that VAWT does not give negative impact on the performance of cooling tower. • The current drawn from the fan motor was 0.39A. • It is appropriate for low wind speed area. (Figure 1)
P.D Abdul Aziz et al. [2] 2014	• A simulation study on airfoils using VAWT design for low wind speed. • With the proper airfoils design that suits the low wind speed condition, the turbine can functions efficiently as well as maximize the power produced by turbine. • The number of blades affects the tip speed ratio (TSR) and power coefficient (Cp) produced by the wind turbine. In this case, three blades are optimal and have stable power coefficient

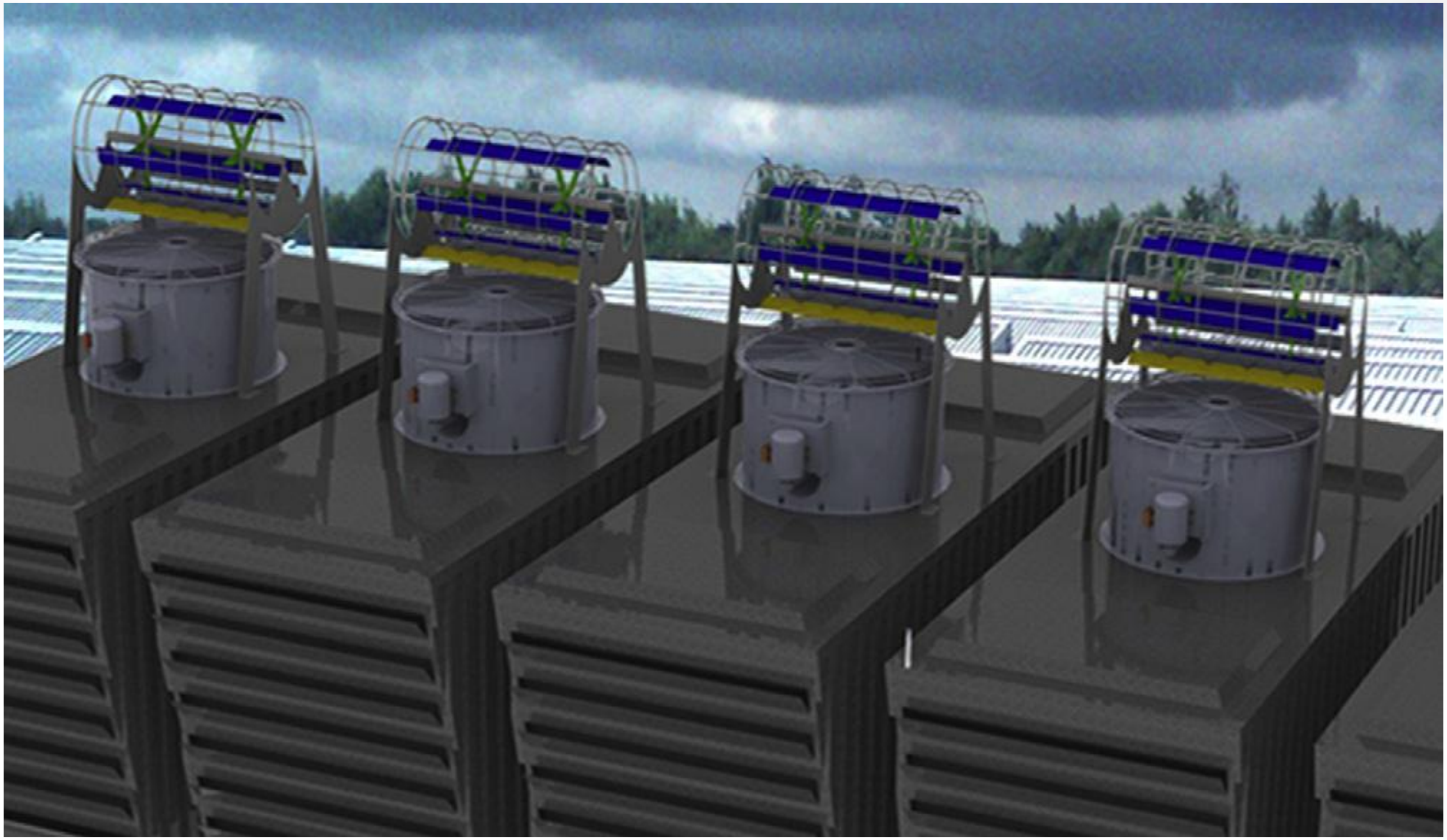


Figure 1 Artist's impression of the energy recovery wind turbine generator on top of the cooling tower.

A.Hamdan et al. [3] 2014	• The application of biocomposites fibers or green material in fabricating VAWT in order to avoid and reduce the utilization of synthetics fiber composite is highlighted. • The smart material in structural health monitoring (SHM) such as piezoelectric can perform as sensor, actuator and energy harvester.
Willy Tjiu et al. [4] 2015	• The variations in Darrieus VAWT is assed including the performance, components, operational reliability. • The current development and future prospects is also being highlighted as shown in Figure 2. • H-Rotor type of VAWT especially of Helical H-rotor is investigated in details in this research.

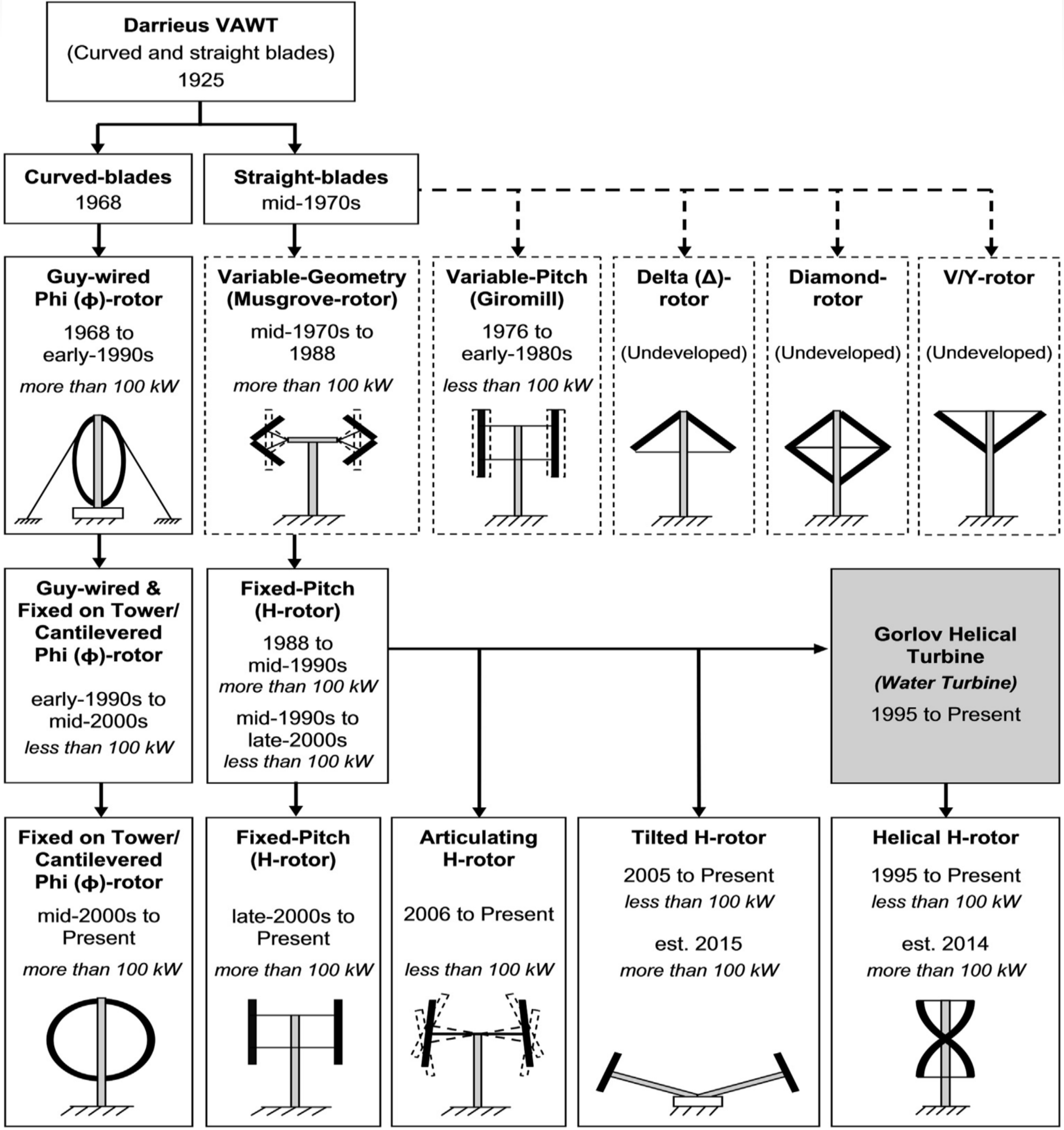


Figure 2 Timeline of Darrieus VAWT development

- For research in wind power, the recent researches is shown in Table 4.

