Wind power planning for isolated systems *- impacts of diurnal variability*

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Outline

1) Introduction to wind resource dynamics - motivation
2) Methodology & validation
3) Wind power planning for Faial and Pico
4) Discussion point & future work

Faial wind park.

Pico wind park.

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Wind resource dynamics

Synthetic hourly wind speed data for energy systems modelling

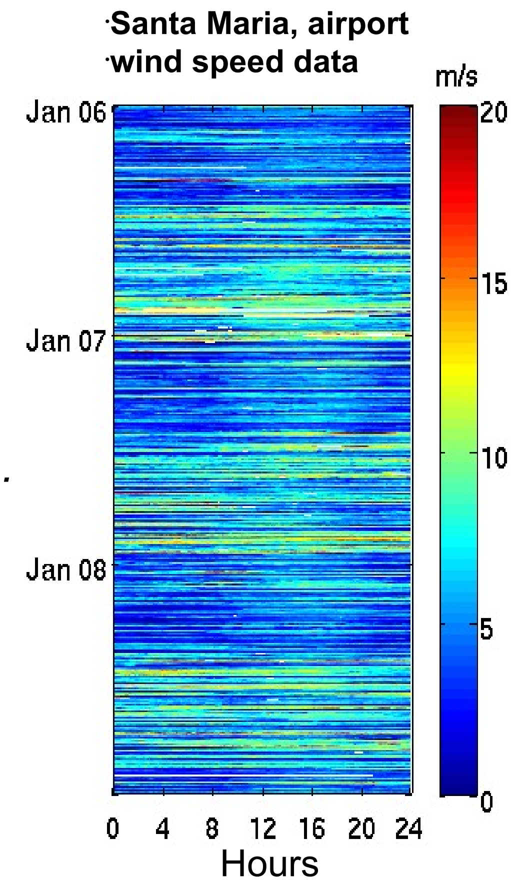
Terceira wind park.

For..

- optimized wind power dimensioning
- surplus & shortage assessment
- storage requirements estimation
- ...

..it is critical to characterise
the wind resource dynamics including..

1) Seasonality
2) Passing weather systems:
   day to day variability
3) Diurnality
4) Hour-to-hour variability



Data source: IM-DRA, 2010.

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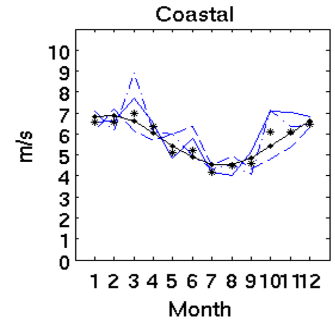
Methodology

Synthetic hourly wind speed data for energy systems modelling

1) Seasonality

Reference ***daily mean*** wind speed:

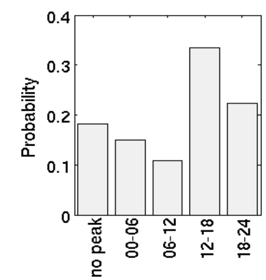
$$\mu_d = a_1 \sin(\omega d + \varphi) + a_2$$



2) Passing weather systems – day to day variability

Variation in daily mean wind speed (AR-model):

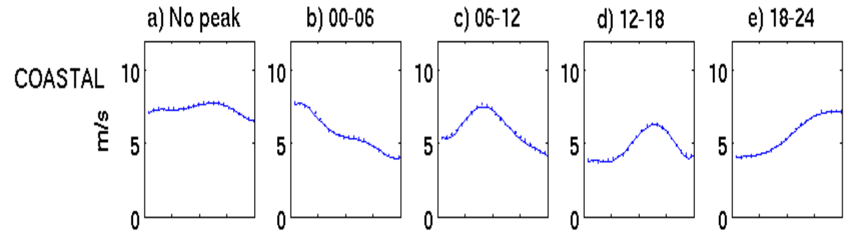
$$\Delta\mu_t = \omega_1 \mu_{t-1} + \omega_2 \mu_{t-2} + \ldots + \omega_n \mu_{t-n} + \varepsilon$$



3) **Diurnality**

Reference ***hourly mean*** wind speed:

$$\mu_{d,h} = a_4 h^4 + a_3 h^3 + \ldots + a_1$$



4) Hour-to-hour variability

Variation in hourly mean wind speed (AR-model):

$$\Delta\mu_h = \omega_1 \mu_{h-1} + \omega_2 \mu_{h-2} + \varepsilon$$

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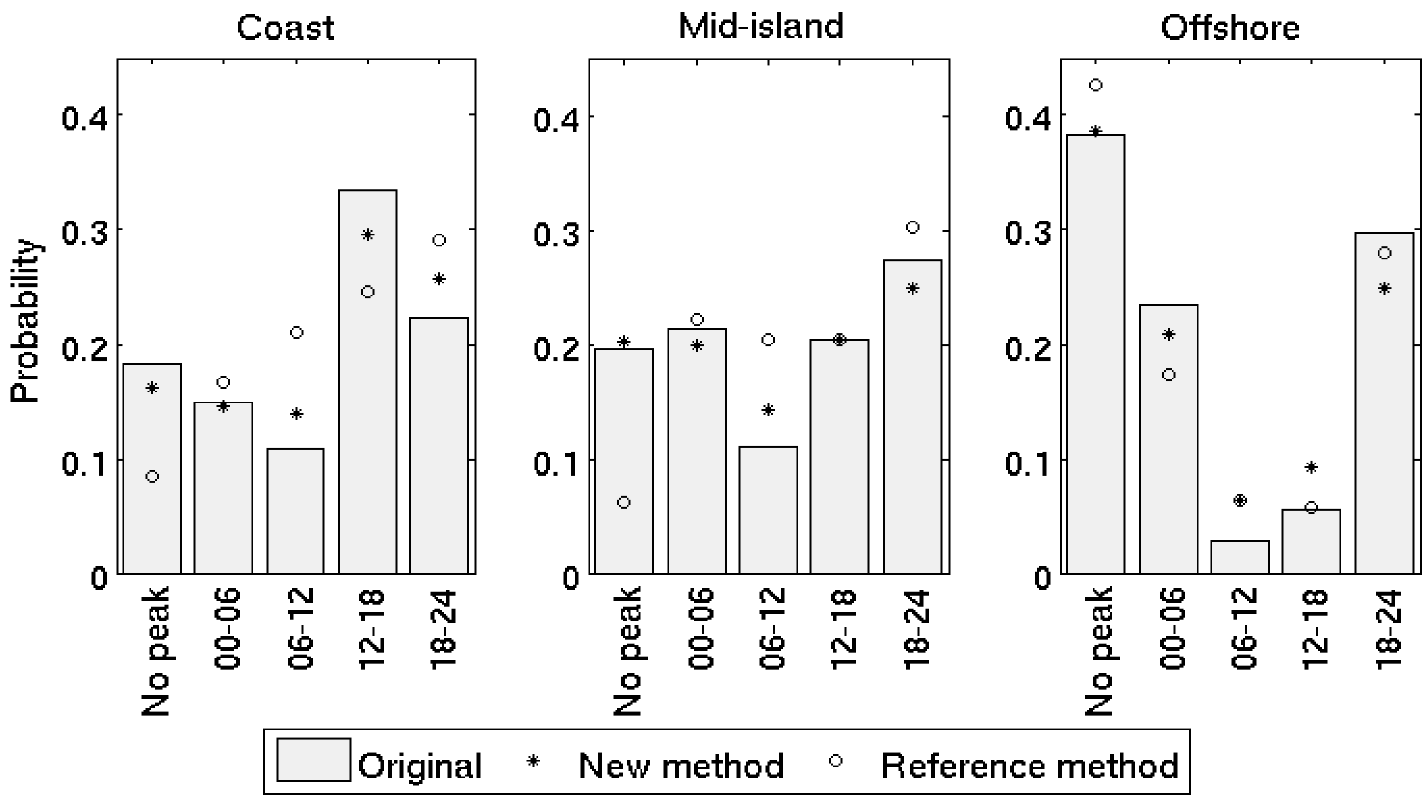
Validation



