Report Dottorato di ricerca in Ingegneria dei Sistemi, Energetica, Informatica e delle Telecomunicazioni XXXIII ciclo A.A 2018/2019

Modeling, experimental analysis and optimization of floating photovoltaic power plants

Catania, 29/10/2019

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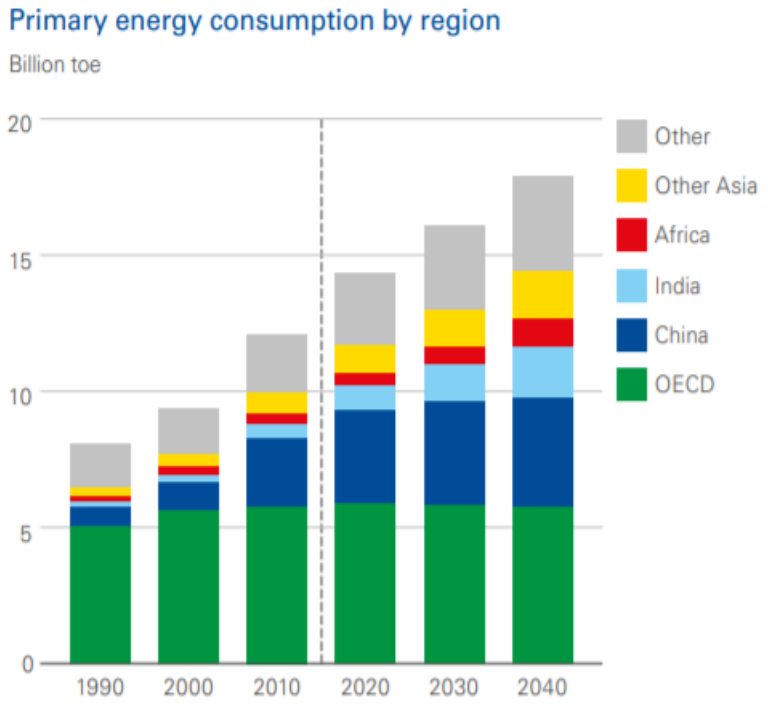
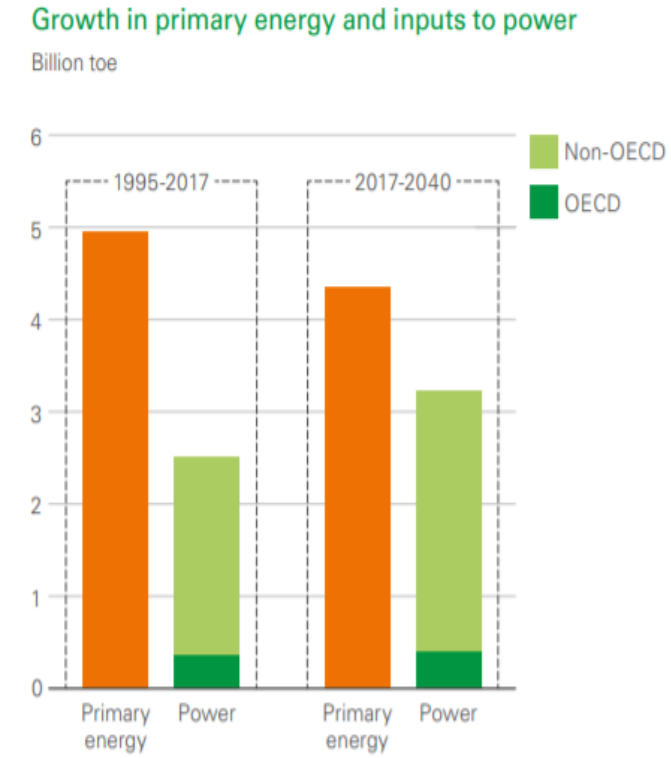
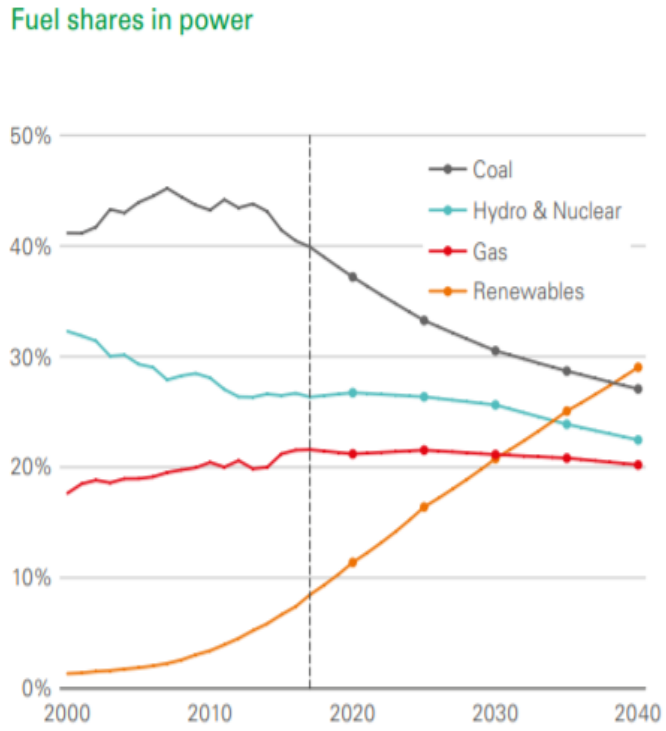
CONTEXT

An ever increasing need for energy in the world

The research work belongs to the general context of the renewable resources, specifically of the photovoltaic energy. The world's energy needs are always growing, so it is necessary to find clean and efficient energy sources. One technology that could meet these requirements is floating photovoltaic systems. In fact they have multiple advantages compared to the classic ground systems, including: Reduced evaporation from water reservoirs, improvements in water quality through decreased algae growth, easy integration into reservoirs of hydroelectric power plants and therefore easy to find water for cleaning and cooling. Furthermore, there is a considerable advantage in saving the land and an increase in efficiency compared to the classic ground systems as they work in favorable operating conditions.







By 2040 renewables overtake coal as the largest source of global power

MAIN ADVANTAGES OF FLOATING PV PLANTS

Reduced evaporation from water reservoirs, as the solar panels provide shade and limit the evaporative effects

Reduction or elimination of the shading of panels by their surroundings

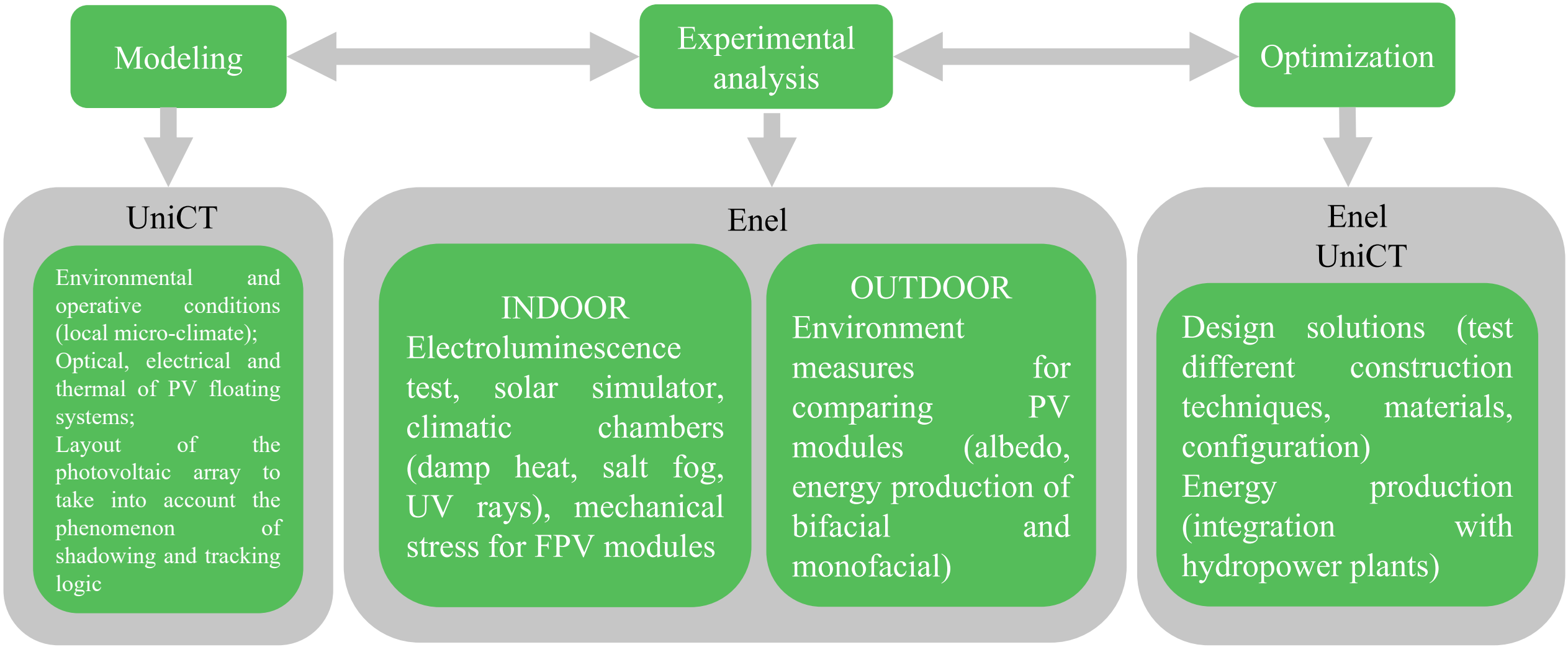
Easy installation and deployment in sites with low anchoring and mooring requirements, with a high degree of modularity, leading to faster installations.

Improvements in water quality, through decreased algae growth

Elimination of the need for major site preparation, such as leveling or the laying of foundations, which must be done for land-based installations