Table 4 Details of researches in wind power

M.F. Akorede et al. [1] 2013	• The potential of wind energy resource for production of electric power has been investigated using Weibull distribution. • Small size turbine is economically wiser to be employed based on the low profile of wind speed. (which is 5.4 m/s @10m height at Mersing).
M.Irwanto et al. [2] 2014	• Study on wind speed in Chuping and Kangar, Perlis have been done. • It reveals that wind energy potential are categorized very poor with the wind power density of 2.13 W/m^2 and 19.69 W/m^2 @50 m height at Chuping and Kangar respectively.

K.M. Nor et al. (2014)	• The use of numerical weather prediction (NWP) models for the wind resource assessment has discerned mesoscale wind that have an eminent impact on the wind regime in Malaysia. • Affirm the existing potential of wind energy in Malaysia.
N. Masseran (2015)	• Discuss the statistical properties of the wind power density function. • The method of Monte Carlo integration is proposed in this study for determining the statistical properties of wind power density such as Gamma and Inverse Gamma pdfs that cannot be easily obtained directly.

Comparison of univariate and bivariate parametric model for wind energy analysis

- Although the trend of jointing wind speed and wind direction in wind power assessment has begun abroad, there is no/very little such analysis in Malaysia.
- This study combines the wind speed and wind direction in a bivariate probability model to investigate the significance effect of wind direction in determining the wind power density at Mersing, Malaysia.
- The method of obtaining circular-linear distribution with specified marginal distributions by Johnson & Wehrly has been used for this purpose.
- The best fit model for univariate and bivariate probabilistic model and annual wind power density for each model are discovered and used to represent the availability of wind energy potential across Mersing, Malaysia.

...... (3) STUDY AREA AND DATA

Mersing is located at the southern part of Peninsular Malaysia, with geographic coordinate 2.4333° N and 103.8333° E.

Throughout the year, Mersing experiences a wet and humid condition with mean daily temperature is 31°C and nearly 70 percent humidity (Razali et al., 2012).

As shown in **Figures and Diagrams next few slide**,

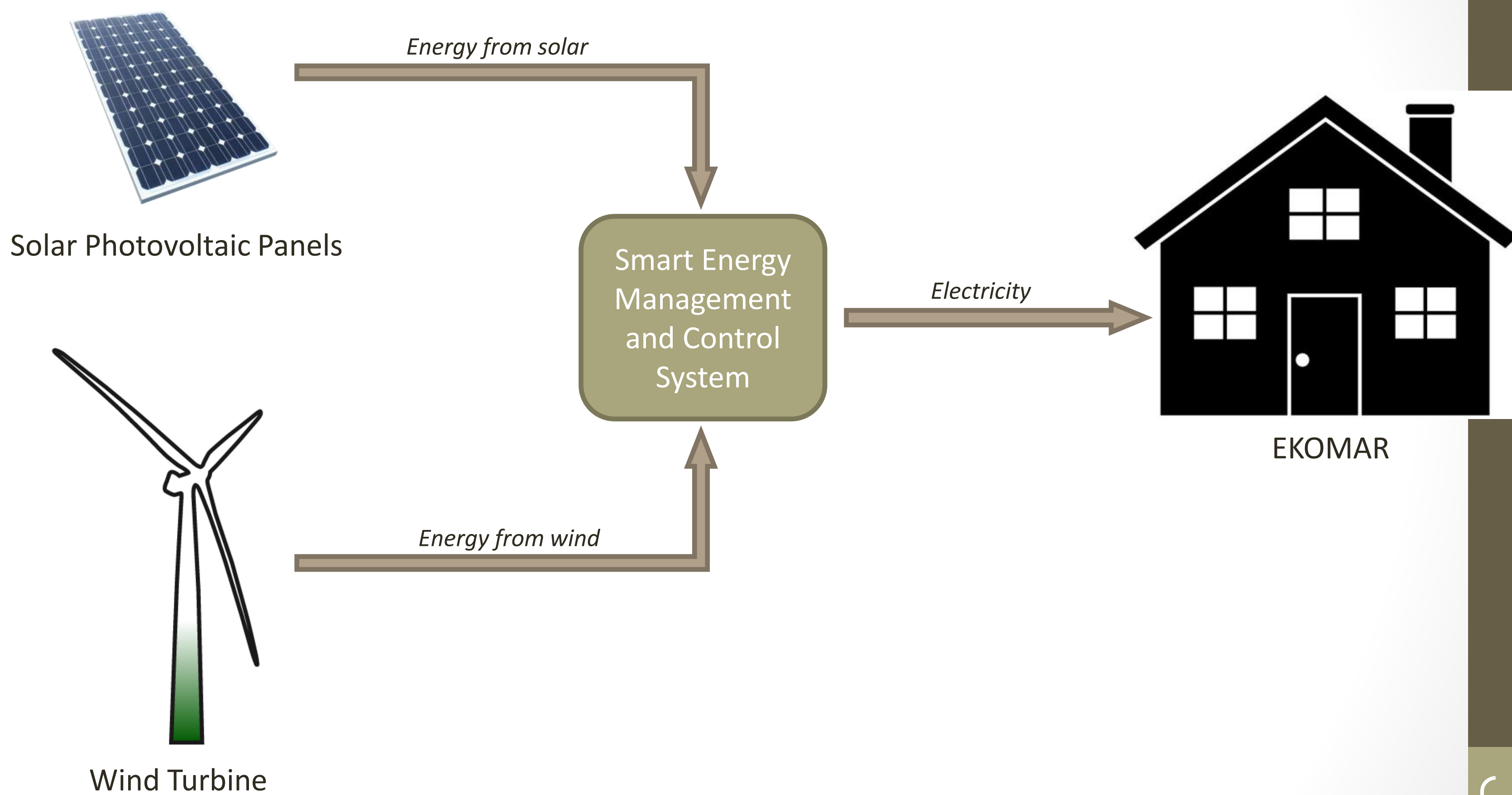
Mersing is located near to the sea that caused influenced by the effect of sea breezes and land breezes.