This results in a ***more accurate estimation*** of ***resource vs. demand dynamics*** from annual to hourly temporal scales.

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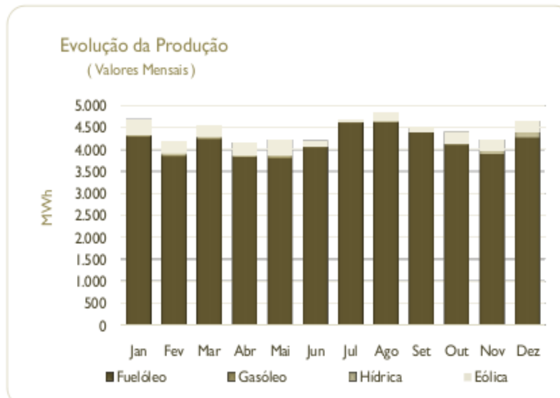
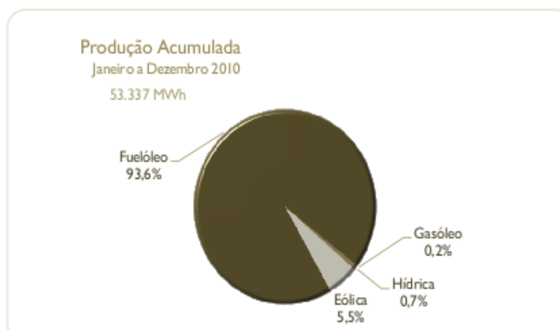
Faial & Pico case study

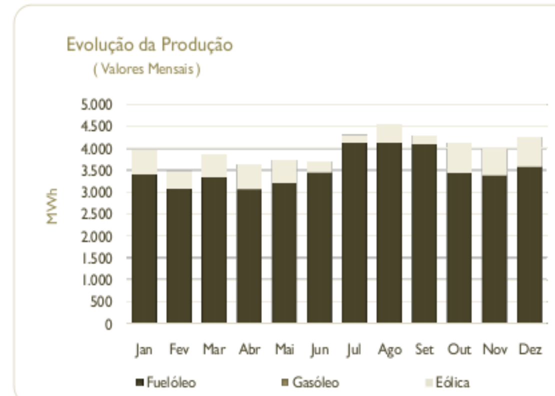
Energy supply 2010

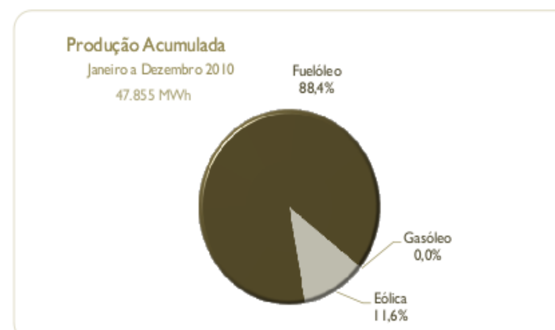
Faial





Pico





Source: EDA, 2010

Table 1: Installed capacities.

kW	Faial	Pico
Fuel oil	22 650	16 100
Hydro	320	
Wind	1 800	1 800

Source: INESC, 2004 and EDA data, 2010

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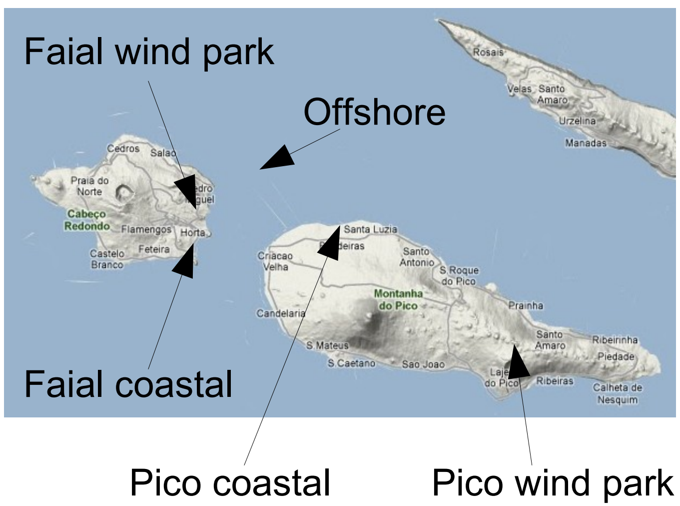
Faial & Pico wind resource characteristics

Day type distribution matrices for Faial and Pico at
- Coastal,
- Mid-island and
- Offshore locations.