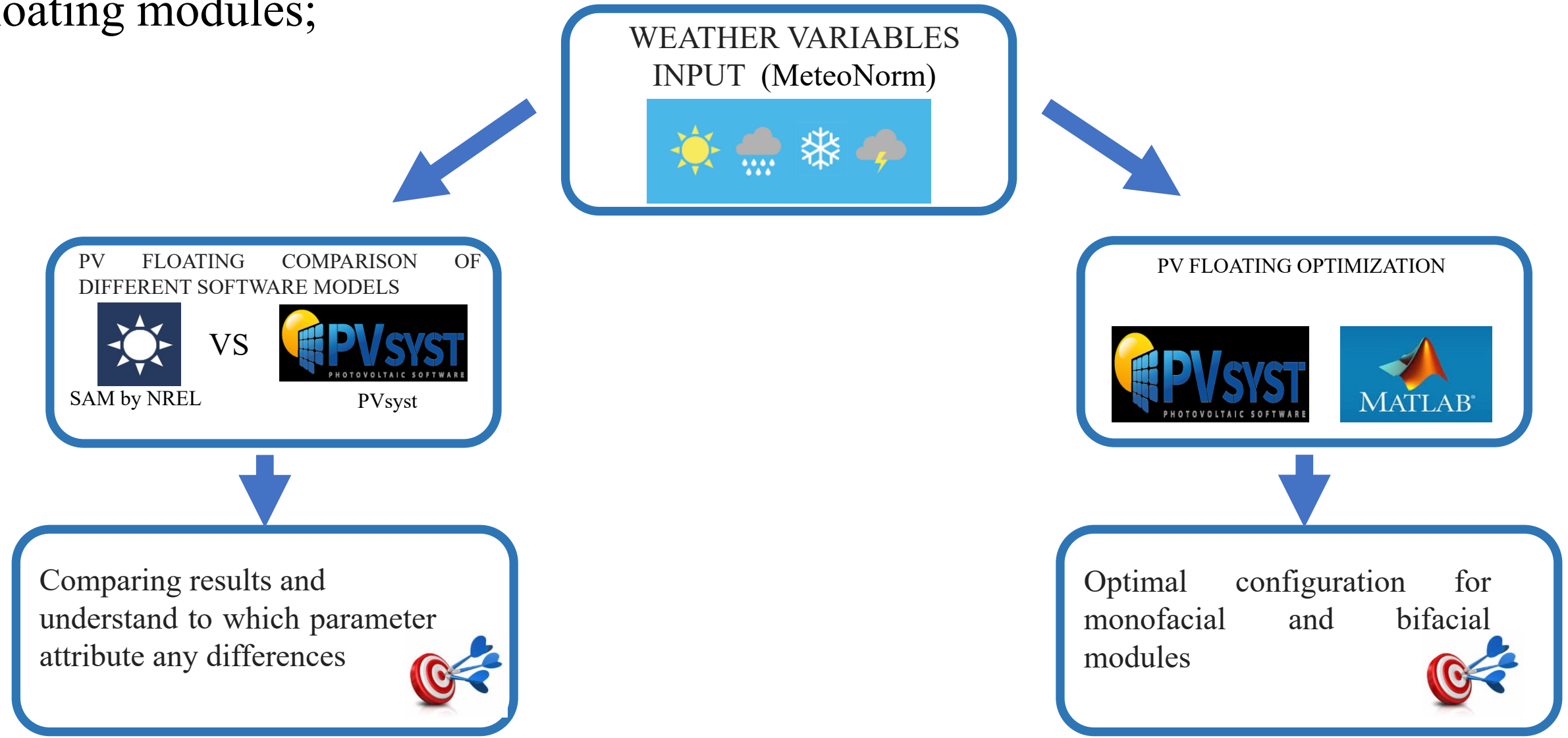
Easy integration into reservoirs of hydroelectric power plants and therefore easy to find water for cleaning and cooling

OBJECTIVES

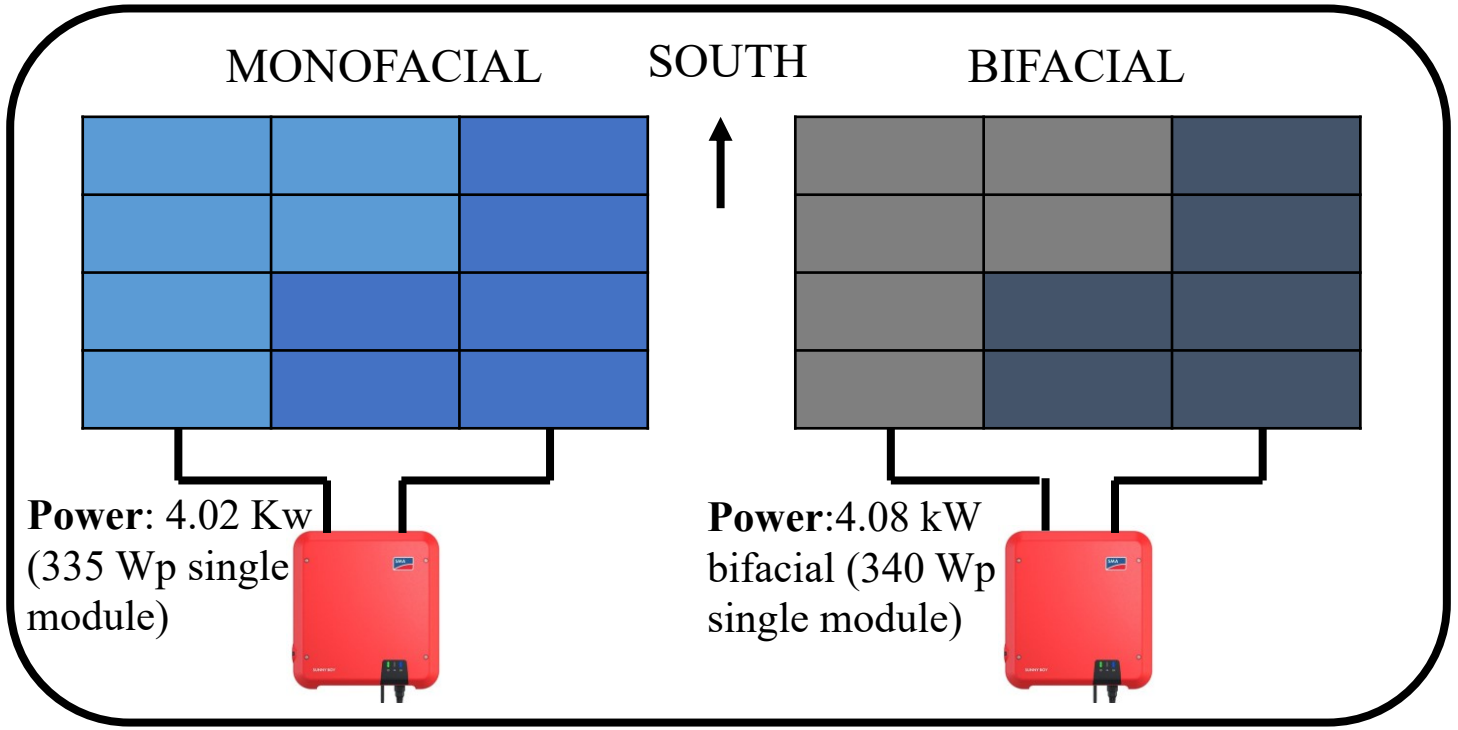

Modeling
Experimental analysis
Optimization
UniCT
Environmental and operative conditions (local micro-climate);
Optical, electrical and thermal of PV floating systems;
Layout of the photovoltaic array to take into account the phenomenon of shadowing and tracking logic
Enel
INDOOR
Electroluminescence test, solar simulator, climatic chambers (damp heat, salt fog, UV rays), mechanical stress for FPV modules
OUTDOOR
Environment measures for comparing PV modules (albedo, energy production of bifacial and monofacial)
Enel
UniCT
Design solutions (test different construction techniques, materials, configuration)
Energy production (integration with hydropower plants)

GOALS ACHIEVED 1

Geometric optimization of a photovoltaic system with monofacial and bifacial floating modules;



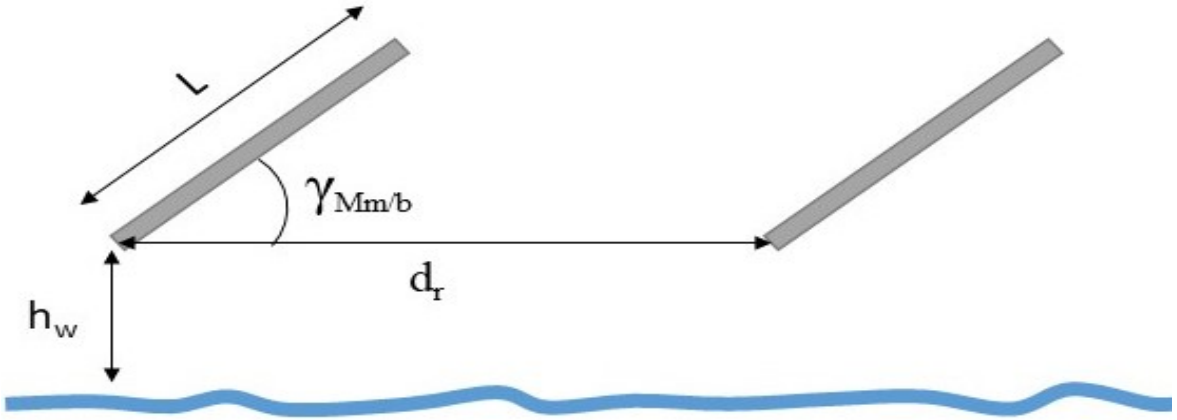
SITES AND PV SYSTEMS DATA



$$Y_{m/b} = \sum_{i=0}^{n} \frac{P_{mpp,m/b,i}\Delta t}{P_{p,m/b}} = \frac{Y'_{m/b}}{P_{p,m/b}}$$

$$f_d = \frac{DHI}{GHI} =$$

$$BF = 100\frac{Y_b - Y_m}{Y_m}$$



Range of the geometrical variables

Variable	Min. value	Max. value	Discrete value number
$\gamma_{Mm/b}$ (°)	5	30	6
d_r/L	1.25	2.0	6
h_w (m)	0	1.5	6

BIFACIAL PV MODELS COMPARISON CATANIA

SAM by NREL VS PVsyst

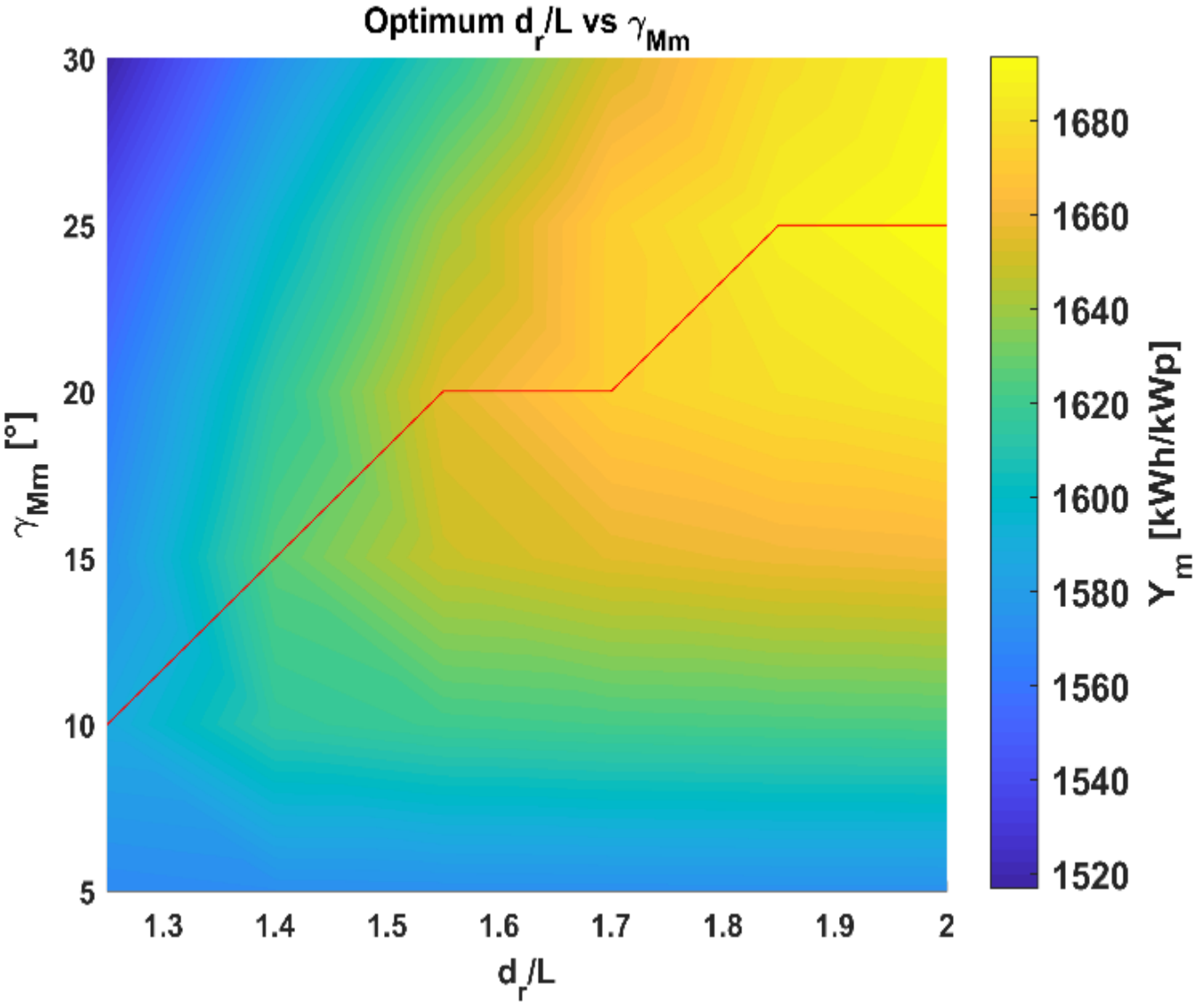
Variables:
-GlobInc: irradiation on the plan of the modules
-GlobBack: irradiation on the back of the modules
-TempLss annual energy losses for the modules
-TArray temperature of the array
-EArrNom annual energy nominal
-Δ ratio between value from the **PVsyst (1)** and value from the **SAM (2)**
- **Gain** ratio between **GlobBack** and **GlobEff**