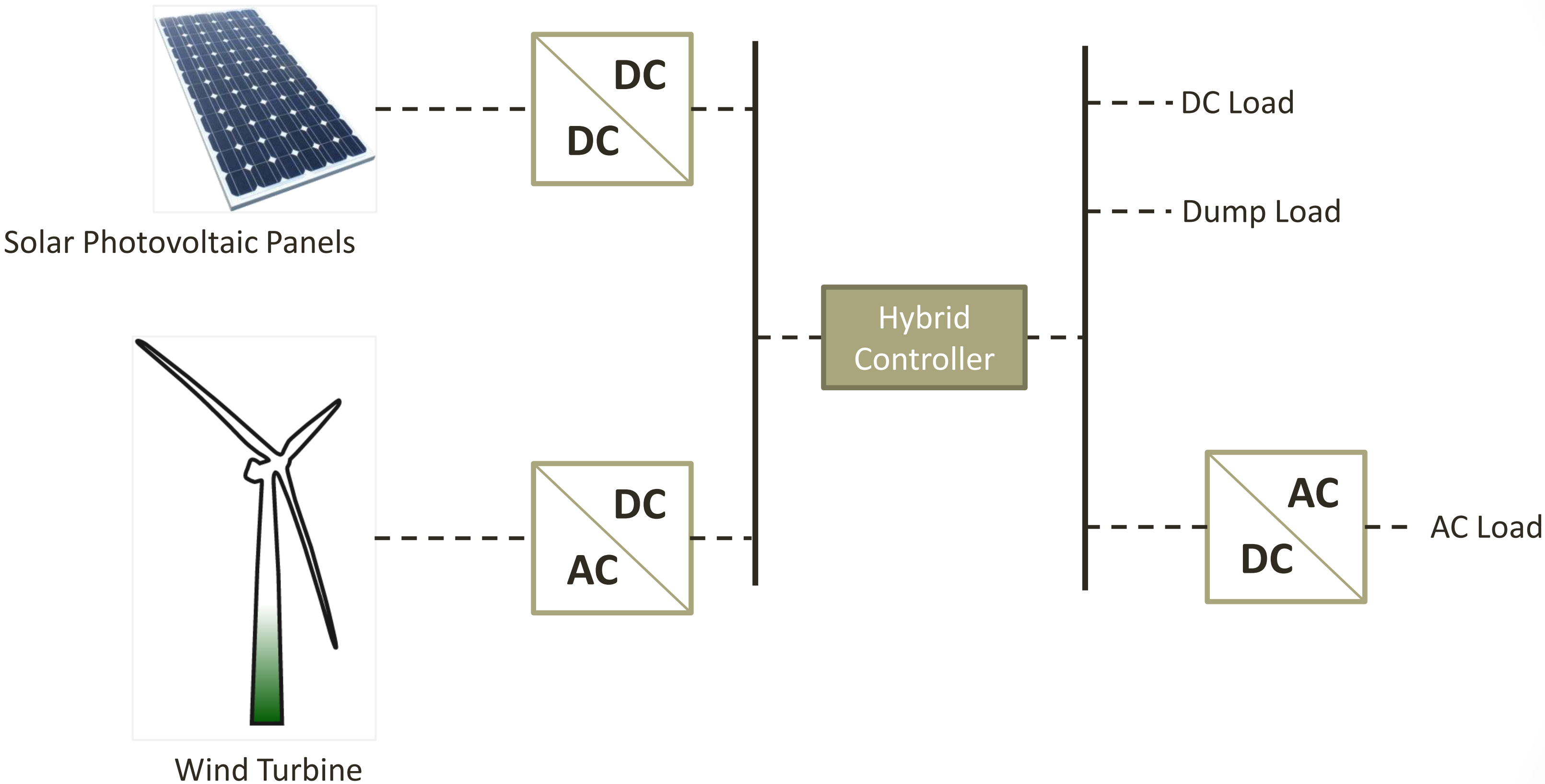
Hourly wind speed (m/s) at 10 meter height data of Mersing is provided by the Malaysian Meteorological Department. The data records is from January 2007 to December 2013.

UKM Marine Ecosystem Research Centre

Demo Projects at Solar Energy Research Institute (SERI) UKM

2 kW Wind PV Hybrid System in UKM Marine Station in Mersing Johor (1kW of Wind Energy Conversion System and1 kW of Silicon Polychrystaline Solar Panel)

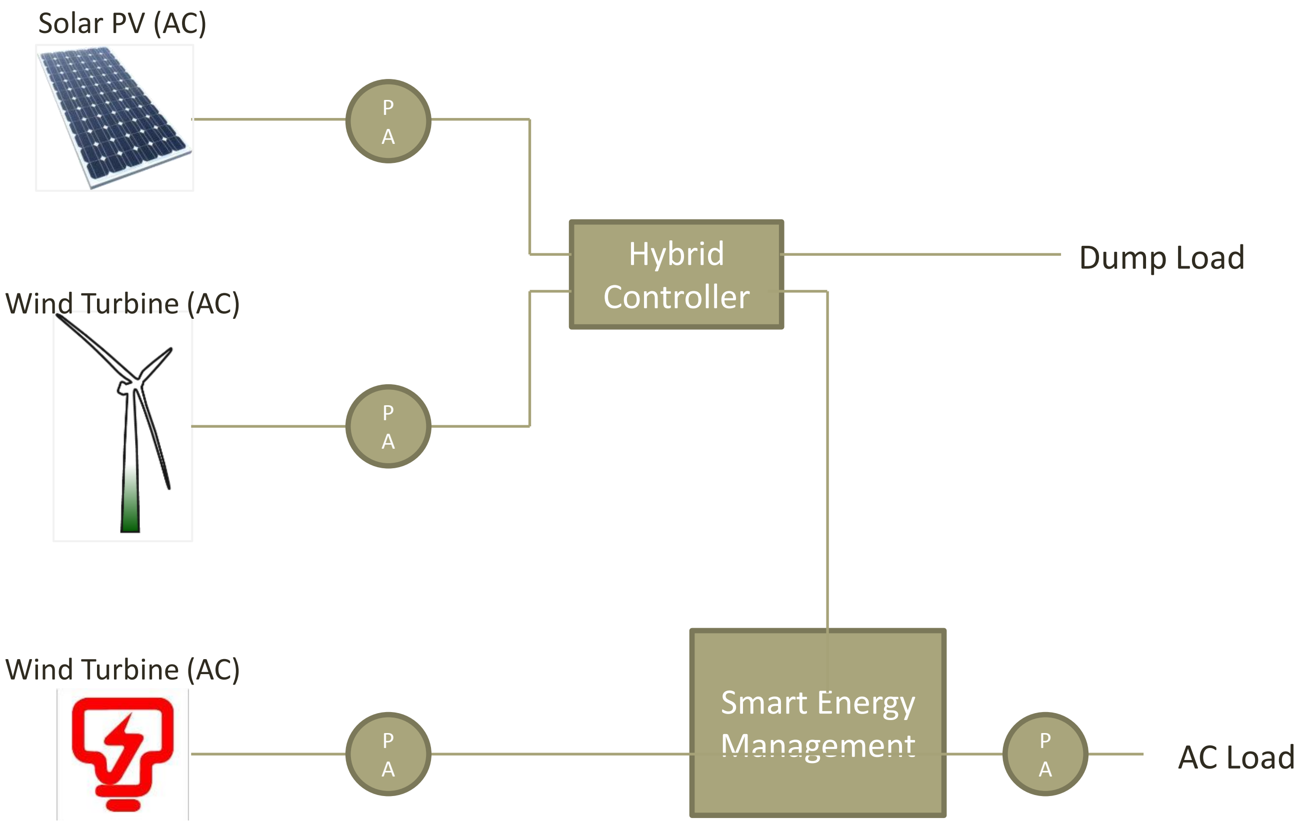

Energy from solar
Solar Photovoltaic Panels
Smart Energy Management and Control System
Electricity
EKOMAR
Wind Turbine
Energy from wind



DC
DC
Solar Photovoltaic Panels
DC
AC
Wind Turbine
Hybrid Controller
DC Load
Dump Load
AC
DC
AC Load

Parameters	Status
Weather Sensors	
Solar Radiation (W/m^2)	Installed & collecting data
Wind speed (m/s)	Installed & collecting data
Wind Direction	Installed & collecting data
Humidity (%)	Installed & collecting data
Temperature (^{o}C)	Installed & collecting data
Energy Generation / Supply	
Voltage (V)	Type of sensor is to be determined
Current (A)	Type of sensor is to be determined
Energy (W.hr)	Type of sensor is to be determined
Energy Consumption	
Energy (W.hr)	Type of sensor is to be determined

Form all source: solar PV, wind turbine & TNB (individually)



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…. (4) METHODOLOGY

Data collection

Method:

Data for the year of 2004-2014 from DOE (52 stations) & MET (1 station)

Expectation: data analysis

Univariate model selection

Method:

R^2, AIC and RMSE to select the best distribution for each station.

- Wind speed: Weibull, Gama, Gama Inverse, Burr
- Wind direction: FmVM

Expectation: one univariate distribution for each station

Bivariate model selection

Method:

R^2 and RMSE to select the best distribution for each station.