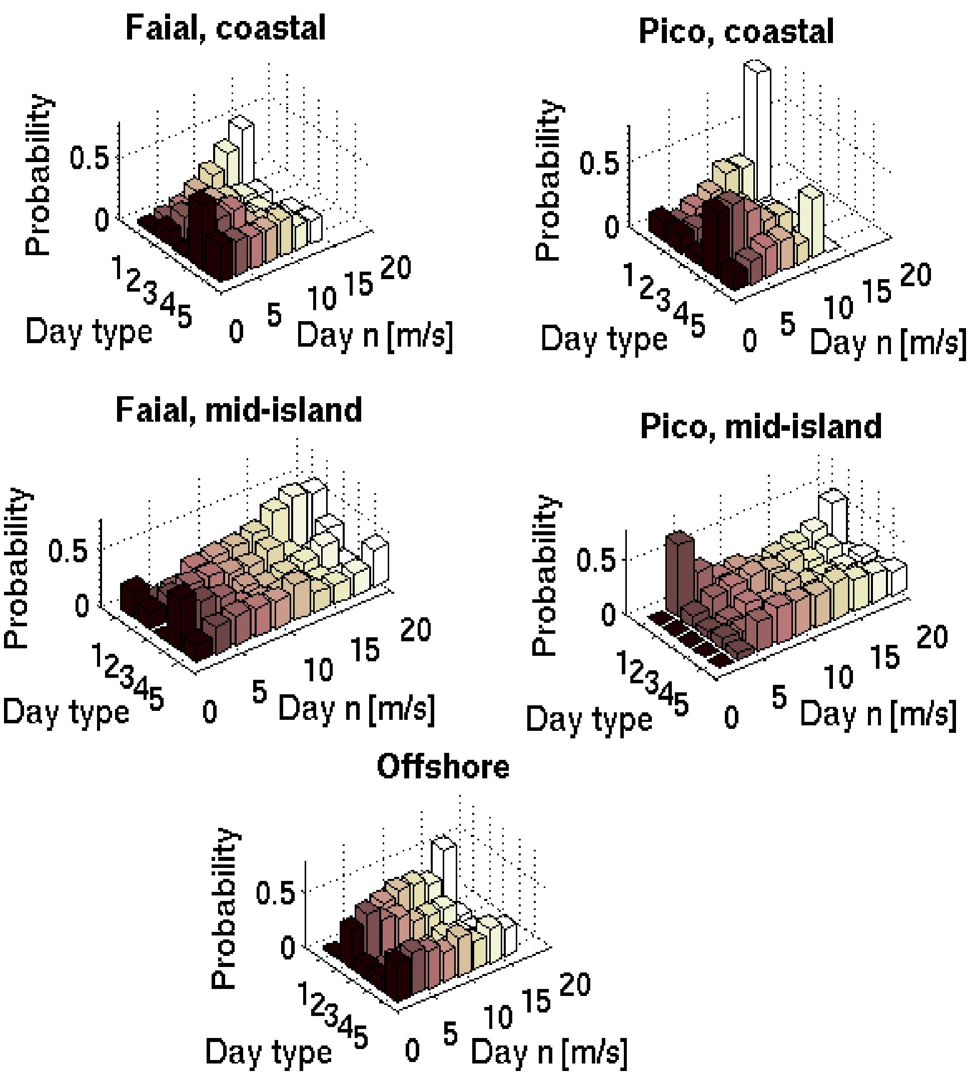


Table 2: Annual mean wind speed.

m/s	Mid-island Hub height	Coastal 10m	Offshore 10m
FAIAL	7.5	5.1	7.1
PICO	10.1	3.8	7.1

Faial & Pico case study

Supply and demand scenarios

Demand:

1) 2010 reference case
2) 2018 at 1% growth rate
3) 2018 at 3% growth rate

Table 3: Assumed demand scenarios.

GWh	Faial	Pico	Faial & Pico
2010	54	39	93
2018 (1%)	58	43	101
2018 (3%)	64	50	118

Table 4: Applied supply side scenarios.

kW	Hydro	Wind existing	Wind **mid-island**	Wind **coastal**	Wind **offshore**
FAIAL	320	1800	0 330 660 990 1980 3300	0 330 660 990 1980 3300	0 (2000)
PICO	0	1800	0 330 660 1320 1980 3300	0 330 660 1320 1980 3300	0 (2000)
FAIAL & PICO	320	F: 1800 P: 1800	F: 0 990 1980 3300 P: 0 660 1320 3300	F: 0 990 1980 3300 P: 0 660 1320 3300	0 2000

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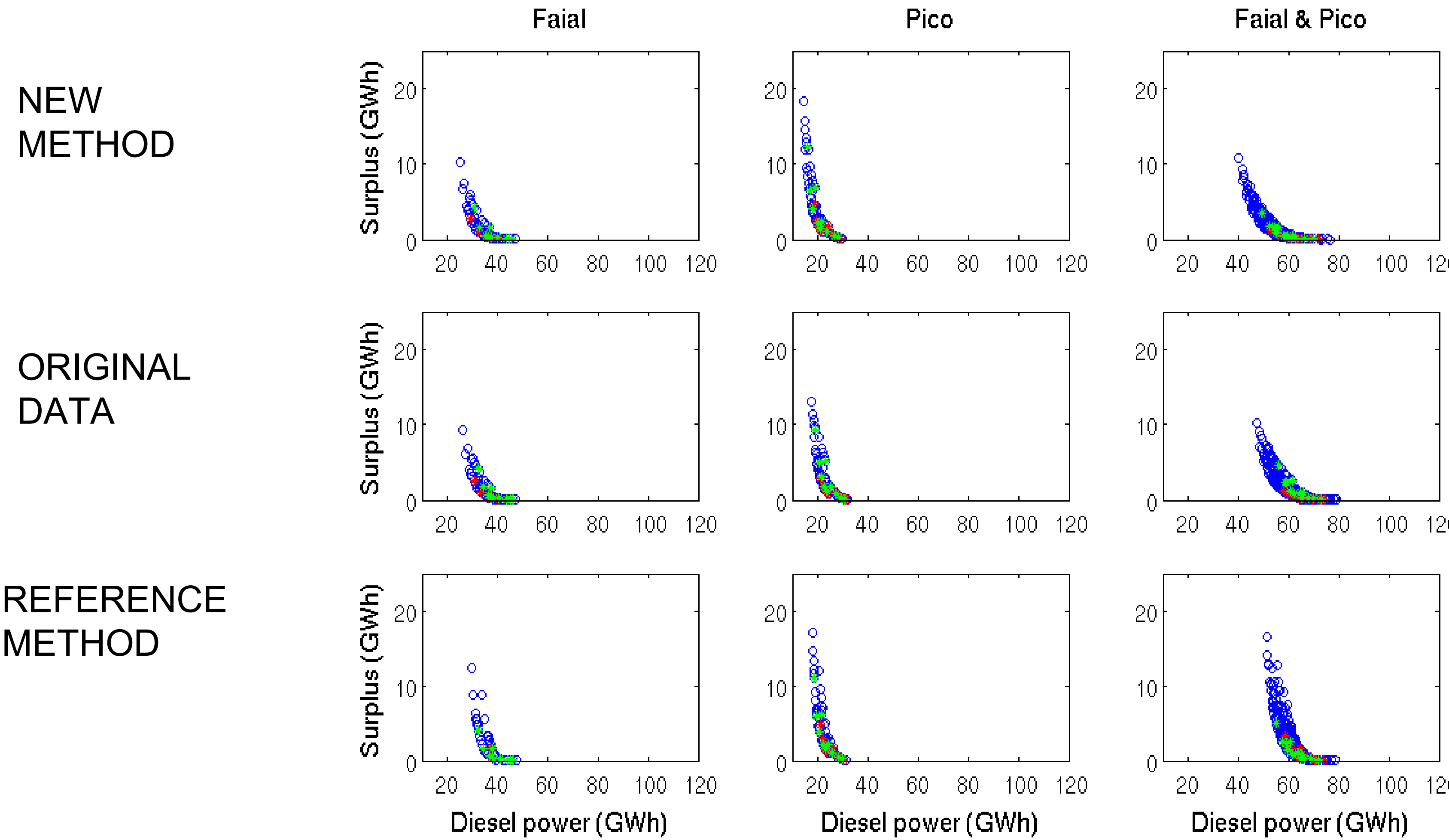
Methods' comparison – validation of new method