γ_{Mb} (°)		GlobInc (kWh/m²)	GlobBack (kWh/m²)	GlobEff (kWh/m²)	TempLss (kWh)	TArray (°C)	EArrNom (kWh)	Gain (%)
0	1	1862.5	0.0	1785.0	367.5	31.2	7294.6	0.0
	2	1791.0	0.0	1718.3	305.8	29.2	7024.0	0.0
	Δ	104.0	0.0	103.9	120.2	107.0	103.9	-
20	1	2094.9	61.2	2037.4	475.6	32.8	8539.0	3.0
	2	1953.3	51.4	2013.1	370.5	30.3	8179.0	2.6
	Δ	107.2	119.2	101.2	128.4	108.3	104.4	-
40	1	2120.5	144.0	2094.4	499.4	33.0	9059.4	6.9
	2	2037.0	116.2	1980.8	379.8	30.4	8560.0	5.9
	Δ	104.1	123.9	105.7	131.5	108.7	105.8	-
60	1	1940.4	243.3	1948.1	418.9	31.9	8806.7	12.5
	2	1865.6	206.6	1801.2	312.1	29.5	8196.0	11.5
	Δ	104.0	117.8	108.2	134.2	108.0	107.5	-

OPTIMAL CONFIGURATION MONOFACIAL SYSTEMS CATANIA

Reference configuration:
$d_r/L=1.25$, $\gamma_{Mm}=10°$, $Y_m=1587$ h with a=5%.

d_r/L	γ_{Mm}	Y_m a=20 %	Y_m a=10 %	Y_m a=5%	ΔY_m (%) a=20 %	ΔY_m (%) a=10 %	ΔY_m (%) a=5%
1.25	10	1588	1587	1587	100	100	100
1.40	15	1627	1626	1626	102	102	102
1.55	20	1655	1654	1654	104	104	104
1.70	20	1673	1672	1672	105	105	105
1.85	25	1687	1686	1686	106	106	106
2.00	25	1694	1693	1692	107	107	107



OPTIMAL CONFIGURATION BIFACIAL SYSTEMS CATANIA

Reference configuration: $d_r/L=1.25$, $\gamma_{Mb}=10°$, $Y_b=1630$ h with a=5%.

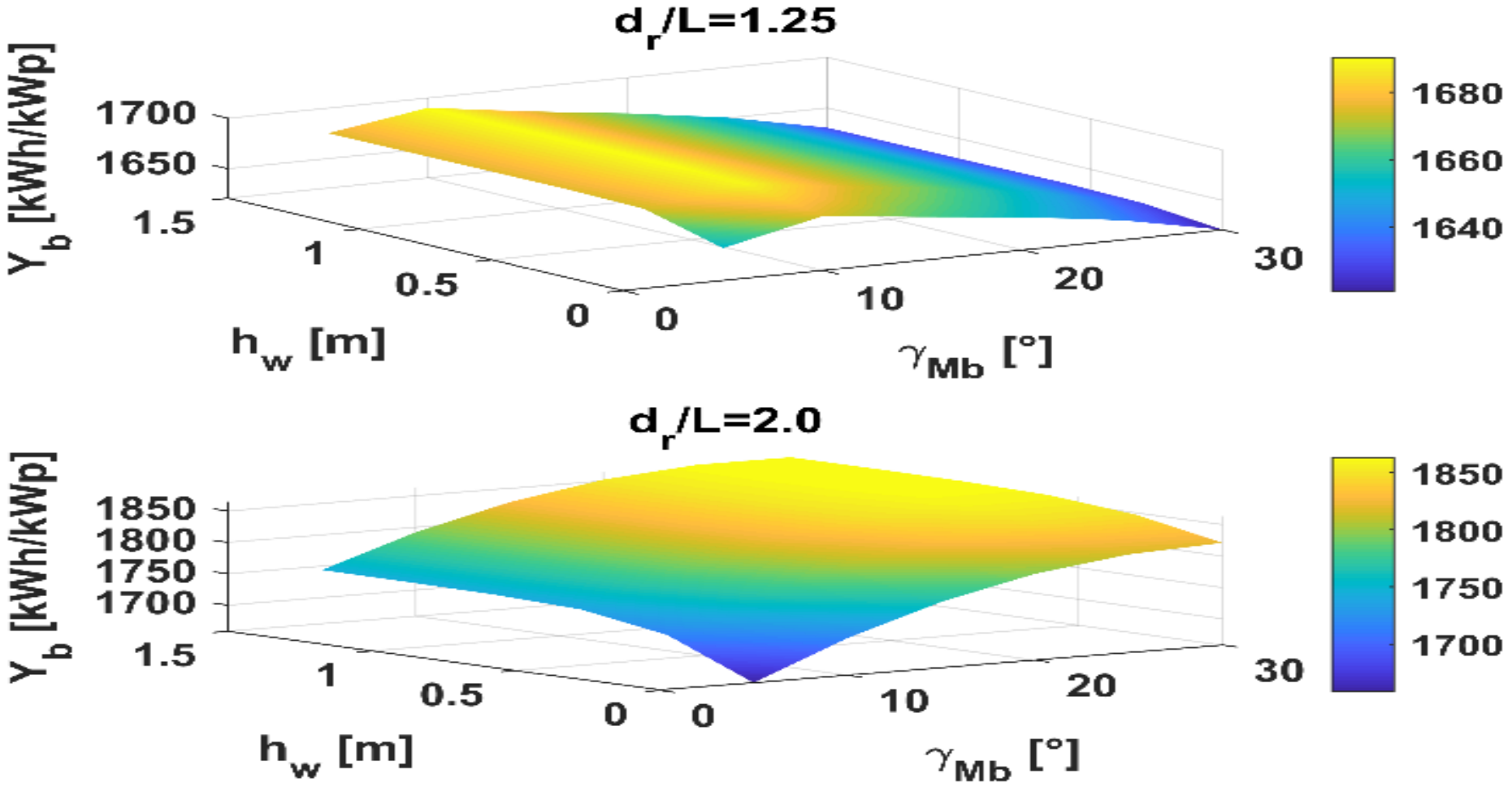
Optimal configuration with $h_w = 0$ m

d_r/L	γ_{Mb}	Y_b a=20	Y_b a=10	Y_b a=5	ΔY_b a=20	ΔY_b a=10	ΔY_b a=5
1.25	10	1675	1645	1630	103	101	100
1.4	15	1722	1689	1672	106	104	103
1.55	20	1759	1724	1706	108	106	105
1.7	25	1788	1750	1730	110	107	106
1.85	25	1806	1765	1746	111	108	107
2	30	1821	1778	1757	112	109	108

Optimal configuration with $h_w = 0.9$ m

d_r/L	γ_{Mb}	Y_b a=20	Y_b a=10	Y_b a=5	ΔY_b a=20	ΔY_b a=10	ΔY_b a=5
1.25	10	1690	1652	1634	103	101	100
1.4	15	1746	1701	1679	107	104	103
1.55	20	1790	1739	1713	110	106	105
1.7	25	1822	1767	1739	112	108	106
1.85	25	1847	1786	1756	113	109	107
2	30	1863	1799	1767	114	110	108

OPTIMAL CONFIGURATION BIFACIAL SYSTEMS CATANIA



Energy yield for two d_r/L values as a function of h_w and of γ_{Mb} at a=20%, in Catania

BIFACIAL GAIN CATANIA

$$BF = 100\,\frac{Y_b - Y_m}{Y_m}$$

BF for h_w=0 m

d_r/L	γ_{Mb}	γ_{Mm}	BF a=20%	BF a=10%	BF a=5%
1.25	10	10	5.5	3.6	2.6
1.4	15	15	5.8	3.8	2.8
1.55	20	20	6.3	4.1	3.1
1.7	25	20	6.9	4.6	3.5
1.85	25	25	7.1	4.7	3.5
2	30	25	7.5	5.0	3.7

BF for h_w=0.9 m

d_r/L	γ_{Mb}	γ_{Mm}	BF a=20%	BF a=10%	BF a=5%
1.25	10	10	6.5	4.1	2.9
1.4	15	15	7.3	4.6	3.2
1.55	20	20	8.1	5.0	3.5
1.7	25	20	8.9	5.6	4.0
1.85	25	25	9.5	5.9	4.1
2	30	25	10.0	6.2	4.4

BIFACIAL GAIN FRANKFURT

$$BF = 100\,\frac{Y_b - Y_m}{Y_m}$$

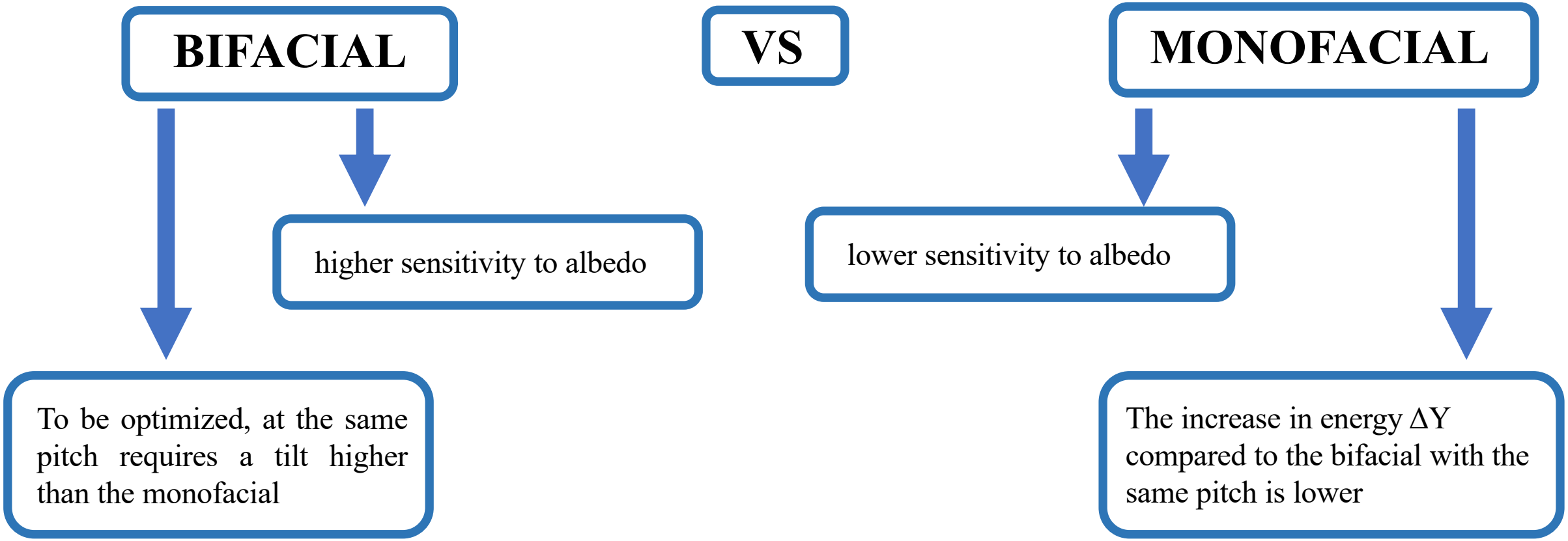
BF for h_w=0 m

d_r/L	γ_{Mb}	γ_{Mm}	BF a=20%	BF a=10%	BF a=5%
1.25	10	10	5.9	3.9	2.9
1.4	15	15	6.4	4.2	3.1
1.55	20	20	7.1	4.7	3.5
1.7	25	20	7.6	5.0	3.8
1.85	25	20	7.9	5.3	4.0
2	25	20	8.2	5.4	4.0