- Weibull-FmVM
- Gama-FmVM
- Gama Inverse-FmVM
- Burr-FmVM

Expectation: one bivariate distribution for each station

Wind power analysis

Method:

$$\bar{P} = \int_{v\min}^{v\max} \frac{1}{2} \rho f_v(v) v^3 dv$$

$$\bar{P} = \frac{1}{2} \int_{0}^{2\pi} \int_{v\min}^{v\max} \rho v^3 f_{v,\theta}(v,\theta) dv d\theta$$

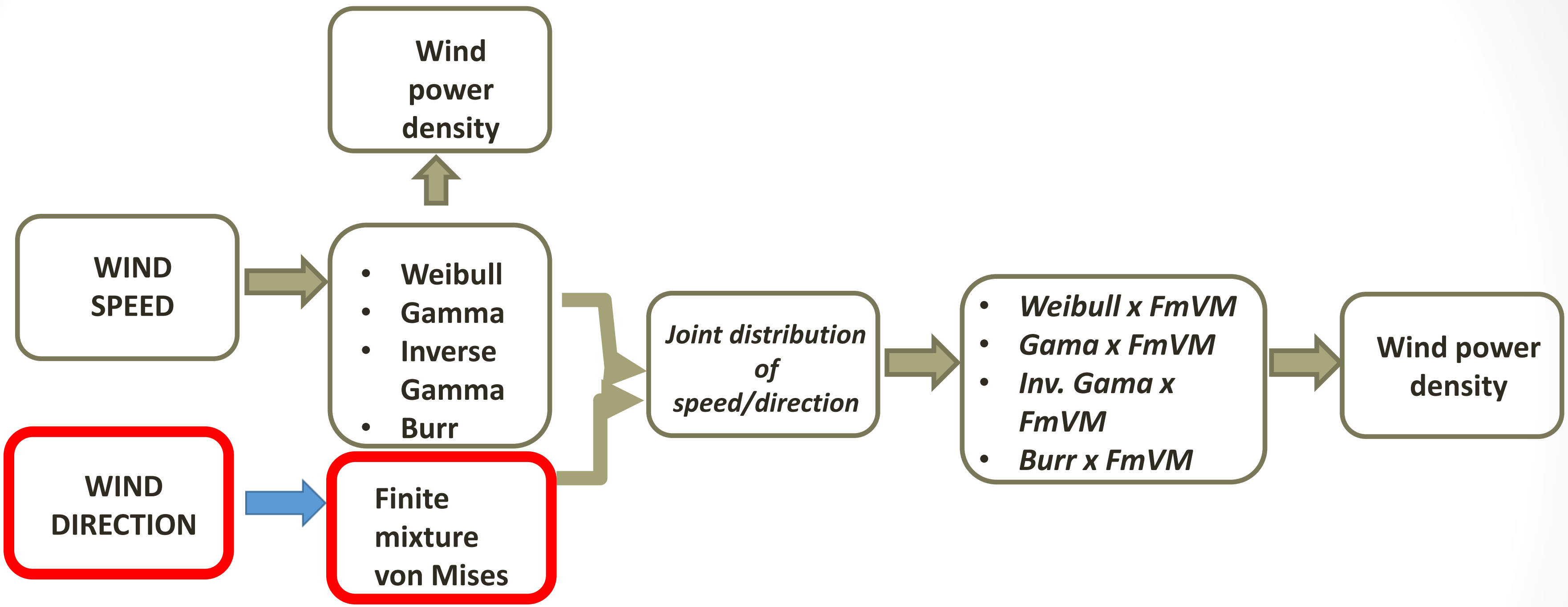
Expectation: Determine station which the highest mean wind power density as the potential station

Wind power comparison

Method:

Mean wind power density (W/m^2) for each univariate and bivariate distribution in each station

Expectation: Bivariate distribution might gives higher (W/m^2)


Wind power density
WIND SPEED
• Weibull
• Gamma
• Inverse Gamma
• Burr
WIND DIRECTION
Finite mixture von Mises
Joint distribution of speed/direction
• Weibull x FmVM
• Gama x FmVM
• Inv. Gama x FmVM
• Burr x FmVM
Wind power density

Finite mixture Von Mises (FmVM)

$$f_{\theta}(\theta) = \sum_{j=1}^{H} \frac{\omega_j}{2\pi I_0(\kappa_j)} \exp(\kappa_j \cos(\theta - \mu_j))$$

For:

$$0 \le \theta < 2\pi, \quad 0 \le \mu_j < 2\pi, \quad \kappa_j \ge 0,$$

$$0 \le \omega_j < 1 \quad \text{for } j = 1,2,\ldots\ldots H \quad \text{and} \sum_{j=1}^{H} \omega_j = 1$$

$$I_0(\kappa_j) = \frac{1}{\sqrt{2\pi}} \int_0^{2\pi} \exp(\kappa_j \cos\theta)\, d\theta$$

$$= \sum_{\kappa=0}^{\infty} \frac{1}{(\kappa!)^2} \left(\frac{\kappa_j}{2}\right)^{2\theta}$$

- There are numerous circular probability distributions such as Uniform, Wrapped Normal (WN), Wrapped Cauchy (WC) and General Wrapped Stable (WS) distribution

- ***Finite mixture Von Mises (FmVM)***

is chosen basically depend on the nature of data which is circular with multi modal that best explain with this type of probability distribution

- The importance of the study of wind direction is to identify dominant direction of wind in order to optimize the wind capture. The significant effect of wind direction in producing a maximum wind power can be distinguish.

Probability distribution of joint wind speed and direction

$$f_{v,\theta}(v,\theta) = 2\pi g(\zeta) f_v(v) f_\theta(\theta);$$

$$-\infty \le v < \infty \quad 0 \le \theta < 2\pi$$

where $\zeta = 2\pi[F_v(v) - F_\theta(\theta)]$

- that originally suggested by Johnson and Wehrly (1978)

Distribution

Weibull Distribution

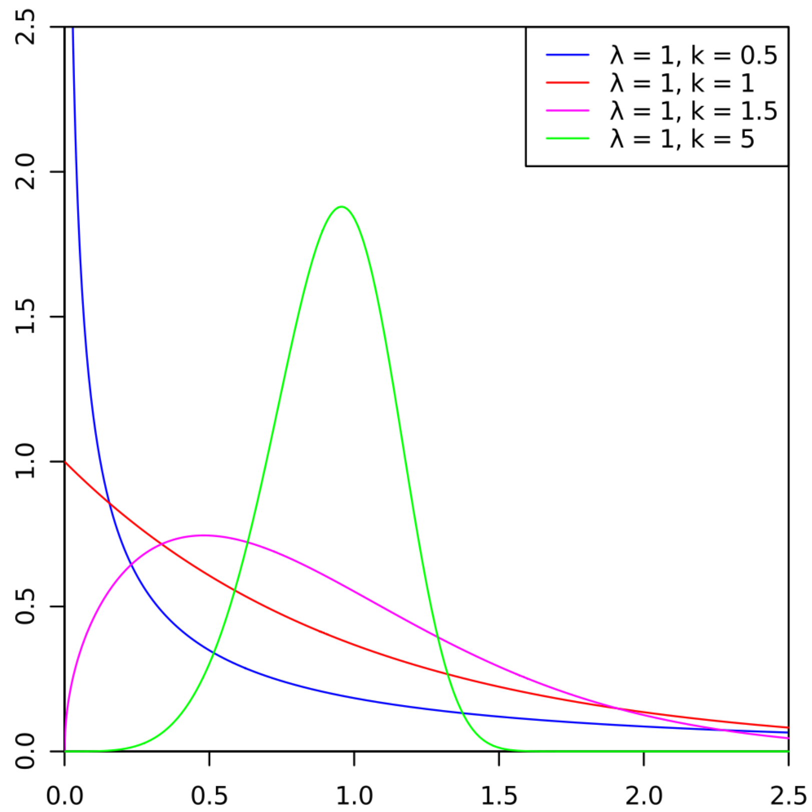
The probability density function of a Weibull random variable is :

$$f(x;\lambda,k) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k} & x \geq 0, \\ 0 & x < 0, \end{cases}$$

where k > 0 is the shape parameter and λ > 0 is the scale parameter of the distribution).