<u>Additional wind</u>

Mid-island: 0 kW **Coastal: 0 kW**

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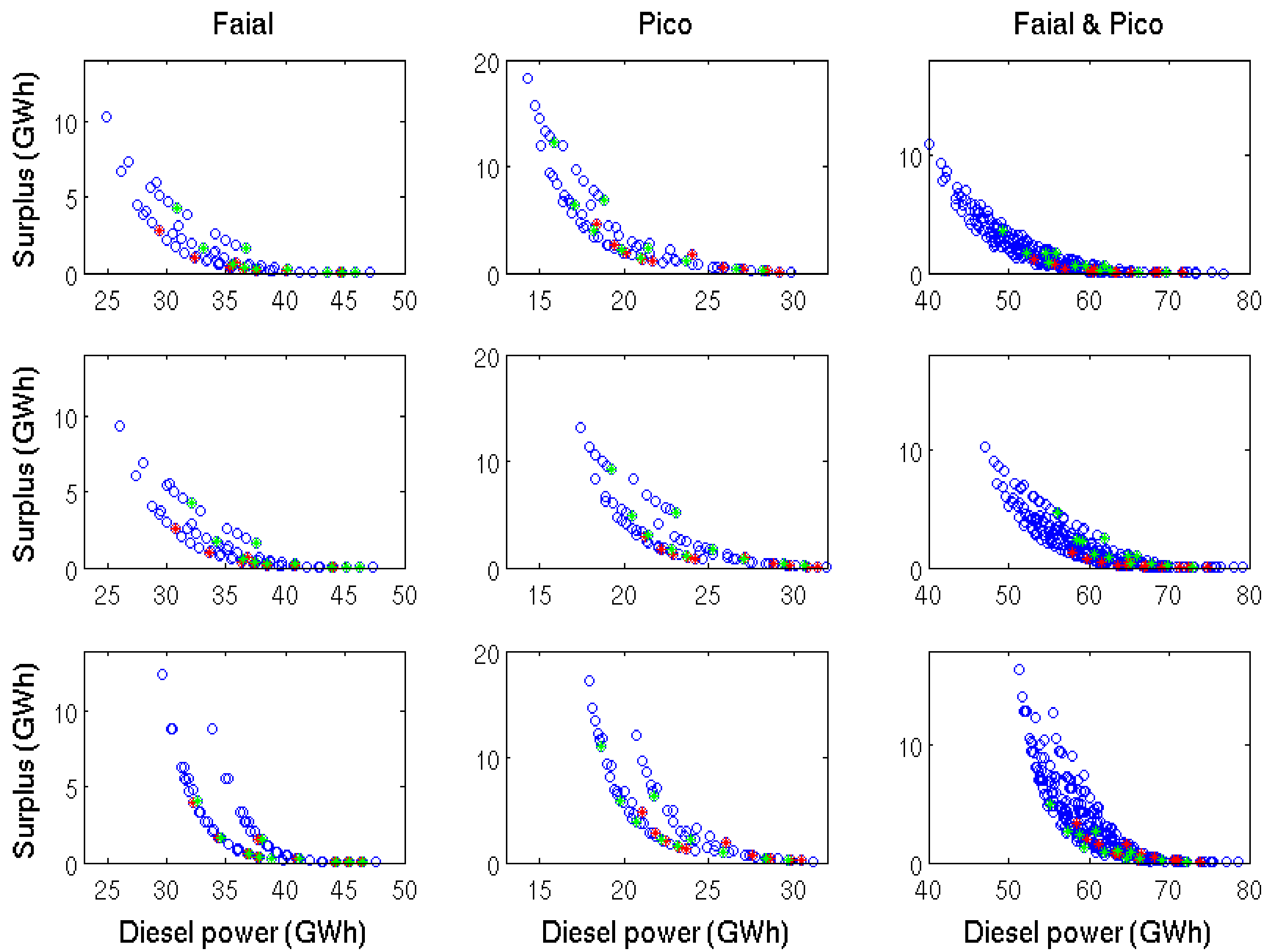
Methods' comparison – validation of new method