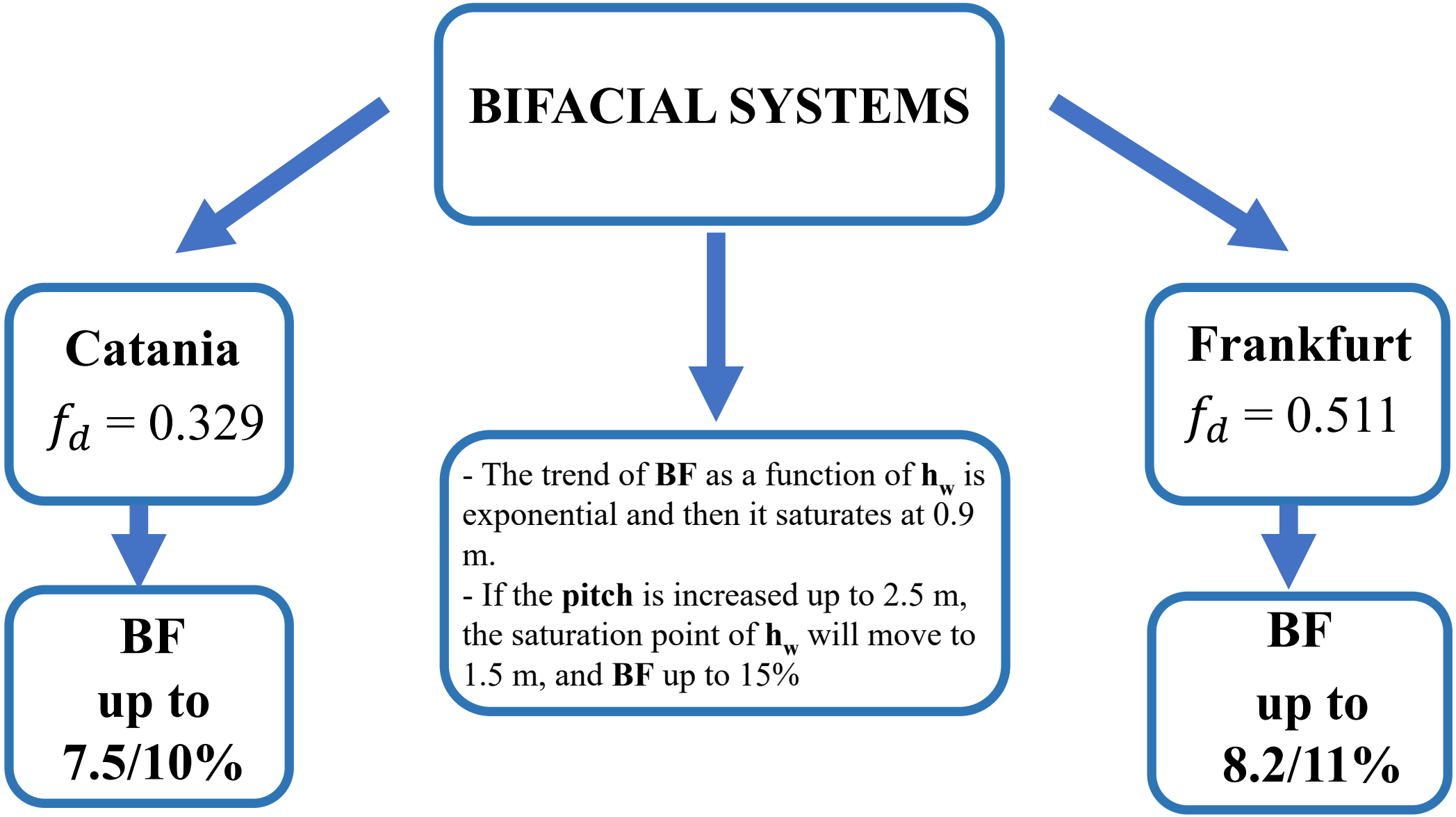
BF for h_w=0.9 m

d_r/L	γ_{Mb}	γ_{Mm}	BF a=20%	BF a=10%	BF a=5%
1.25	10	10	7.0	4.4	3.1
1.4	15	15	8.0	5.0	3.5
1.55	20	20	9.0	5.6	4.0
1.7	25	20	9.7	6.1	4.3
1.85	25	20	10.4	6.5	4.6
2	25	20	11.0	6.8	4.8

CONSIDERATION OF COMPARISON



CONSIDERATION OF COMPARISON



GOALS ACHIEVED 2

- Study and modeling of the evaporative phenomenon of water basins in the presence of floating photovoltaic systems

Literature models

Models	*Input variables*
Penman Monteith [6] $E = \left(\frac{0.404\Delta(Q^* - N) + \gamma\frac{900u_2(e_s - e_a)}{T+273}}{\Delta + \gamma(1+0.34u_2)}\right)$ (1)	$R_s\ RH\ T\ u_2$
Penman-Monteith modified [8] $E = \frac{1}{\lambda}\left(\frac{\Delta_w(Q^* - N) + \frac{86400\rho_a C_a(e_w^* - e_a)}{r_a}}{\Delta_w + \gamma}\right)$ (2)	$R_s\ RH\ T\ u_2$
Valiantzas [9] $E = 0.051(1-\alpha)R_s\sqrt{T+9.5} - 0.188(T+13)\left(\frac{R_s}{R_a} - 0.194\right)\left(1 - 0.00014(0.7T_{max} + 0.3T_{min} + 46)^2\sqrt{\frac{RH}{100}}\right) + 0.049(T_{max}+16.3)\left(1 - \frac{RH}{100}\right)(0.62 + 0.53u_2)$ (3)	$R_s\ RH\ T\ T_{min}\ T_{max}\ u_2$
Rohwer [10] $E = 0.44(1 + 0.27u_{10})(e_s - e_a)$ (4)	$R_s\ RH\ T\ u_{10}$
Mc Guinness and Bordne [11] $E = (0.082T - 0.19)\left(\frac{R_s}{1500}\right)2.54$ (5)	$R_s\ T$
Hargreaves [12] $E = 0.408 * 0.0025(T+16.8)(T_{max} - T_{min})^{0.5}R_a$ (6)	$T\ T_{min}\ T_{max}$

DoE and Linear regression proposed models

Models	*Input variable and method*
$E = 0.2389 + 0.0133R_s + 0.0077T + 0.1589T_w - 0.0325RH + 0.2302u_{10}$ (47)	$R_s\ T\ T_w\ RH\ u_{10}$ (lin.reg. 5)
$E_{l.r.\ 4} = 2.421 + 0.012R_s + 0.159T - 0.056RH + 0.122u_{10}$ (48)	$R_s\ T\ RH\ u_{10}$ (lin.reg. 4)
$E = -0.307 - 0.0486R_s + 0.177T + 0.0119RH + 1.00781u_{10} + 0.00163R_sT + 0.00098R_sRH - 0.00601R_su_{10} - 0.00244T\ RH + 0.0153T\ u_{10} - 0.0115RH\ u_{10} + 0.0045R_s^2 + 0.00248T^2 - 0.0109u_{10}^2$ (49)	$R_s\ RH\ T\ u_{10}$ (DoE 4)
$E = 1.802 + 0.047R_s - 0.133T - 0.146u_{10} + 0.028R_sT + 0.012R_su_{10} + 0.013T\ u_{10} + 0.003R_s^2 + +0.006T^2 + 0.001u_{10}^2$ (50)	$R_s\ T\ u_{10}$ (DoE 3)
$E = 1.505 + 0.052R_s - 0.080T + 0.002R_sT + 0.003R_s^2 + 0.006T^2$ (51)	$R_s\ T$ (DoE 2)

Design of experiments (DoE)

$$y = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n} a_{ii} x_i^2 + \sum_{\substack{i,j=1 \\ j<i}}^{n} a_{ij} x_{ij} \qquad x = \frac{A - A_0}{step} \qquad [a] = (X'X)^{-1}X'[y]$$

Linear regression

$$y = a_0 + a_1\ x_1 + \ldots + a_n\ x_n + \varepsilon$$

COMPARATIVE ANALYSIS OF EVAPORATION MODELS

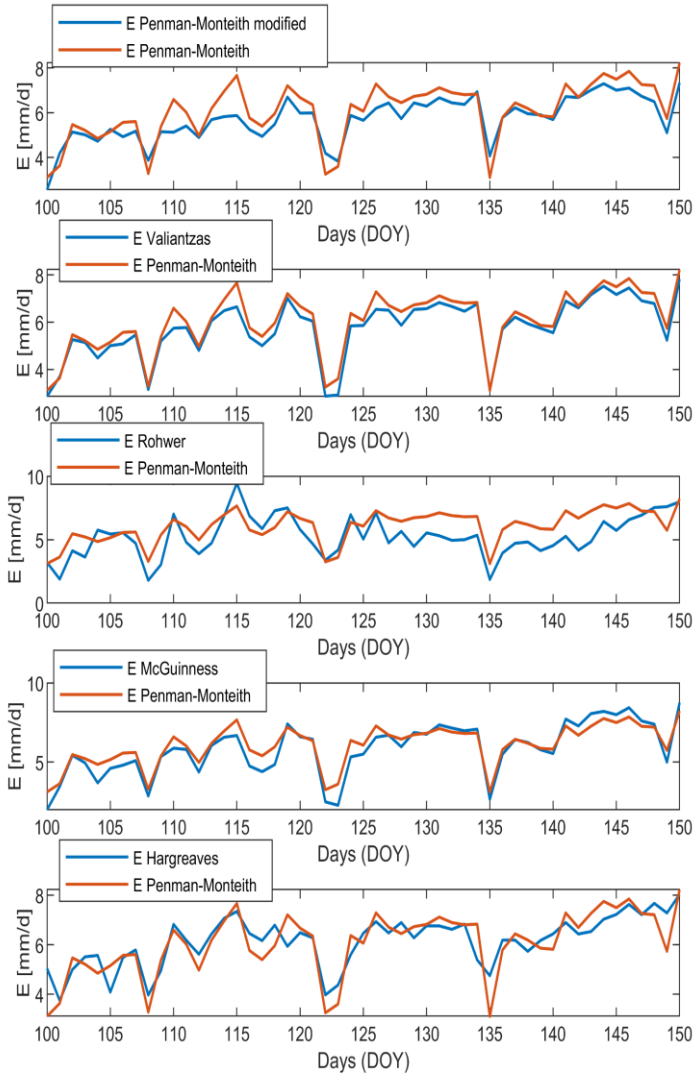
- Comparison of reference model (Penman), literatue and proposed models