The Weibull distribution is widely used in reliability and life data analysis due to its versatility. Depending on the values of the parameters, the Weibull distribution can be used to model a variety of life behaviors.

Probability density function



❖ *Gamma distribution*

$$f(x;\alpha,\beta) = \frac{1}{\Gamma(\alpha)} x^{\alpha-1} exp\left(-\frac{x}{\beta}\right)$$

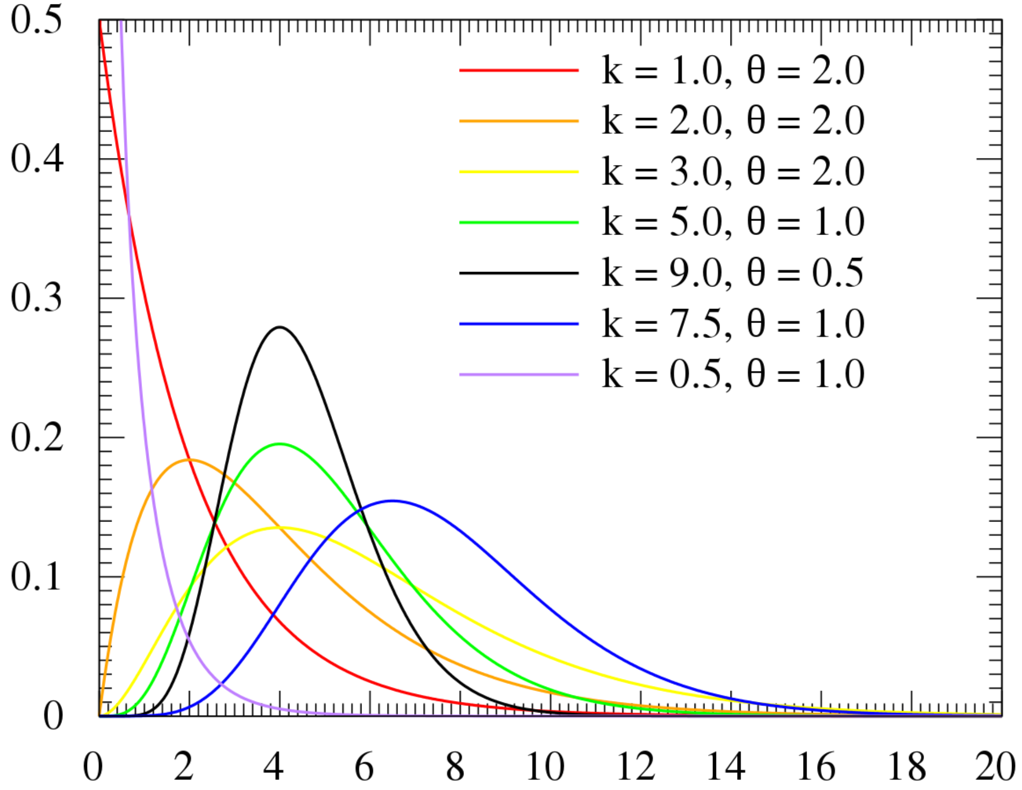
represents the probability density function (pdf) for Gama distribution where α = shape parameter, β = scale parameter; $\Gamma(x)$ = Gama function. As for α and β, the value can be estimated by using:

$$\hat{\beta} = \frac{\bar{x}}{\alpha}$$

$$\ln(\hat{\alpha}) - \Psi(\hat{\alpha}) = ln\left(\frac{1}{n}\sum_{i=1}^{n} x_i\right) - \frac{1}{n}\sum_{i=1}^{n} \ln x_i$$

The Gamma distribution is widely used in engineering, science, and business, to model continuous variables that are always positive and have skewed distributions. The Gamma distribution can be useful for any variable which is always positive, such as cohesion or shear strength for example.

Probability density plots of gamma distributions



❖ *Inverse-gamma distribution*

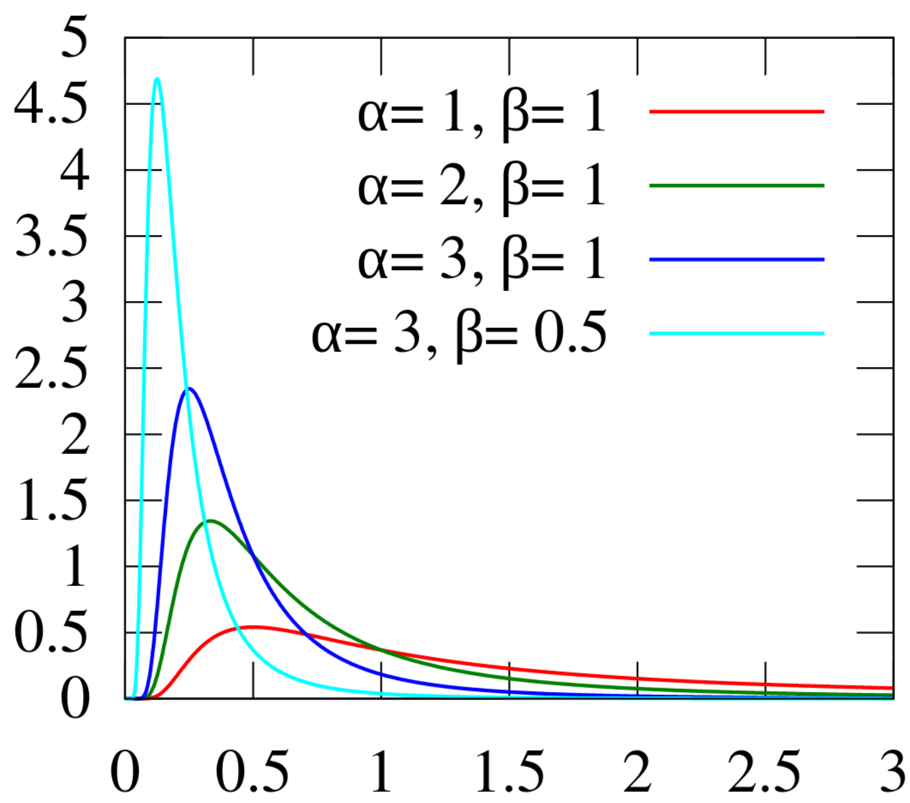
The inverse gamma distribution's probability density function is defined over the support $x > 0$

$$f(x;\alpha,\beta) = \frac{\beta^\alpha}{\Gamma(\alpha)}(1/x)^{\alpha+1}\exp(-\beta/x)$$

with shape parameter α and scale parameter β. Here $\tau(.)$ denotes the gamma function.

The inverse gamma distribution (also called the inverted gamma distribution) is the reciprocal of the gamma distribution. It has two positive parameters (α and β): The shape parameter α controls the height and the scale parameter β controls the spread.