NEW METHOD

ORIGINAL DATA

REFERENCE METHOD



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Additional wind

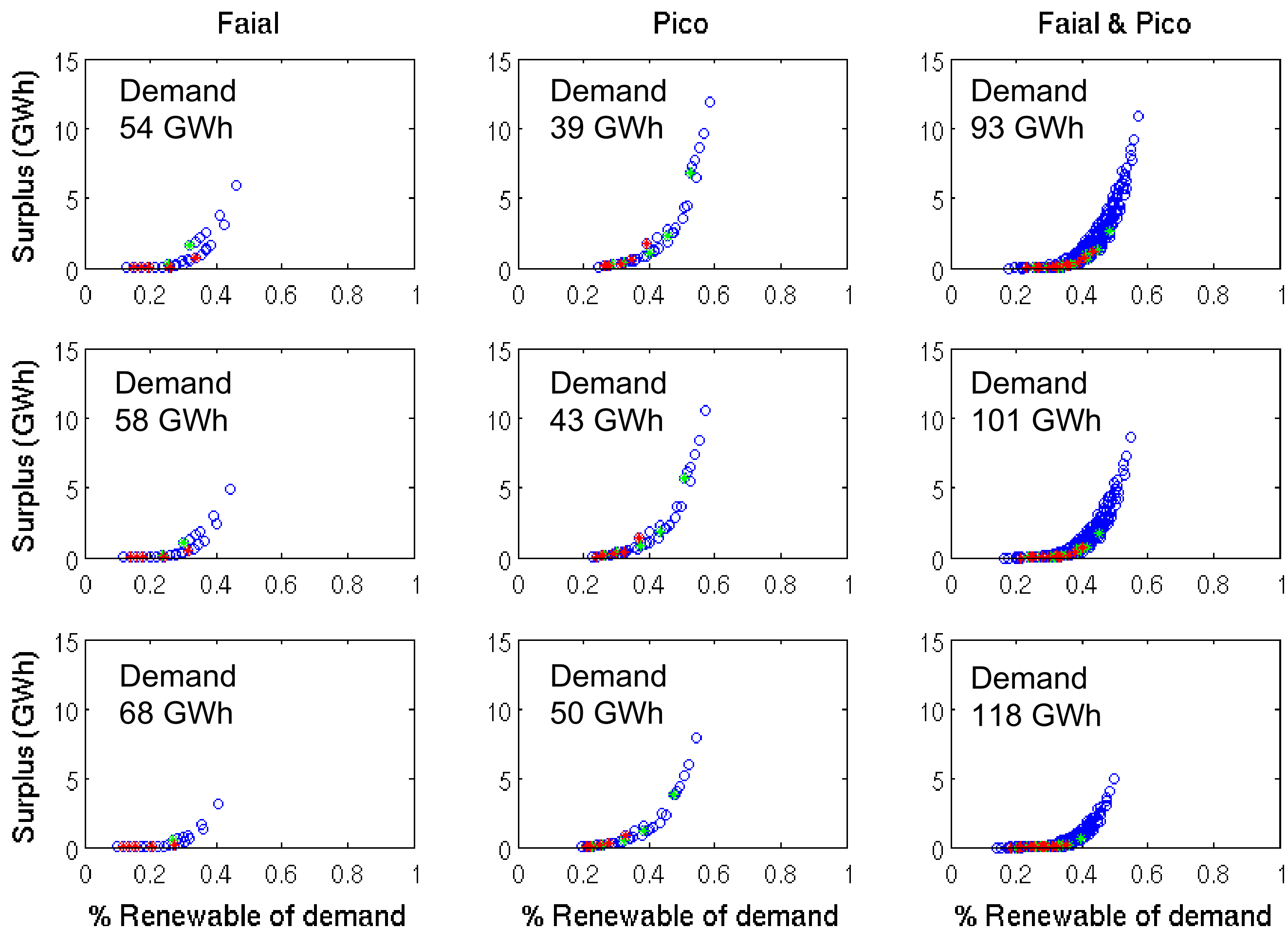
Mid-island: 0 kW   Coastal: 0 kW

Surplus vs. renewables penetration of demand

2010

2018
1% growth rate

2018
3% growth rate



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Additional wind

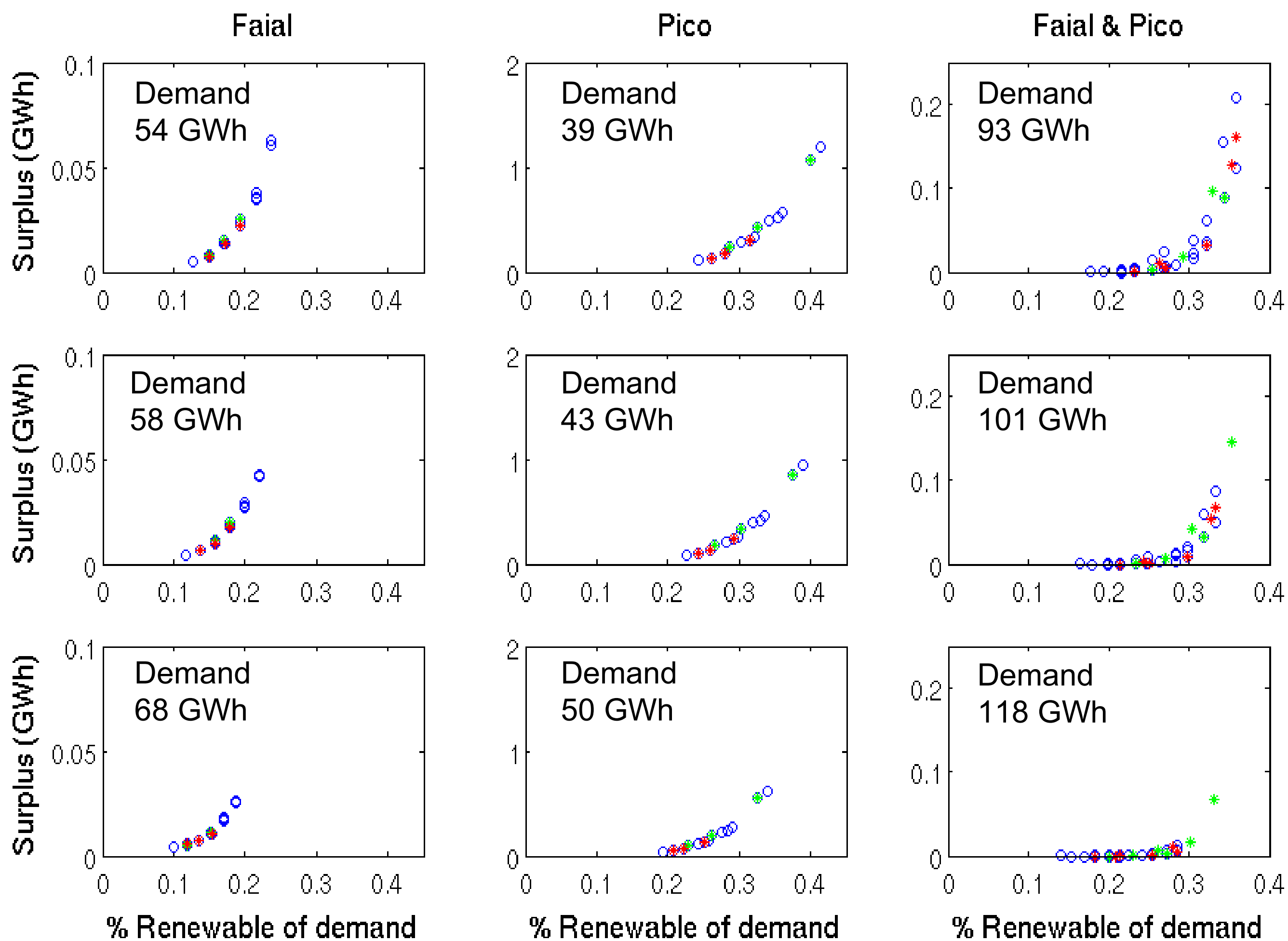
Mid-island: 0 kW **Coastal: 0 kW**

Surplus vs. renewables penetration of demand: max 6 – 4 – 10 new turbines per system