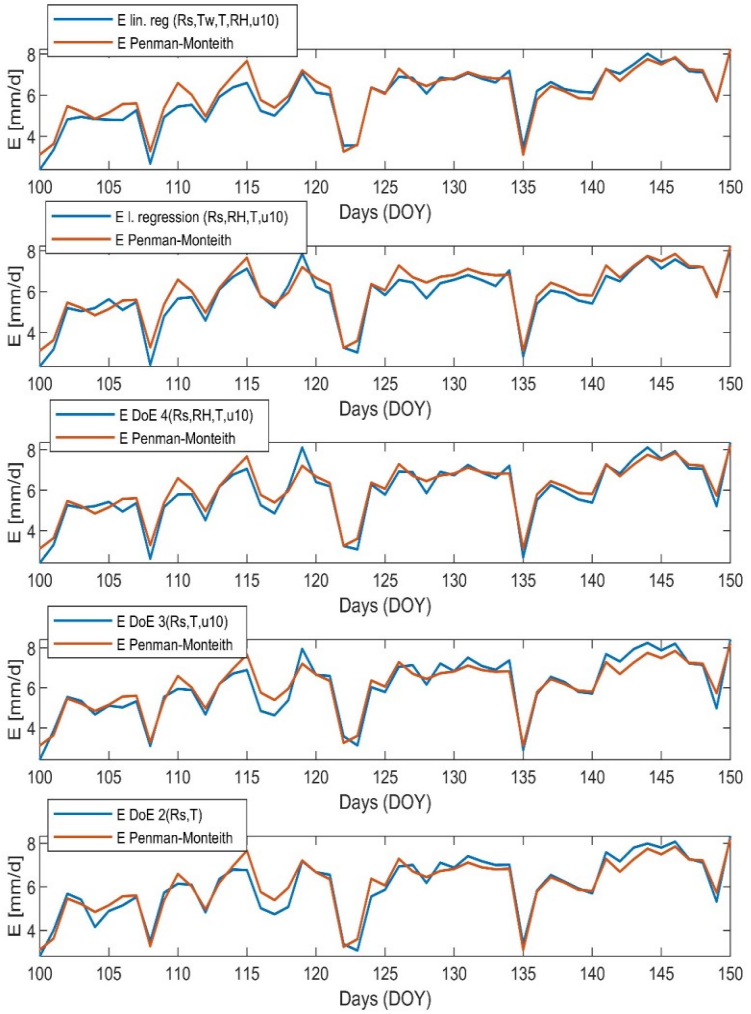
Literatue vs reference model

	Penman Monteith mod.	***Valiantzas***	**Rohwer**	***Mc Guinness Bordne***	***Hargreaves***
MBE (mm*d^{-1})	0.36	0.31	0.81	0.24	-0.07
PE (%)	6.38	5.38	15.39	4.19	1.14
RMSE (mm*d^{-1})	0.61	0.37	1.38	0.58	0.67
R^2	0.93	0.98	0.71	0.96	0.85

Proposed vs reference model

	Lin. Reg. 4	***DoE 4***	***DoE 3***	***Doe 2***
MBE (mm*d^{-1})	0.12	0.03	-0.10	-0.09
PE (%)	2.07	0.53	1.48	1.59
RMSE (mm*d^{-1})	0.92	0.89	0.97	1.02
R^2	0.85	0.86	0.83	0.81





COMPARATIVE ANALYSIS OF EVAPORATION MODELS

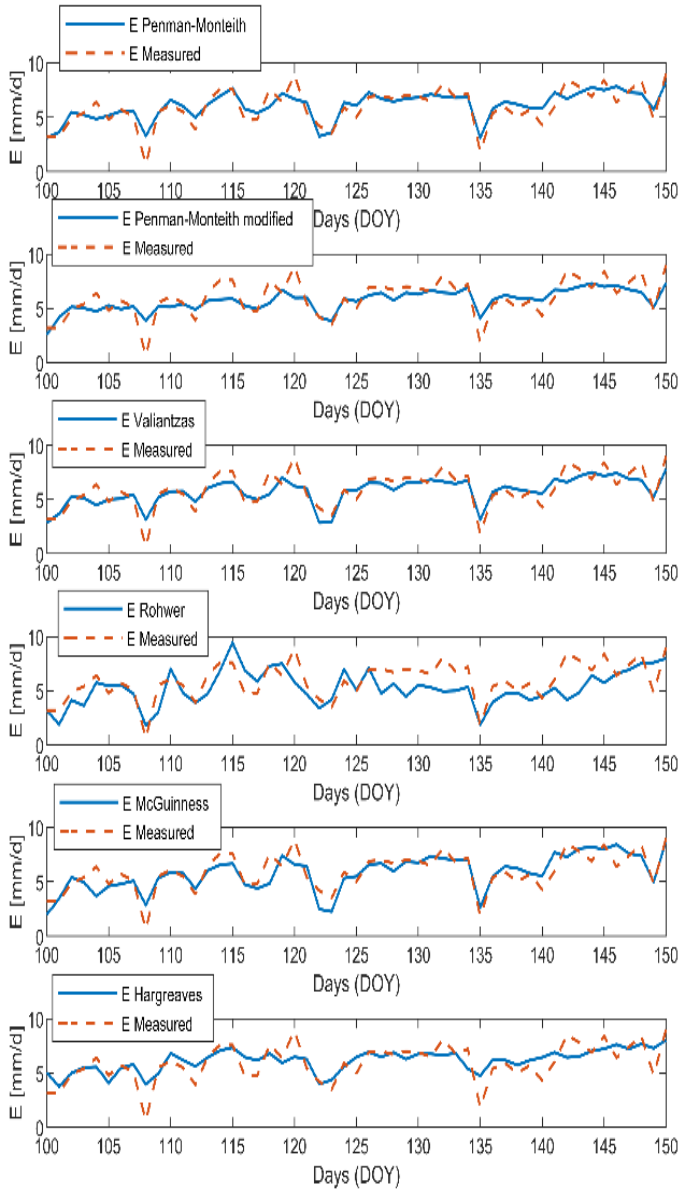
- Comparison of reference model (Penman), literatue and proposed models

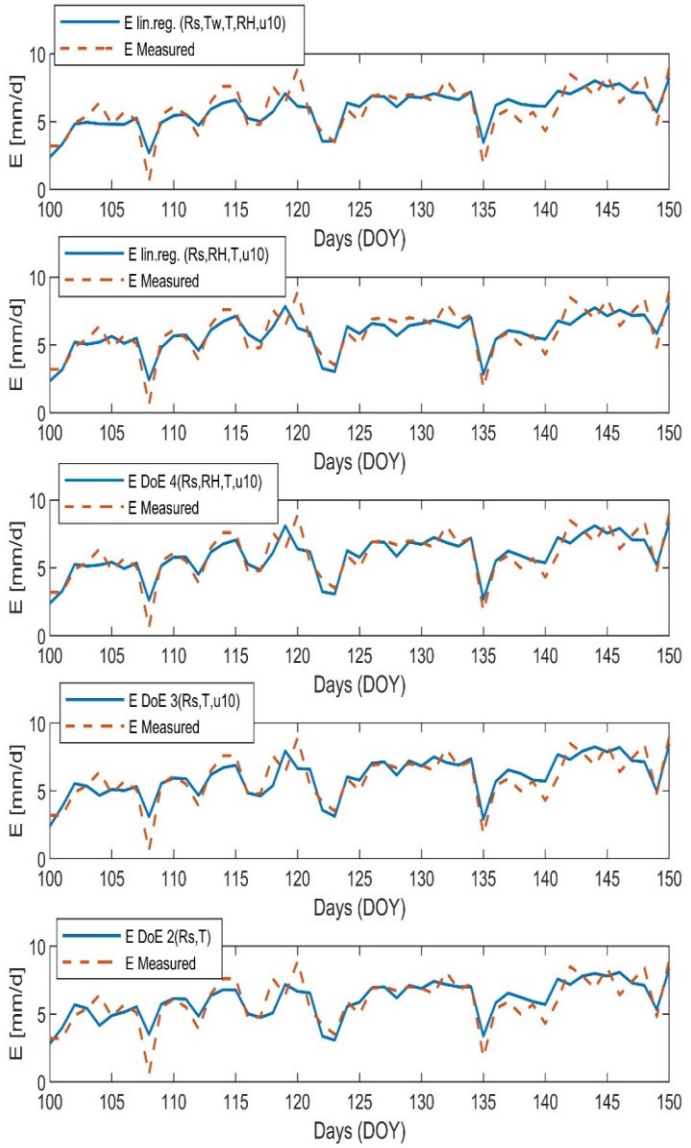
Literatue vs measure

	Penman Monteith	***Penman Monteith mod.***	***Valiantzas***	**Rohwer**	***Mc Guinness Bordne***	***Hargreaves***
MBE (mm d^{-1})	0.12	-0.22	-0.17	-0.67	-0.10	0.21
PE (%)	2.18	3.94	3.03	11.44	1.92	3.37
RMSE (mm d^{-1})	0.94	1.13	1.01	1.56	1.06	1.22
R^2	0.85	0.79	0.83	0.64	0.81	0.74

Proposed vs measure

	Linear Regression 5	***Linear Regression 4***	***Design of Experiment 4***	***Design of Experiment 3***	***Design of Experiment 2***
MBE (mm d^{-1})	-0.03	-0.12	-0.03	0.09	0.10
PE (%)	0.56	2.07	0.53	1.50	1.61
RMSE (mm d^{-1})	0.98	0.92	0.89	0.97	1.02
R^2	0.82	0.85	0.86	0.83	0.81