Inverse-gamma distributions



❖ *Burr distribution*

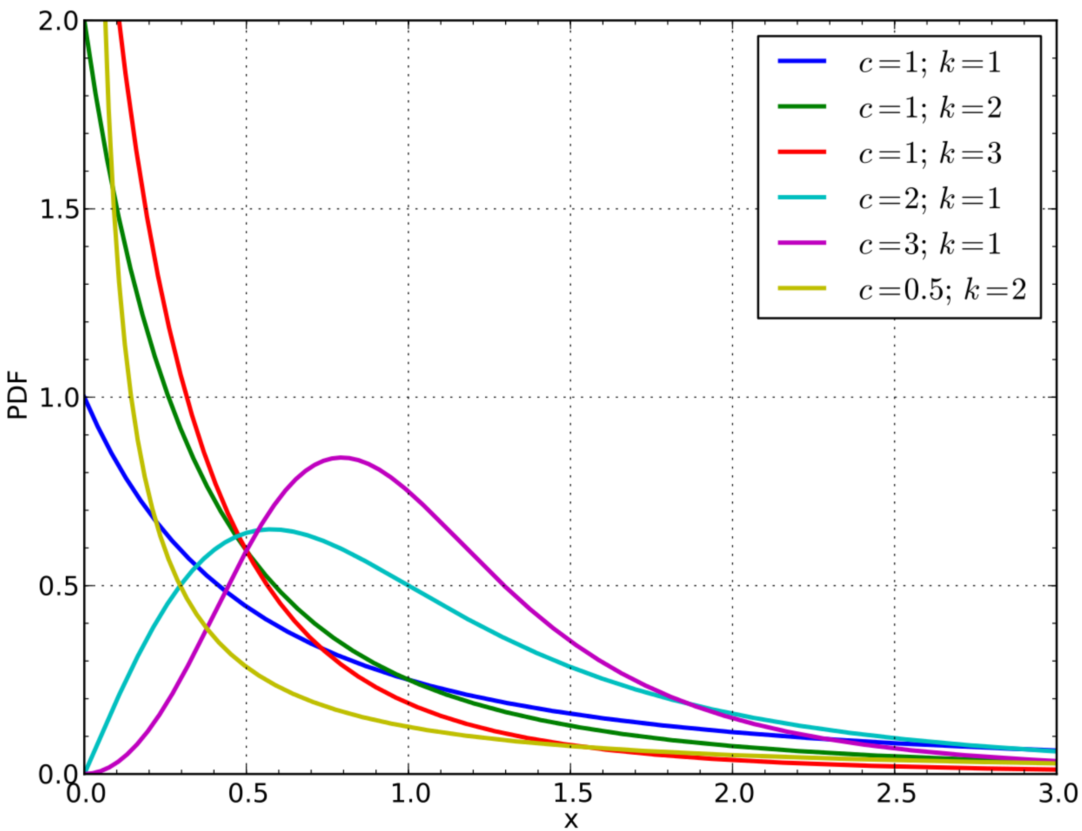
The Burr (Type XII) distribution has probability density function :

$$f(x; c, k) = ck \frac{x^{c-1}}{(1 + x^c)^{k+1}}$$

$$f(x; c, k, \lambda) = \frac{ck}{\lambda} \left(\frac{x}{\lambda}\right)^{c-1} \left[1 + \left(\frac{x}{\lambda}\right)^{c}\right]^{-k-1}$$

The Burr distribution (sometimes called the Burr Type XII distribution or Singh–Maddala distribution) is a unimodal family of distributions with a wide variety of shapes. ... The Burr distribution Type XII is defined by the following parameters: c and k: shape parameters.

Probability density function of Burr distribution



Wind Power Analysis

The wind power density is the number of watts of electrical energy produced per square meter of air space (W/m²).

The general formula for wind power is:

$$P = \frac{1}{2}\rho_k V^3$$

But for calculating the probability of wind power density at different wind speed and direction will be:

$$P(v,\theta) = \frac{1}{2}\rho f_{v,\theta}(v,\theta)v^3$$

with assuming that air density and wind speed are not correlated and that the air density is constant

....(5) RESULT & DISCUSSION

❖ *UNIVARIATE (WIND SPEED)*

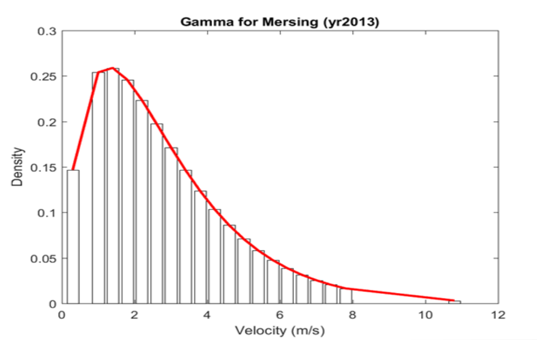
Stesen	Weibull	Gama	Gama Songsang	Burr
	R^2	R^2	R^2	R^2
A05	**0.996899**	0.986178	0.920197	0.881672
E01	0.977579	**0.995016**	0.934345	0.924682
G03	0.94559	**0.955917**	0.894872	0.918076
I06	**0.998042**	0.940832	0.891178	0.961566
K05	0.96213	0.907459	0.94831	**0.986514**
L01	0.964101	0.907408	0.933424	**0.985029**
N02	0.946792	0.948063	0.942363	**0.98175**

Stesen	Weibull	Gama	Gama Songsang	Burr
	AIC	AIC	AIC	AIC
A05	**158774**	188916	185724	184211
E01	455027	**429242**	442943	451432
G03	439831	**411129**	419161	429213
I06	438610	**405350**	440806	442829
K05	422480	418918	433996	**407494**
L01	423033	453190	458482	**403577**
N02	433102	411995	446722	**411531**

Weibull distribution is best for representing wind speed data in Mersing.

Stesen	Weibull	Gama	Gama Songsang	Burr
	RMSE	RMSE	RMSE	RMSE
A05	**0.026396**	0.0339182	0.0449569	0.026854
E01	0.0513391	**0.047676**	0.0545139	0.0502155
G03	0.0102681	**0.005129**	0.0365057	0.0435398
I06	**0.018805**	0.0213129	0.0387335	0.0522882
K05	0.0433222	0.0472967	0.0467208	**0.021613**
L01	**0.0123**	0.0260848	0.0440105	0.0542975
N02	0.0519422	0.056503	0.0522876	**0.024238**

NOTE:
A05 Mersing
E01 Bkt Rambai
G03 USM, P.Pinang
I06 Kangar
K05 Sandakan
L01 Kuching
N02 Kuala Terengganu



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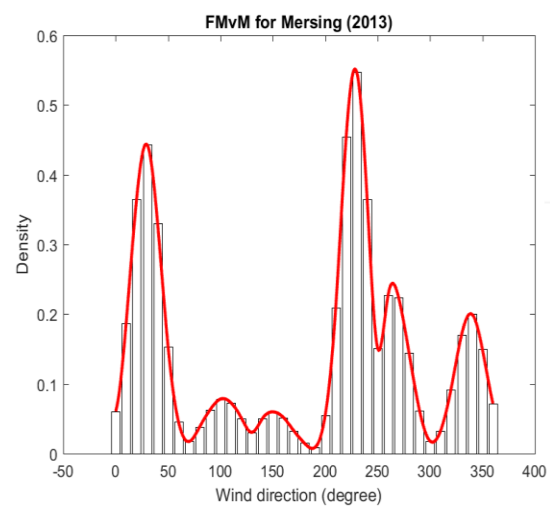
❖ *UNIVARIATE (WIND DIRECTION)*

- R^2 dan AIC for each FmVM model component for Mersing

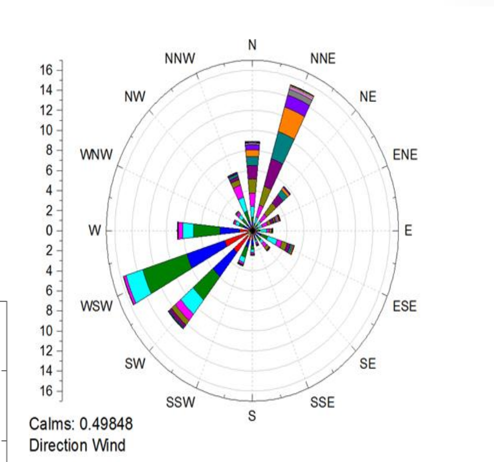
H	1	2	3	4	5	6	7	8
R^2	0.91200	0.94413	0.95687	0.97542	0.98784	***0.99827***	0.99852	0.99872
AIC	35482.6	28619.23	28394.1	28369.15	28274.19	***28212.13***	28211.95	28211.7

- PDF estimation for FmVM (H=6)

$$
\begin{aligned}
f_\theta(\theta) = {} & \frac{0.276666}{2\pi I_0(12.25072)} \exp\left(12.25072 \cos(\theta - \mu_1)\right) + \\
& \frac{0.065021}{2\pi I_0(14.95576)} \exp\left(14.95576 \cos(\theta - \mu_2)\right) + \\
& \frac{0.046866}{2\pi I_0(10.62431)} \exp\left(10.62431 \cos(\theta - \mu_3)\right) + \\
& \frac{0.317662}{2\pi I_0(19.55538)} \exp\left(19.55538 \cos(\theta - \mu_4)\right) + \\
& \frac{0.16176}{2\pi I_0(14.04048)} \exp\left(14.04048 \cos(\theta - \mu_2)\right) + \\
& \frac{0.132026}{2\pi I_0(14.95576)} \exp\left(14.95576 \cos(\theta - \mu_2)\right)
\end{aligned}
$$