2010

2018
1% growth rate

2018
3% growth rate



Additional wind

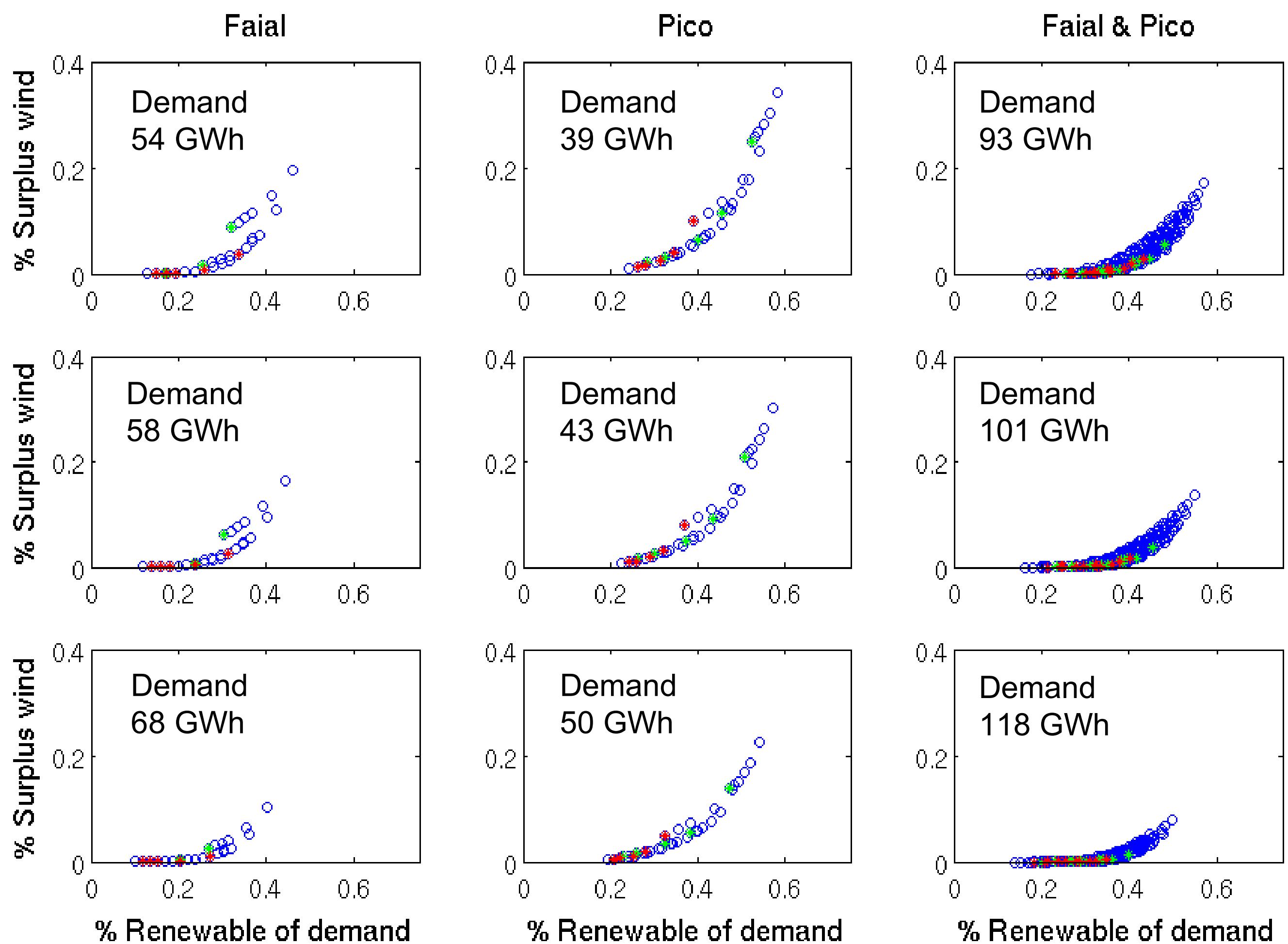
Mid-island: 0 kW **Coastal: 0 kW**

% Surplus wind vs. renewables penetration

2010

2018
1% growth rate

2018
3% growth rate



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<u>Additional wind</u>

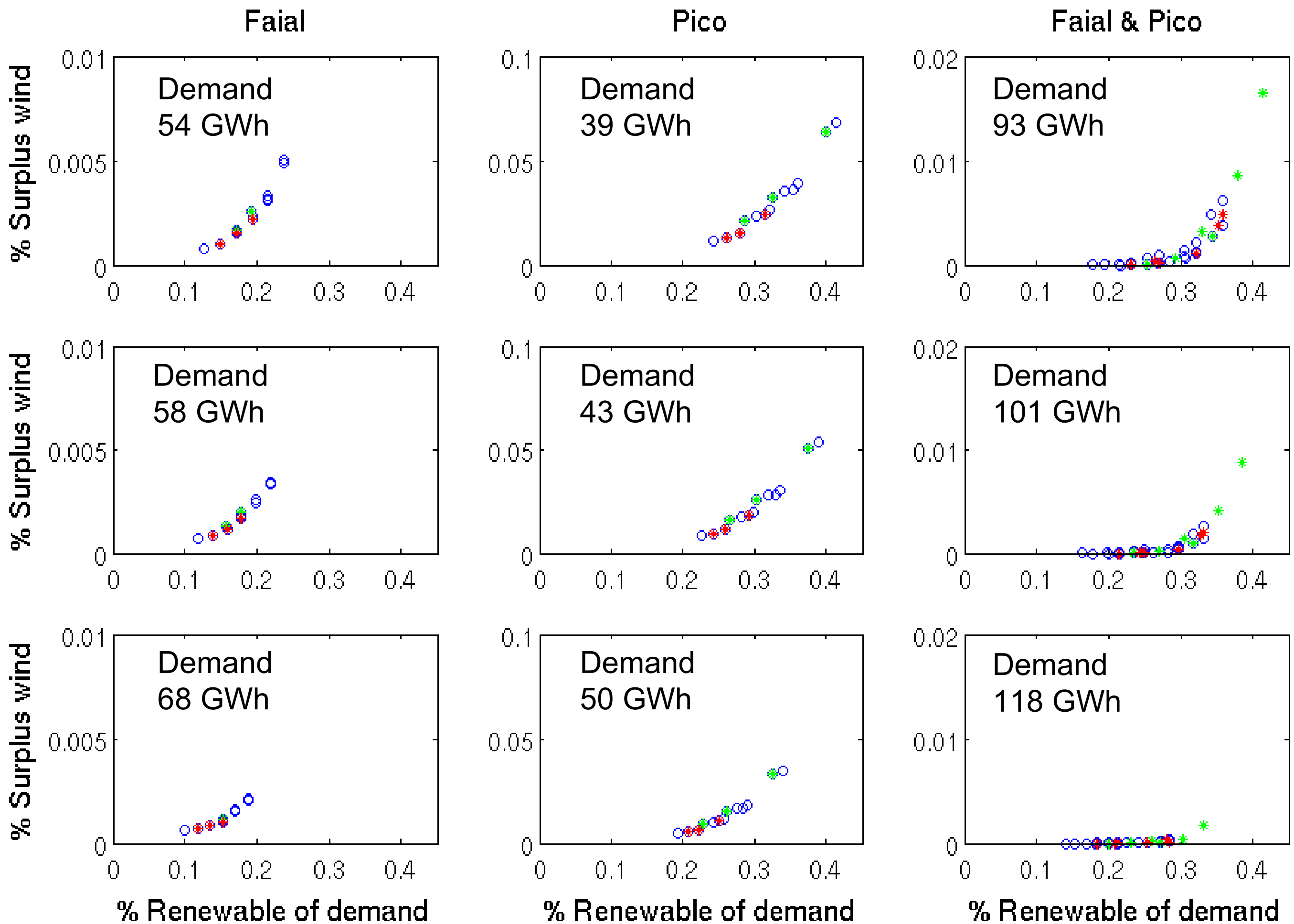
Mid-island: 0 kW **Coastal: 0 kW**

% Surplus wind vs. renewables share, 6 – 4 – 10 new turbines

2010

2018
1% growth rate