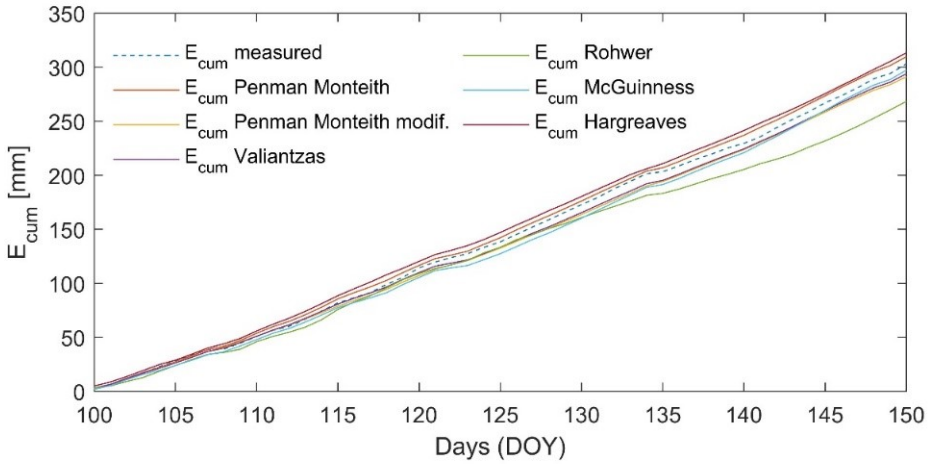


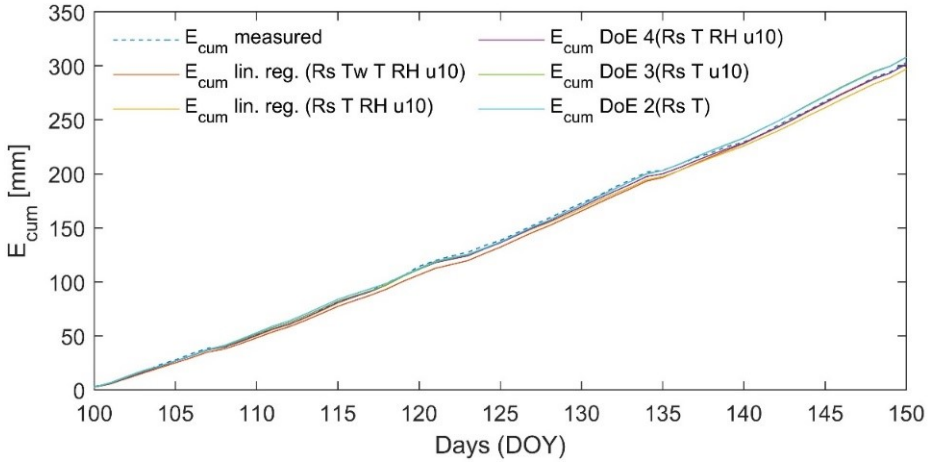
COMPARATIVE ANALYSIS OF EVAPORATION MODELS

- Comparison of reference model (Penman), literatue and proposed models cumulated evaporation

$$\mathrm{E}_{cum}(\mathrm{DOY}) = \sum_{d=1}^{DOY} E_d(DOY)$$

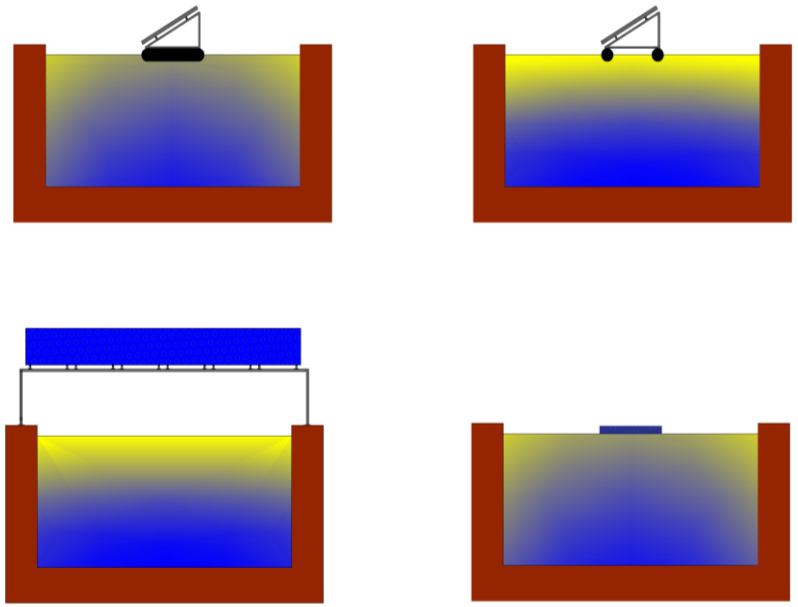
Measures/models	E_{cum} *(mm)*	ΔE_{cum} *(mm)*	ΔE_{cum} *(%)*
Measures	303.21	0.00	0.00
Penman Monteith	309.82	-6.62	-2.18
Penman Monteith-modif.	291.24	11.96	3.94
Valiantzas	293.99	9.21	3.04
Rohwer	268.49	34.71	11.45
Mc Guinness Bordne	297.35	5.85	1.93
Hargreaves	313.39	-10.19	-3.36
Linear Regression 5	301.49	1.71	0.56
Linear Regression 4	297.05	6.15	2.03
Design of Experiment 4	301.59	1.61	0.53
Design of Experiment 3	307.76	-4.56	-1.50
Design of Experiment 2	308.09	-4.89	-1.61





EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

Features and models



Typologies of FPVs (a) with floats that cover entirely the surface below the module, (b) with modules anchored to a tubular buoyancy systems, (c) canal top solar systems, (d) flexible floats.

Energy balance for free water surface

$$Q^* = SW_i - SW_o + LW_i - LW_o$$
$$SW_i = R_d + R_b$$
$$SW_o = \alpha(R_d + R_b)$$
$$SW_n = SW_i - SW_o = (1-\alpha) * (R_d + R_b)$$
$$LW_n = LW_i - LW_o = \sigma T_w^4 \left(0.56 - 0.0092\sqrt{e_a}\right)(0.10 + 0.90\, C)$$

Energy balance for floats that cover entirely the surface below the module

$$SW_{nFcover\ ,a} = 0$$
$$LW_{nFcover\ ,a} = \sigma T_w^4 \left(0.56 - 0.0092\sqrt{e_a}\right)0.10$$
$$Q^* = Q^*_{free}\,(1-x) + Q^*_{Fcover}\,(x)$$
$$E_{FPVF,a/d\ Penman} = (1-x)E'_{free}$$
$$E_{Fcover\ ,a\ lin.reg.} = a_0 + (1-x)a_1R_s + a_2T_a + a_3RH + a_4u_{10} \qquad E_{FPVF,a/d\ lin.reg.} = E_{Fcover\ lin.reg.}\,(1-x)$$

Energy balance for flexible floats.

$$SW_{nFcover\ ,d} = \alpha_{pv}(R_d + R_b)(1-\eta_{el})0.4$$
$$LW_{nFcover\ ,d} = \sigma T_w^4 \left(0.56 - 0.0092\sqrt{e_a}\right)0.10$$
$$Q^* = Q^*_{free}\,(1-x) + Q^*_{Fcover}\,(x)$$
$$E_{FPVF,a/d\ lin.reg.} = E_{Fcover\ lin.reg.}\,(1-x)$$
$$E_{FPVF,a/d\ Penman} = (1-x)E'_{free} \qquad E_{Fcover\ ,d\ lin.reg.} = a_0 + (1-0.95x)a_1R_s + a_2T_a + a_3RH + a_4u_{10}$$

Energy balance for modules anchored to a tubular buoyancy systems and canal top

$$SW_{nScover} = (1-\alpha)R_d$$
$$LW_{nScover} = \sigma T_w^4 \left(0.56 - 0.0092\sqrt{e_a}\right)(0.10 + 0.90 * 0.3)$$
$$E_{Scoverlin\ .reg.} = a_0 + 0.2a_1R_s + a_2T_a + a_3RH + a_4u_{10}$$
$$E_{FPVS} = (1-x)E_{free} + xE_{Scover}$$

Yield indexes and model comparison

$$\Delta E_{FPV} = E_{free\ cum} - E_{FPV\ cum}$$

$$\eta = \frac{\Delta E_{FPV}}{E_{free\ cum}} * 100$$

$$\varepsilon_{FPV\ cum} = \frac{E_{FPV\ \ Penman\ \ cum} - E_{FPV\ lin.reg.cum}}{E_{FPV\ Penman\ \ cum}} * 100$$

EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

Test validation for the proposed models

Biviere Lake in Lentini (CT) Italy

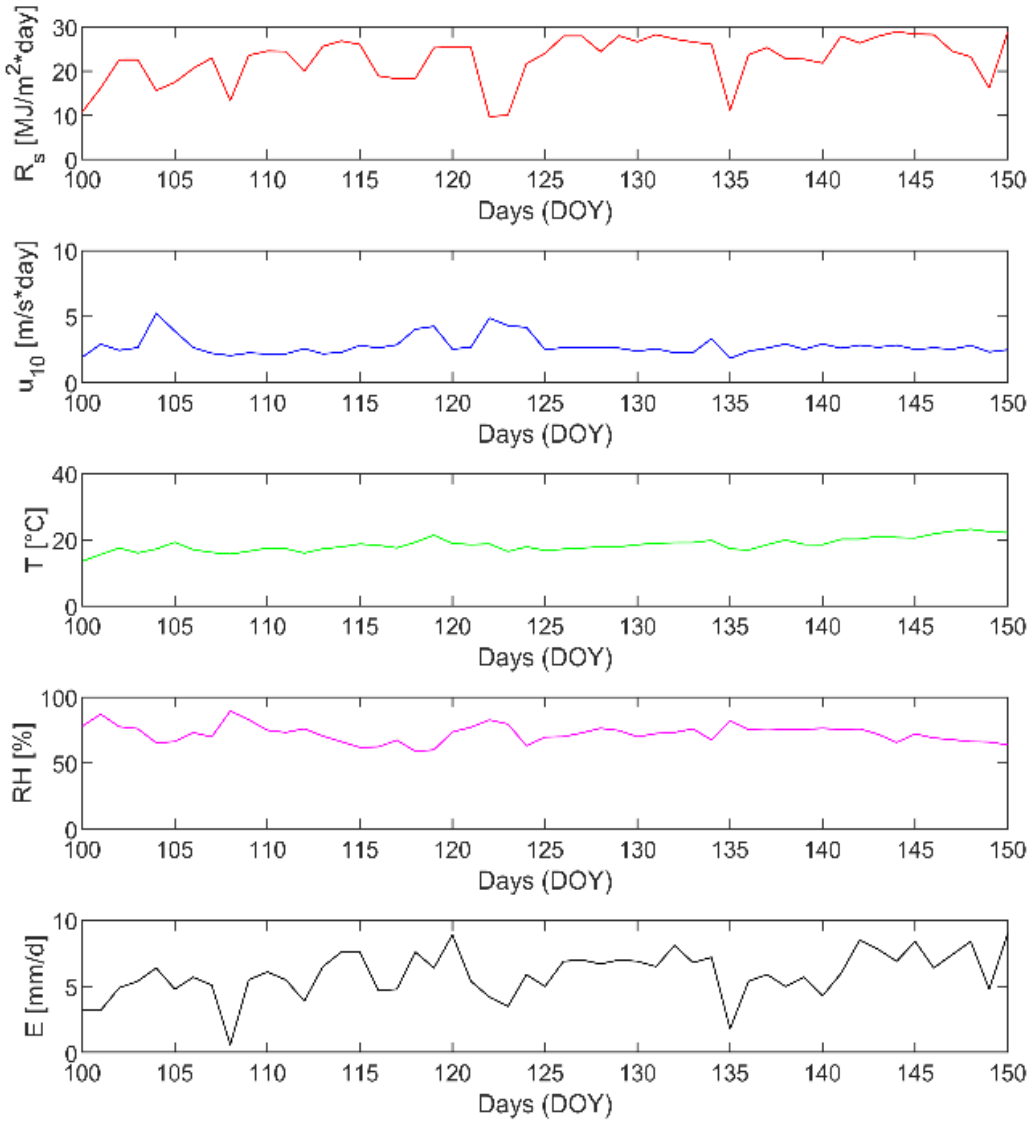
Meteo station by EGP

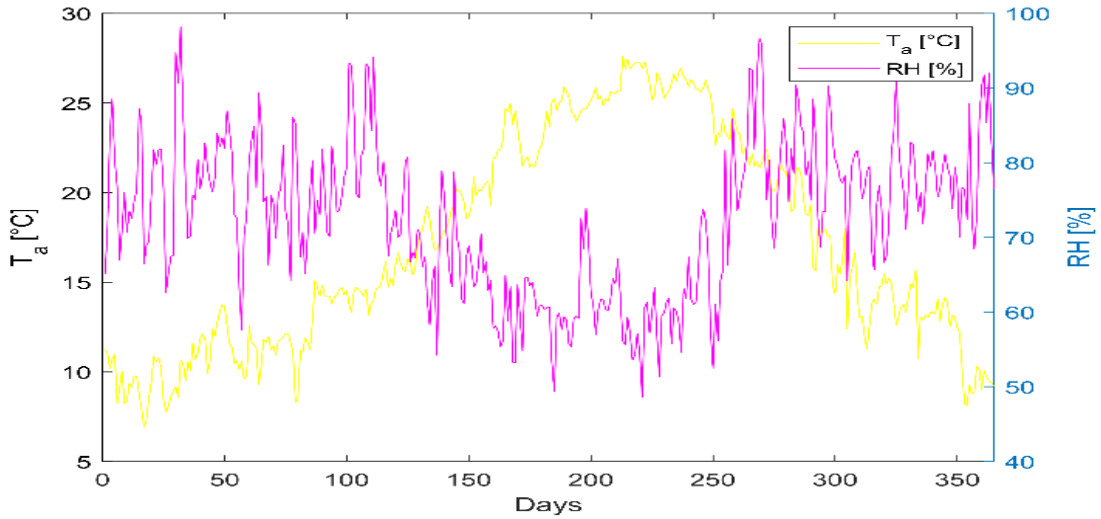
FPVs by EGP

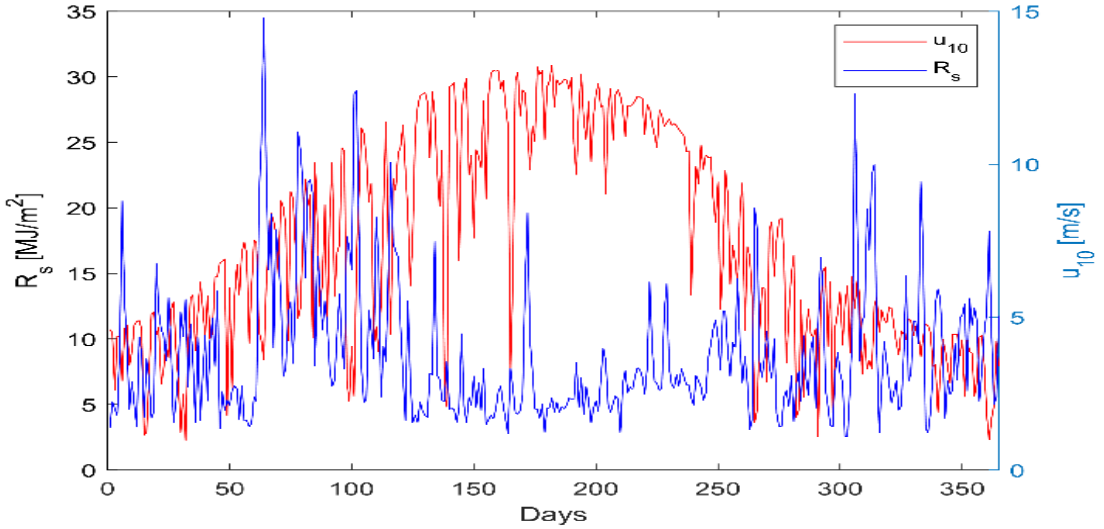
A practical application has been conducted with the aim to evaluate the accuracy of the results carried out by the proposed evaporation models. With this aim experimental observations on weather climate (ambient temperatures, solar radiation, wind velocity, humidity) as well the measure of the evaporation rate were used. These data have been collected by the climate station owned by the EGP (37°24'41.4"N 15°02'38.4"E, IT). As case study the Lentini Lake, located at lat. 37°19′22.8″N and long 14°57′00″E, water body altitude 18 m a.s.l., depth of water Z=10 m, lake water body area, A=12 km^2 , was chosen to compare the results of the proposed EVMs with experimental observations.

EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

Meteo data



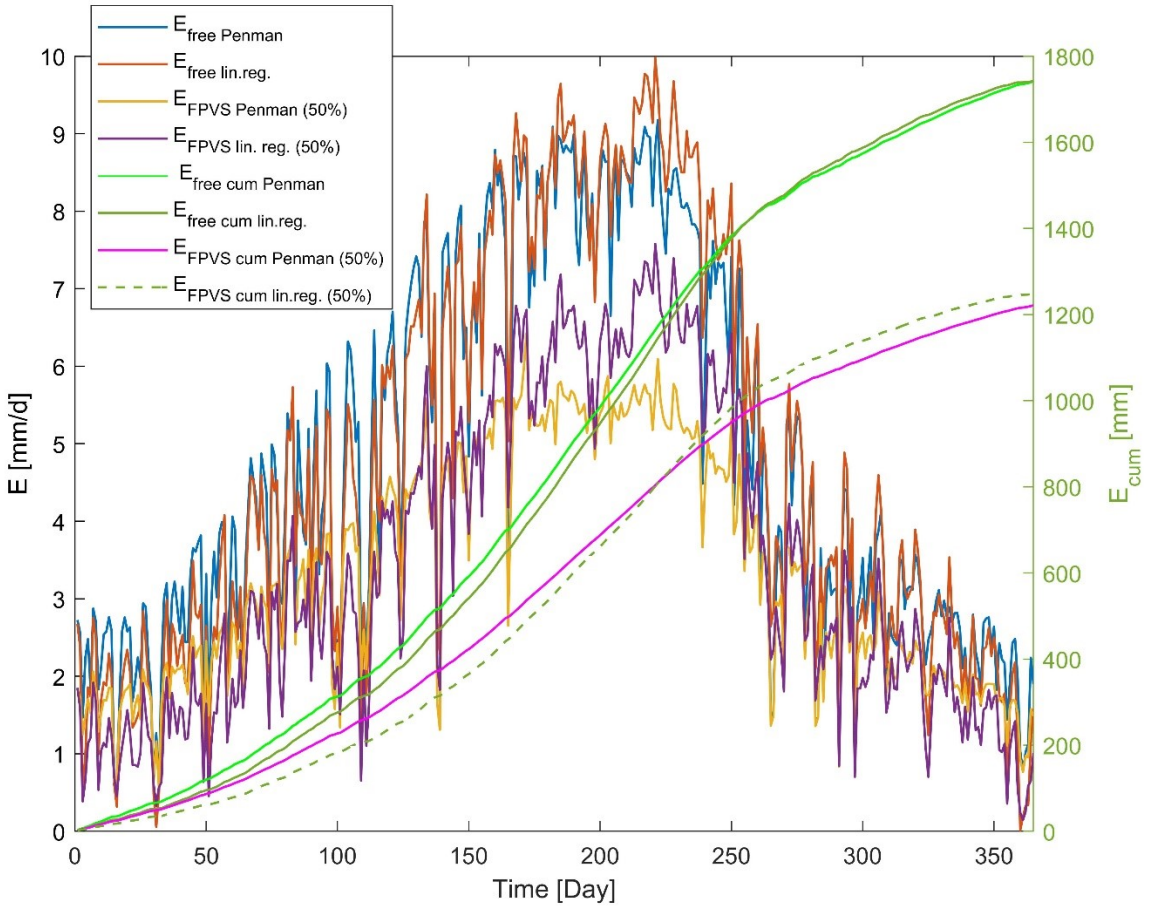




EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

Suspended systems results

For this type of installation, the evaporation was calculated by the proposed EVM model as a function of the percentage of covered area. These model take into account of the reduction of the solar energy incident on the water surface.



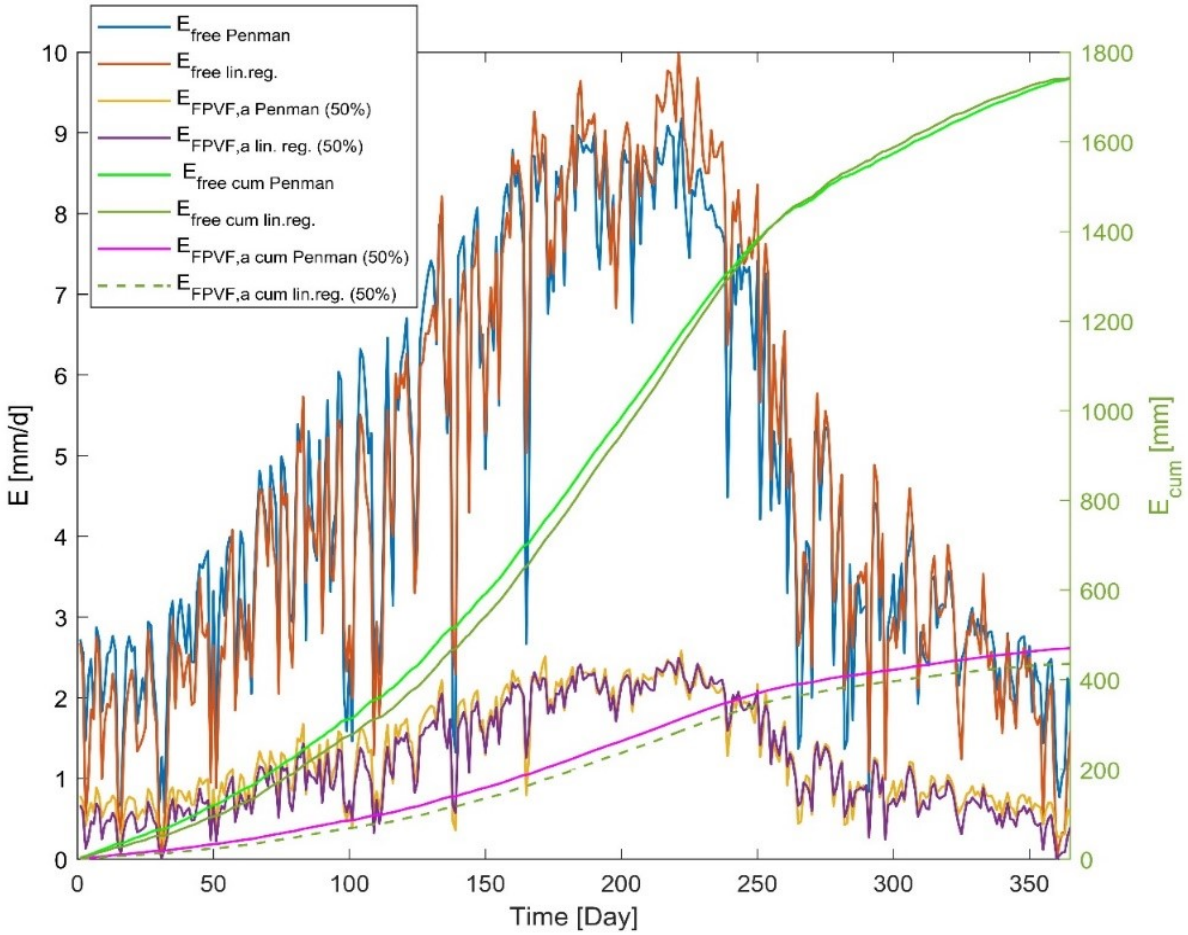
Daily and cumulated evaporation for free and 50% of covered water surface by suspended FPVs