- FmVM (H=6) is proven with six peaks in the graf



- Dominant direction for Mersing are southwest and northeast

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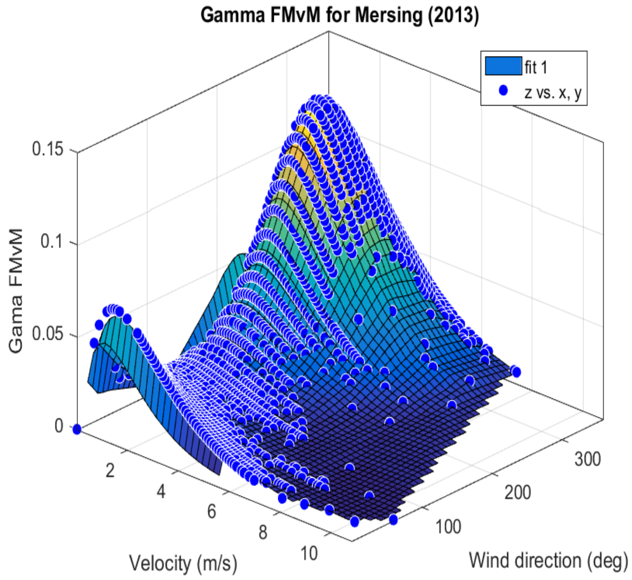
- *BIVARIATE (WIND SPEED AND WIND DIRECTION)*

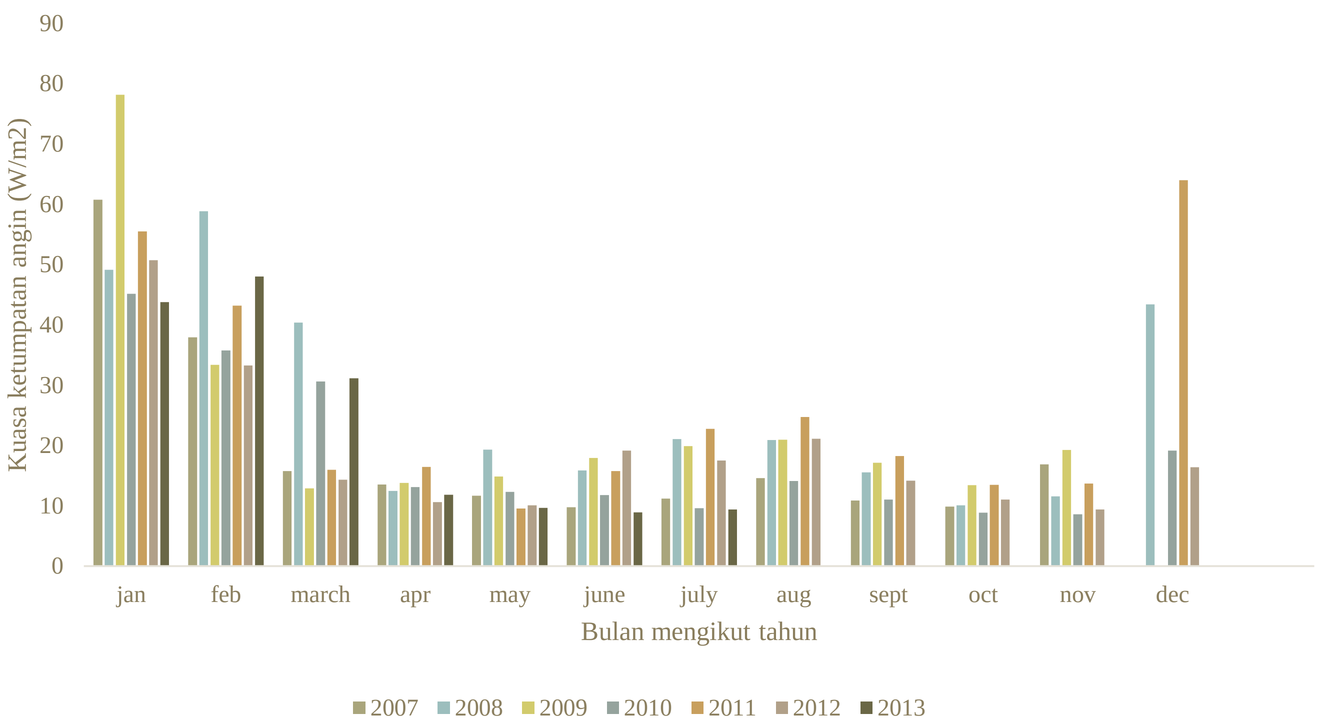
R^2 and RMSE value for each distribution for Mersing

	Weibull-FMvM	Gama-FMvM	Inverse Gama-FMvM	Burr-FMvM
R^2	0.795418	**0.999820**	0.992452	0.963967
RMSE	0.652964	**0.217915**	0.984396	0.376102



Wind Power Density (W/m^2)

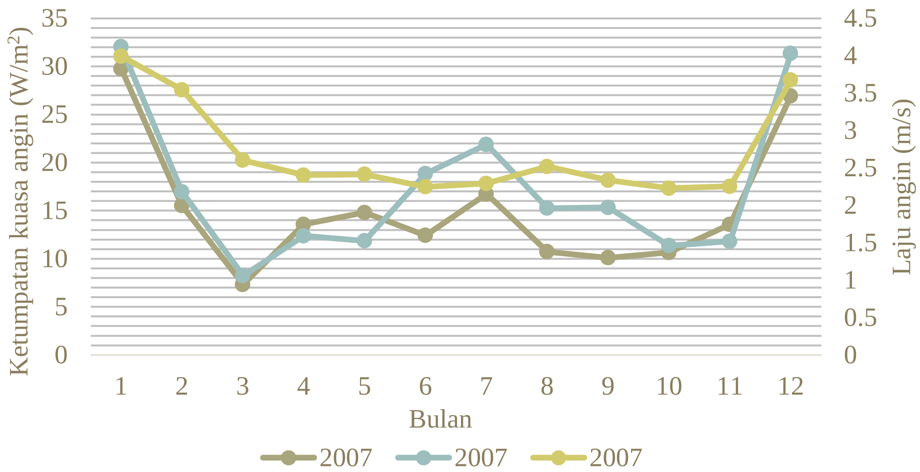
Univariate distribution - Mersing (A05)

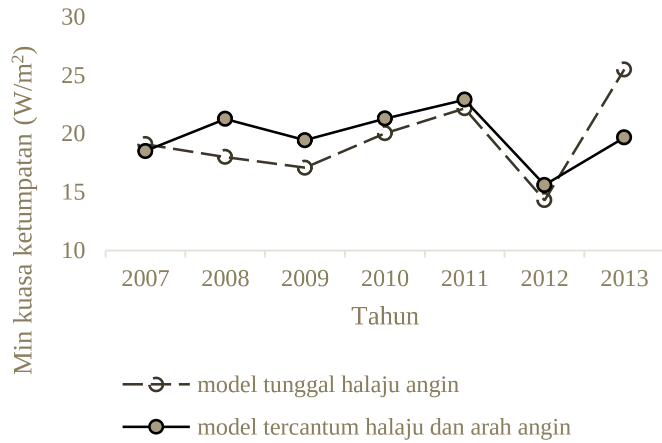


The highest Mean wind power density (W/m^2) is between Dec-March each year because of the effect of North East monsoon.