2018
3% growth rate



<u>Additional wind</u>

Mid-island: 0 kW **Coastal: 0 kW**

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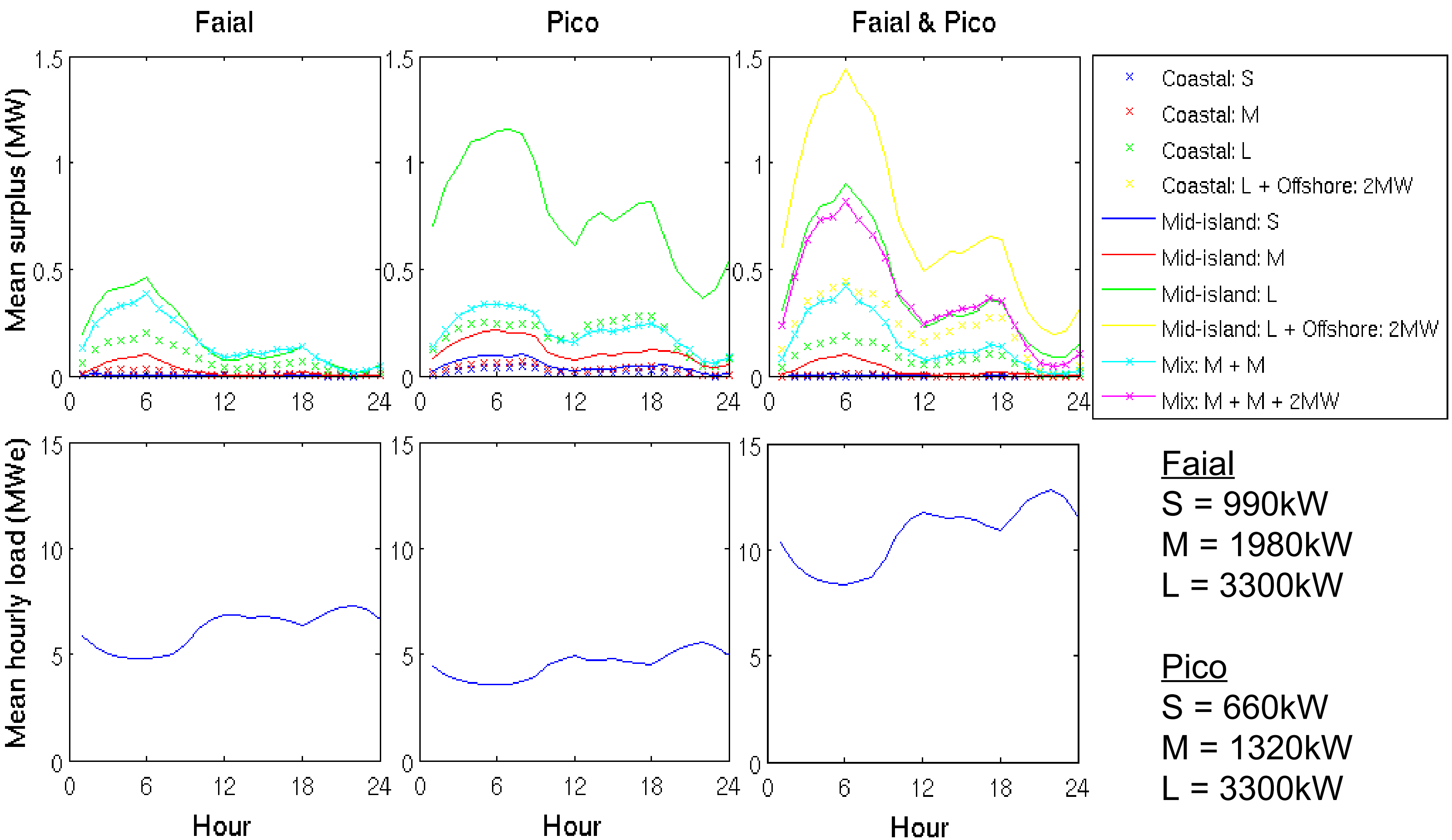
Hourly surplus vs. demand – by hour of day

Quantifying mean surplus wind power for additional installed wind power



<u>Faial</u>
S = 990kW
M = 1980kW
L = 3300kW

<u>Pico</u>
S = 660kW
M = 1320kW
L = 3300kW

Some details of the scenarios - **Faial**

Table 5: Selected scenarios for Faial.