Percentage of covering [%]	0 (free surface)	10	30	50	70	100
$E_{FPVS\ cum\ Penman}$ $[mm\ y^{-1}]$	1742	1638	1429	1221	1013	701
$E_{FPVS\ cum\ lin.reg.}$ $[mm\ y^{-1}]$	1743	1644	1446	1248	1051	754
$\varepsilon_{FPV\ cum}$ $[\%]$	-	-0.39	-1.17	-2.22	-3.69	-7.55
$\Delta E_{FPVS\ cum\ Penman}$ $[mm\ y^{-1}]$	-	104	312	520	728	1041
$\Delta E_{FPVS\ cum\ lin\ reg.}$ $[mm\ y^{-1}]$	-	99	297	494	692	989
η $[\%]$	-	6	18	30	42	60

Yearly Water evaporation for suspended FPVs

EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

FPVF $_a$ systems results



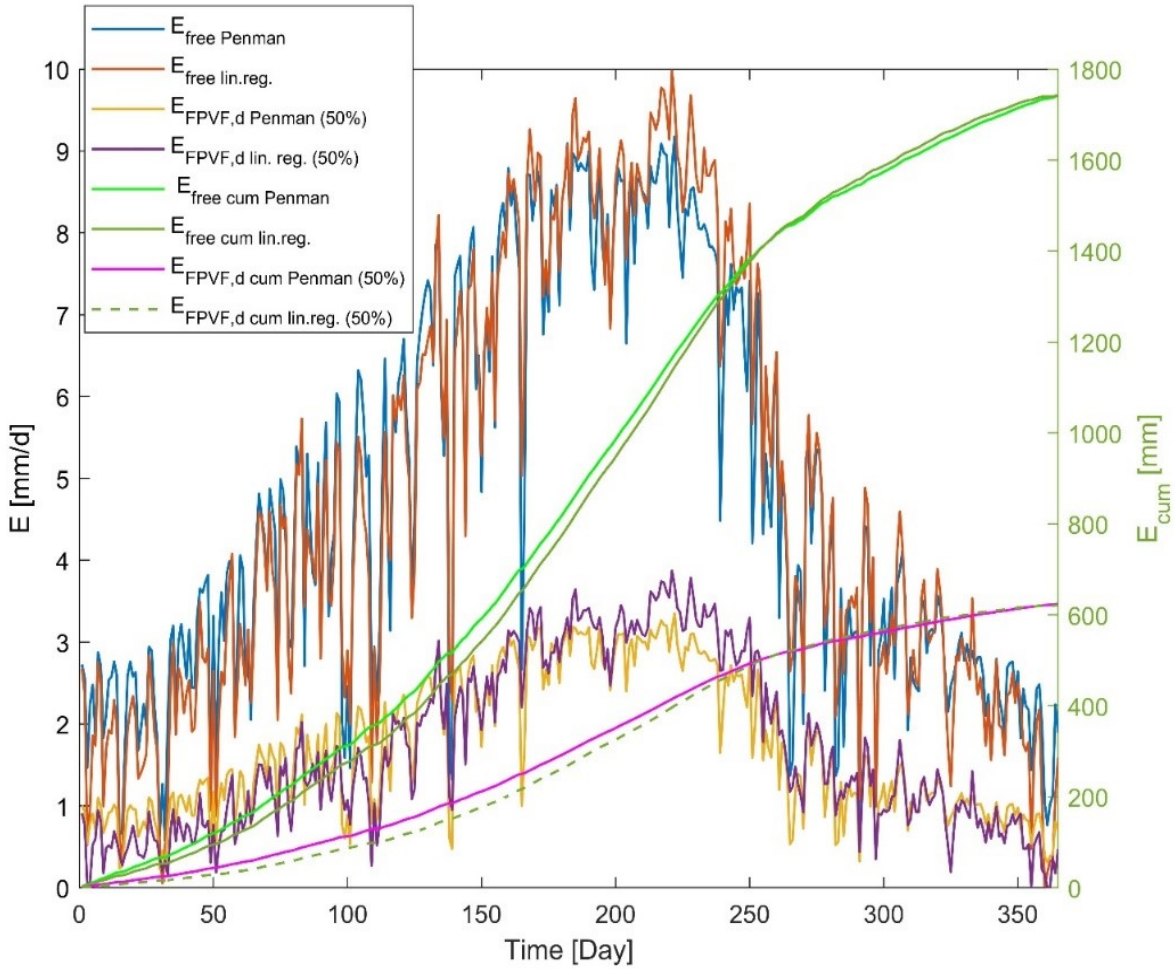
Percentage of covering [%]	0 (free surface)	10	30	50	70	100
$E_{FPVF,a\ cum\ Penman}$ $[mm\ y^{-1}]$	1742	1423	883	471	186	0
$E_{FPVF,a\ cum\ lin.reg.}$ $[mm\ y^{-1}]$	1743	1412	854	436	171	0
$\varepsilon_{FPV\ cum}$ $[\%]$	-	0.82	3.30	7.45	8.29	-
$\Delta E_{FPVF,a\ cum\ Penman}$ $[mm\ y^{-1}]$	-	318	859	1271	1555	1742
$\Delta E_{FPVF,a\ cum\ lin\ reg.}$ $[mm\ y^{-1}]$	-	331	889	1307	1572	1743
η $[\%]$	-	18	49	73	89	100

Daily and cumulated evaporation for free and 50% of covered water surface by floating FPVF $_a$

Yearly Water evaporation for floating FPVF $_a$

EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

FPVF $_d$ systems results



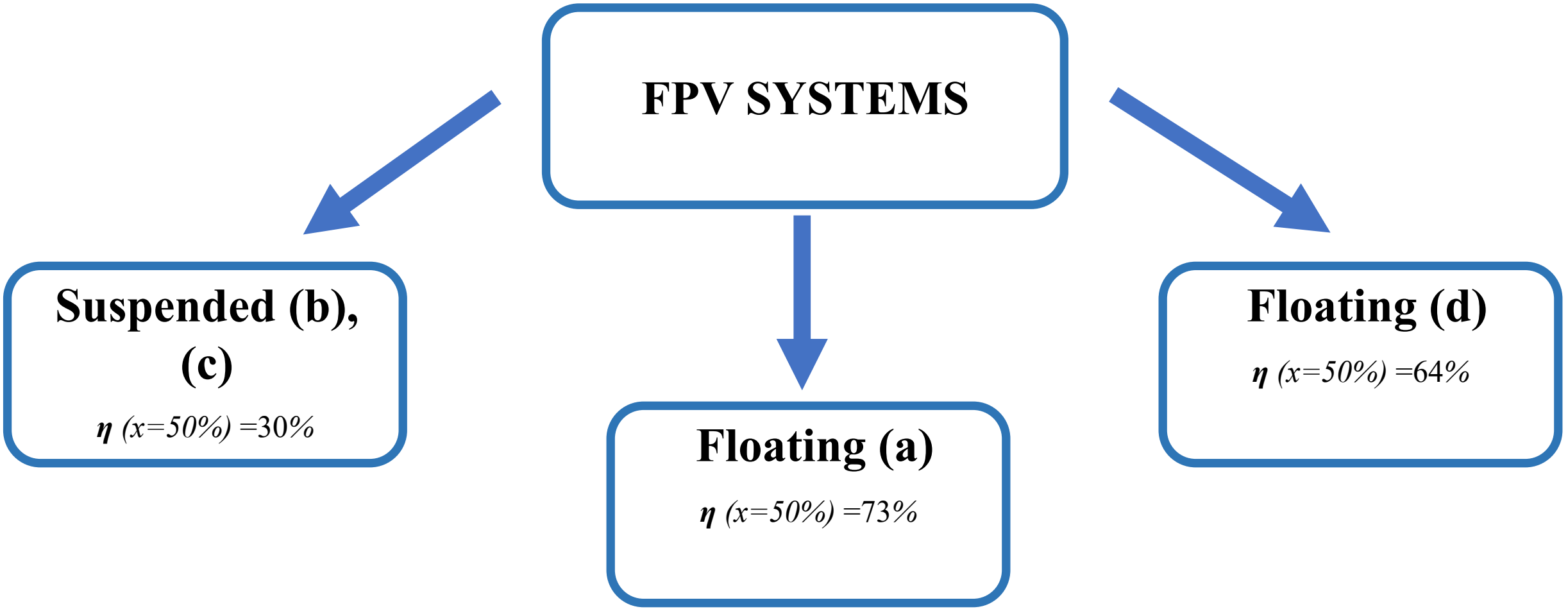
Daily and cumulated evaporation for free and 50% of covered water surface by floating FPVF $_d$

Percentage of covering [%]	0 (free surface)	10	30	50	70	100
$E_{FPVF,d\ cum\ Penman}$ $[mm\ y^{-1}]$	1742	1479	1012	624	315	0
$E_{FPVF,d\ cum\ lin.reg.}$ $[mm\ y^{-1}]$	1743	1478	1010	621	313	0
$\varepsilon_{FPV\ cum}$ [%]	-	0.01	0.18	0.40	0.57	-
$\Delta E_{FPVF,d\ cum\ Penman}$ $[mm\ y^{-1}]$	-	263	730	1118	1427	1742
$\Delta E_{FPVF,d\ cum\ lin\ reg.}$ $[mm\ y^{-1}]$	-	264	733	1121	1430	1743
η [%]	-	15	42	64	82	100

Yearly Water evaporation for floating FPVF $_d$

EVAPORATION FOR WATER SURFACES PARTIALLY COVERED BY FPVS

Considerations



CONCLUSION

- Models have been developed that have allowed to obtain the optimal geometric configurations for the energy yield of floating photovoltaic systems, in particular for different technologies (monofacial and bifacial) and locations (Catania, Frankfurt).
- With the geometrical configurations examined, it is possible to obtain a gain due to bifacity, from 7% up to 11%.
- Models have been developed that are able to predict the reduction of the evaporation rate due to the partial coverage of water surfaces, in relation to the characteristics of the floating systems.
- It has been shown that by covering 50% of the water surface it is possible to reduce from 30 to 73% of evaporated water.

PUBLICATIONS

1. F. Bontempo S., G. M. Tina, A. Gagliano, S. Nižetić, “Floating photovoltaic plants over water basins: Assessment of evaporation rate’’, International Journal of Energy Research, 2019.
2. F. Bontempo S., G. M. Tina, A. Gagliano, S. Nižetić, “Study of the evaporation reduction in water basins with floating photovoltaic plants”, 4th International Conference on Smart and Sustainable Technologies (SpliTech), 2019.
3. F. Bontempo S., G. M. Tina, A. Gagliano, “ Comparison of evaporation models for free water basins surfaces, ”, 4th International Conference on Smart and Sustainable Technologies (SpliTech), 2019.
4. G. M. Tina, F. Bontempo S., L. Merlo, F. Bizzarri, “Comparative analysis of monofacial and bifacial PV modules for floating power plants”, 14th Conference on Sustainable Development of Energy, Water and Environment Systems, 2019.

PARTICIPATION IN CONFERENCES

1. 4th International Conference on Smart and Sustainable Technologies (SpliTech), 2019.
2. 14th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES), 2019

CORRELATOR IN

1. Master thesis: “Valutazione degli effetti di sistemi fotovoltaici flottanti sull’evapotraspirazione nei bacini idrici’’ degree course: Ingegneria per l’Ambiente e il territorio, candidate: Salvatore Drago

ACTIVITIES ABROAD

1. Three-month stage at the LTEF laboratory of the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture at the University of Split.

Thank you for your attention

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