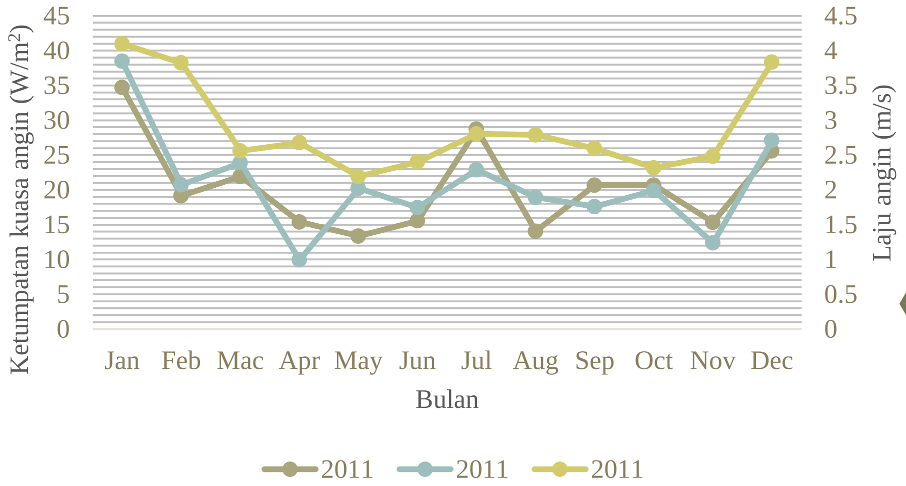
❖ *Wind Power Density (W/m²)*

Bivarite Distribution –Mersing Station (A05)





Yearly mean wind power density



Monthly wind power density comparison for the year of 2007 and 2011

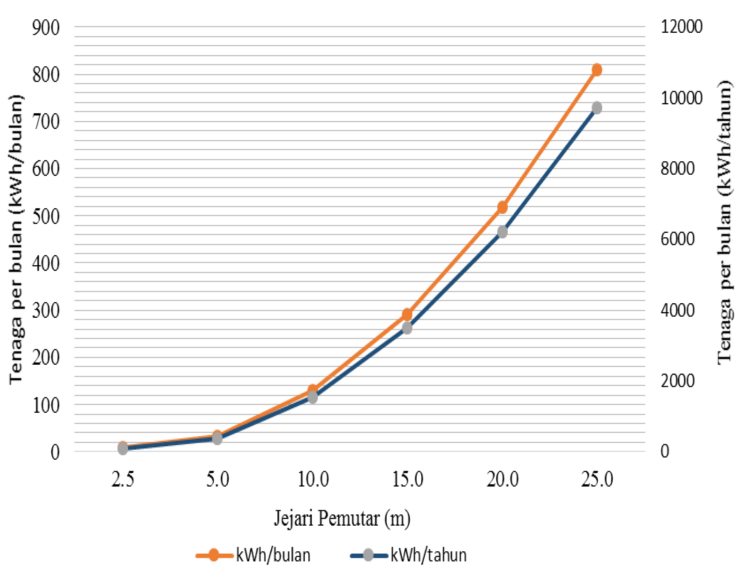
Mean Wind Power Density (W/m^2)

Kod	Negeri	Min kuasa Univariat (W/m2)	Min kuasa Bivariat (W/m2)	Kod	Negeri	Min kuasa Univariat (W/m2)	Min kuasa Bivariat (W/m2)
A01	Johor	2.865371	3.300833	I05	Perak	2.454603	3.007613
A02	Johor	1.717685	2.482579	I06	Perlis	12.118465	13.160617
A03	Johor	3.724170	4.391232	J01	Putrajaya	4.275321	4.973804
A04	Johor	2.830018	3.058678	K01	Sabah	1.693251	2.009030
B01	K.Lumpur	2.076809	2.698878	K02	Sabah	4.924081	3.293787
B02	K.Lumpur	2.183713	3.004837	K03	Sabah	2.132249	3.746043
C01	Kedah	3.536048	4.142882	K04	Sabah	1.819608	2.713090
C02	Kedah	2.176932	2.203653	K05	Sabah	2.154176	3.035266
C03	Kedah	3.454630	3.929410	L01	Sarawak	4.159495	4.360648
D01	Kelantan	3.132914	3.701892	L02	Sarawak	2.485864	2.911435
D02	Kelantan	2.592936	3.201550	L03	Sarawak	8.789561	9.913950
E01	Melaka	6.435791	7.198625	L04	Sarawak	1.816859	3.129930
E02	Melaka	4.686600	4.943361	L05	Sarawak	1.527487	2.339029
F01	N.Sembilan	7.803786	8.422670	L06	Sarawak	1.452409	1.994502
F02	N.Sembilan	2.120636	2.876307	L07	Sarawak	2.006543	2.122130
F03	N.Sembilan	4.505838	5.718471	L08	Sarawak	1.042157	1.634772
G01	P.Pinang	1.626808	2.617868	L09	Sarawak	1.959992	1.065011
G02	P.Pinang	2.279498	2.438833	L10	Sarawak	2.987399	3.884843
G03	P.Pinang	2.521373	3.481835	M01	Selangor	2.501364	3.506558
H01	Pahang	1.100129	1.485416	M02	Selangor	1.757678	2.712422
H02	Pahang	2.899468	3.296379	M03	Selangor	2.292602	3.175162
H03	Pahang	3.334175	3.945696	M04	Selangor	5.875507	5.148712
I01	Perak	4.281090	4.377591	M05	Selangor	2.065338	2.866829
I02	Perak	2.005725	2.873321	N01	Terengganu	2.674440	2.735186
I03	Perak	1.193083	1.751586	N02	Terengganu	2.682187	3.118565
I04	Perak	2.532040	3.464673	N03	Terengganu	1.913448	2.087685

- Mersing (A05) - 19.4510 W/m^2 (univariate) and 19.8092 W/m^2 (bivariate).
- Most of the stations show increment (W/m^2) in the bivariate compared to univariate.
- Except for ILP Miri (L09) and SM Sains K.Selangor (M04) show decrement for about (-0.895) and (-0.727) respectively.
- This shows that, the increment in (W/m^2) in bivariate is not affected by the equation, but by the data of wind speed and direction in each station.

Estimation of electric energy generated by turbine

Jejari pemutar (m)	Luas litupan turbin (m^2)	Kuasa angin kasar (kW)	Kuasa elektrik terhasil (kW)	Tenaga (bulan)	
				KJoules	kWh
2.5	19.63	0.449478318	0.089895664	29126.19	8.090674
5.0	78.54	1.798371221	0.359674244	116534.5	32.37094
10.0	314.16	7.193484883	1.438696977	466137.8	129.4838
15.0	706.86	16.18534099	3.237068197	1048810	291.3385
20.0	1,256.64	28.77393953	5.754787907	1864551	517.9351
25.0	1,963.50	44.95928052	8.991856104	2913361	809.2735



Estimation of electric energy generated by turbine

	WPD (W/m²)		kWh/m2/bulan		kwh/m²/thn	
	univ	biv	univ	biv	univ	biv
2007	19.091535	18.511455	13.743996	13.326396	167.24184	162.16034
2008	18.003251	21.262403	12.96054	15.306804	157.70848	186.25865
2009	17.086919	19.437374	12.300873	13.992966	149.68141	170.2714
2010	20.029275	21.291334	14.419075	15.327631	175.45645	186.51208
2011	22.16106	22.897519	15.953747	16.483924	194.13089	200.58227
2012	14.296003	15.600313	10.291693	11.230666	125.23299	136.65875
2013	25.489205	19.664268	18.349679	14.156306	223.28544	172.25899

The estimation is based on the mean wind speed of 2.86 m/s with the mean wind power density of 22.89752 (W/m²), for Mersing (2011).

…. (6) CONCLUSION

- ***Finite mixture of Von Mises (FmVM)*** is the best distribution that explain wind direction data in Malaysia

- ***Bivariate Gamma – FmVM and Inverse Gamma – FmVM*** distribution are the distribution that suit to model the wind data in Malaysia

- Not all stations give the same wind speed distribution for both univariate and bivariate model. For example, Mersing (univariate = Weibull and bivariate = Gamma - FmVM).

- 96.23% stations show increment in mean wind power density (W/m^2) for bivariate compared to univariate model which 1.8% increment in (W/m^2) in Mersing
- Spin radius=10 m will generates 129.4838 kWh monthly. Eventhough it is only 37% domestic energy consumption (350 kWh monthly), but it can be an alternative to energy sources
- Small scale wind energy system may be appropriate in Malaysia based on the lower mean speed average throughout the year (2.15-2.39 m/s) which help domestic users in remote areas

THANK YOU