Wind park	Coastal	Total kW	Fuel use Gwh	Renewable Gwh	Surplus Gwh	Renewable penetration	Wind surplus share
330	660	990	48.0	10.43	0.018	0.179	0.002
660	330		48.0	10.42	0.019	0.179	0.002
0	**990**		**47.9**	**10.43**	**0.017**	**0.179**	**0.002**
990	0		48.0	10.42	0.020	0.178	0.002
660	660	1320	46.8	11.61	0.028	0.199	0.002
330	990		46.8	11.62	0.027	0.199	0.002
990	330		46.8	11.60	0.029	0.199	0.003
660	1980	2640	42.1	16.23	0.194	0.278	0.012
1980	660		42.2	16.13	0.274	0.276	0.017
990	1980	2970	41.1	17.32	0.302	0.297	0.018
1980	990		41.2	17.21	0.393	0.295	0.023
0	**3300**	**3300**	**40.0**	**18.36**	**0.470**	**0.314**	**0.025**
3300	0		40.7	17.67	1.110	0.303	0.060
330	3300	3630	39.0	19.36	0.660	0.332	0.034
3300	330		39.7	18.65	1.331	0.319	0.068
1980	1980	3960	38.2	20.21	0.983	0.346	0.047
660	**3300**		**38.1**	**20.31**	**0.905**	**0.348**	**0.043**
3300	660		38.8	19.58	1.592	0.335	0.076
1980	3300	5280	34.8	23.55	2.435	0.403	0.095
3300	1980		35.4	22.97	2.997	0.393	0.117
3300	3300	6600	32.6	25.81	4.942	0.442	0.163

Some details of the scenarios - **Pico**

Table 6: Selected scenarios for Pico.

Wind park	Coastal	Total kW	Fuel use Gwh	Renewable Gwh	Surplus Gwh	Renewable penetration	Wind surplus share
0	660	660	31.7	11.074	**0.129**	0.259	**0.012**
660	0	660	**29.8**	**12.924**	0.343	**0.302**	0.026
330	330	660	30.7	12.020	0.215	0.281	0.018
330	660	990	30.0	12.721	0.262	0.298	0.020
660	330	990	29.1	13.623	0.392	0.319	0.028
0	1320	1320	30.3	12.465	0.235	0.292	0.018
1320	0	1320	26.8	15.972	0.854	0.374	0.051
660	660	1320	28.4	14.308	0.455	0.335	0.031
0	1980	1980	29.0	13.754	**0.442**	0.322	**0.031**
1980	0	1980	**24.2**	**18.545**	1.840	**0.434**	0.090
660	1320	1980	27.1	15.600	0.659	0.365	0.041
1320	660	1980	25.5	17.245	1.077	0.404	0.059
0	3300	3300	26.9	15.796	1.393	0.370	0.081
3300	0	3300	21.0	21.753	5.751	0.509	0.209
1320	1980	3300	23.5	19.283	2.032	0.451	0.095
1980	1320	3300	22.2	20.507	2.871	0.480	0.123
330	3300	3630	25.6	17.163	**1.805**	0.402	**0.095**
3300	330	3630	**20.6**	**22.119**	6.133	**0.518**	0.217
660	3300	3960	24.3	18.441	2.306	0.432	0.111
3300	660	3960	20.3	22.462	6.539	0.526	0.225
1980	1980	3960	21.5	21.251	3.623	0.497	0.146

Discussion points & future work

Discussion points

- Minimum 30% from fuel generators limit – flexible?
- Future turbine sizes & numbers?
- Surplus management strategies (turbine blades, water heating load, fly wheels,..)?
- Cost differences in the scenarios - How much surplus necessary to make EVs an interesting option?
-
-

Future work

- Specific scenarios design
- Include cost estimates
-
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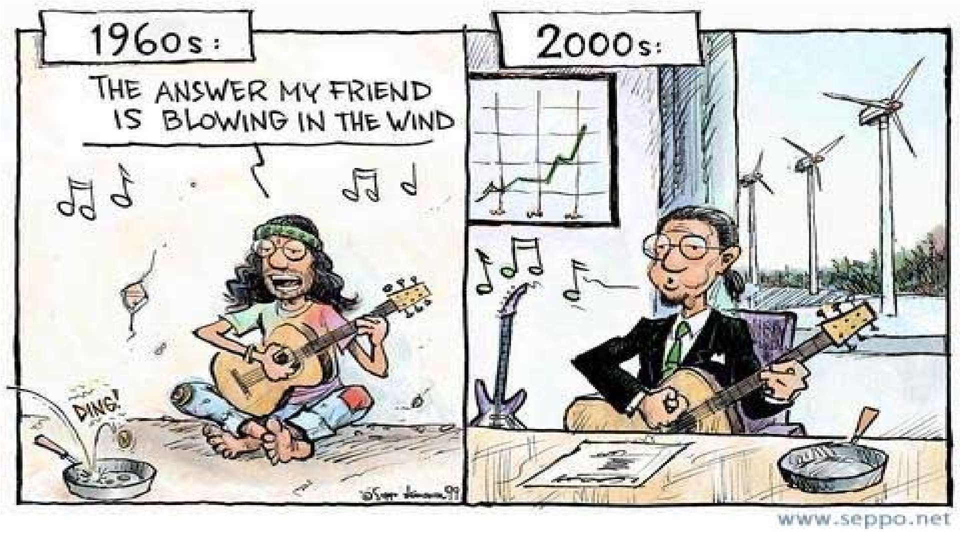

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