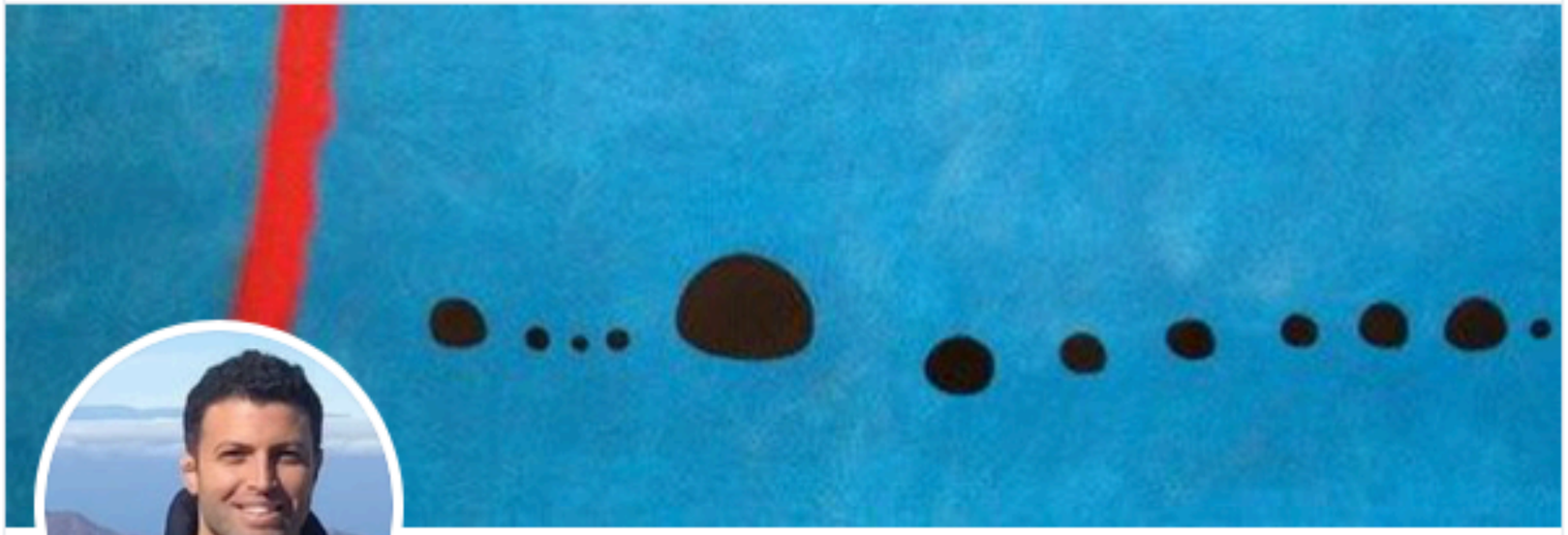
Gestión inteligente de la desalación con el objetivo de maximizar la integración de energías renovables en islas

Pedro J. Cabrera Santana
Group for the Research on Renewable Energy Systems
Profesor del Departamento de Ingeniería Mecánica

22 de noviembre de 2022

Ciclo de Conferencias del Máster UNED-UCM y del Programa de Doctorado en "Ingeniería de Sistemas y de Control"



Pedro Cabrera

@PedroJCabrera_

Researcher at #ULPGC, working on #Renewables, #Water and #ArtificialIntelligence to #plan alternative #SmartEnergySystems.

@CI_CEA coordinator

grres ULPGC
group for the research on renewable energy systems

DESAL+
DESALINATION LIVING LAB

CEA
IFAC
comité español de automática

CONTROL INTELIGENTE

ULPGC Universidad de Las Palmas de Gran Canaria | Escuela de Ingenierías Industriales y Civiles

eIIC

COMPONENTES DEL GRUPO

grres ULPGC
group for the research on
renewable energy systems

COORDINADOR:

José Antonio Carta González

Sergio Velázquez Medina

Jaime González Hernández

Julieta Schallenberg

Pedro Jesús Cabrera Santana

Alexis Lozano Medina

Noemi Melián Martel

Beatriz Del Río Gamero

Ana María Blanco-Marigorta

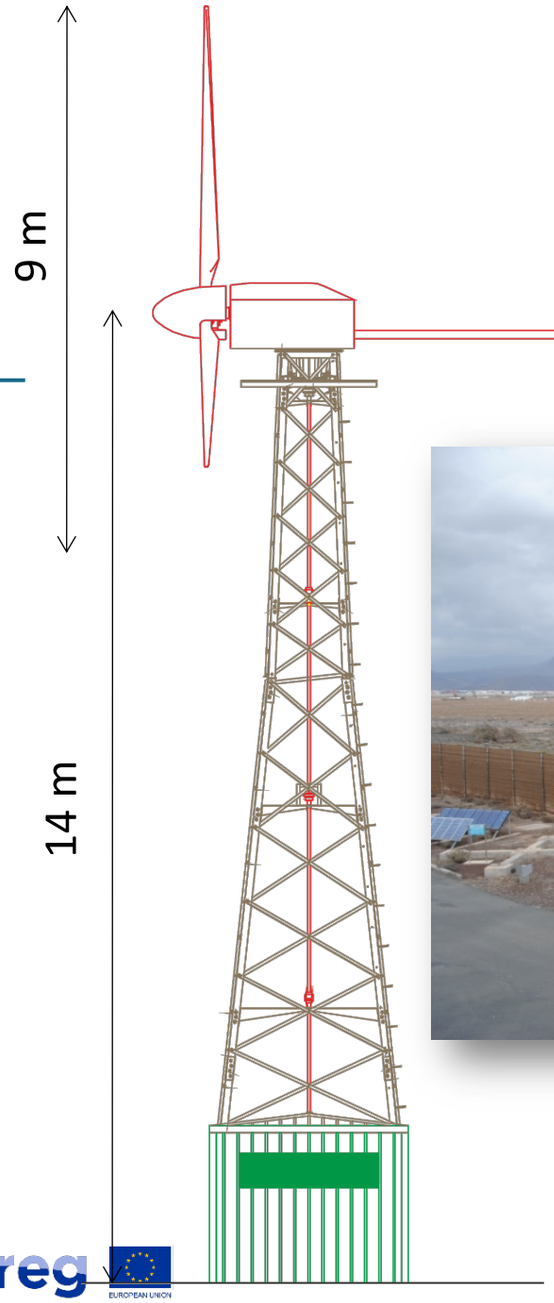
Enrique Rosales Asensio

DESAL+ 5des

MAC 2014-2020 Cooperación Territorial

Interreg Fondo Europeo de Desarrollo Regional EUROPEAN UNION

Desalación Eólica



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Interreg
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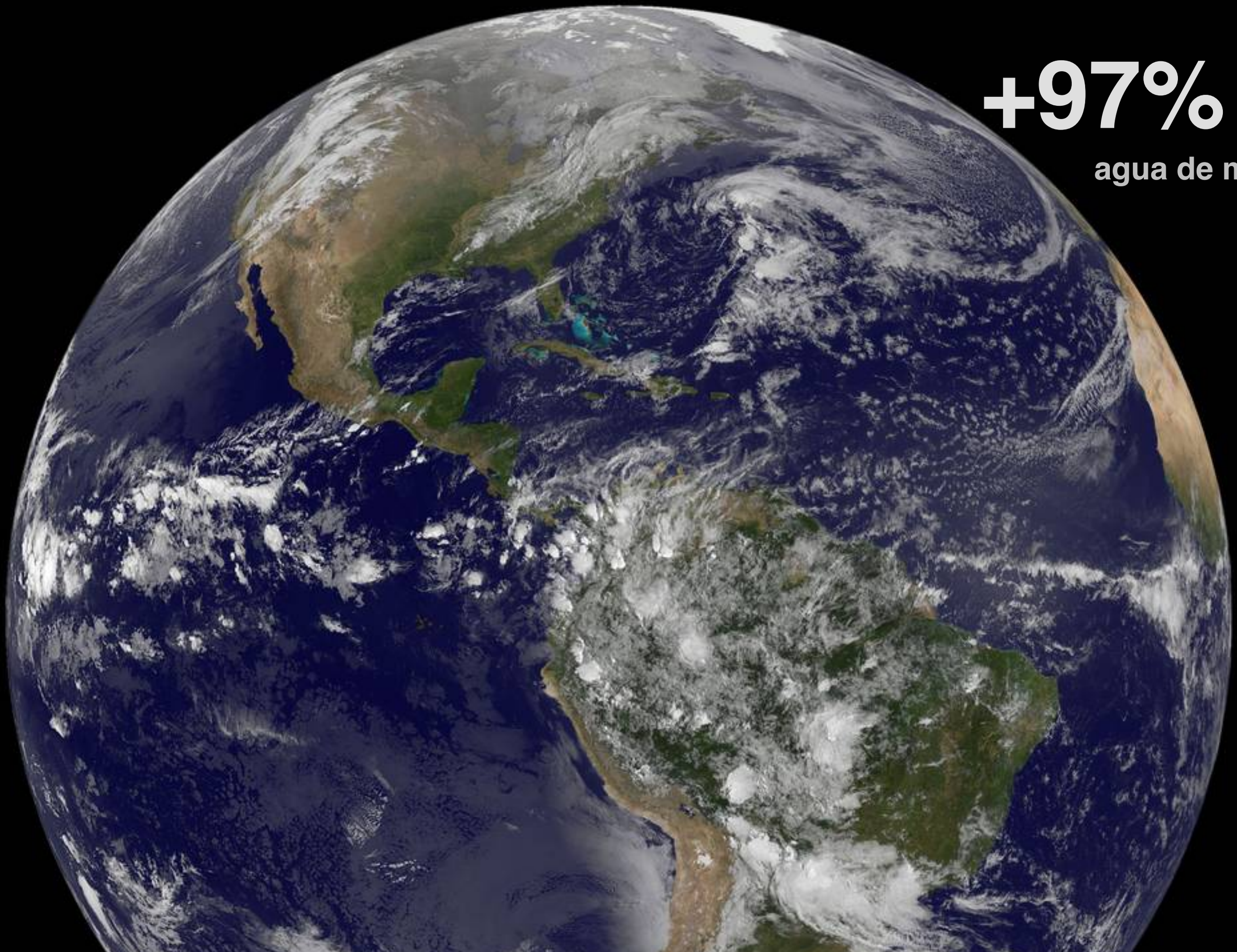
El café con sabor a sal

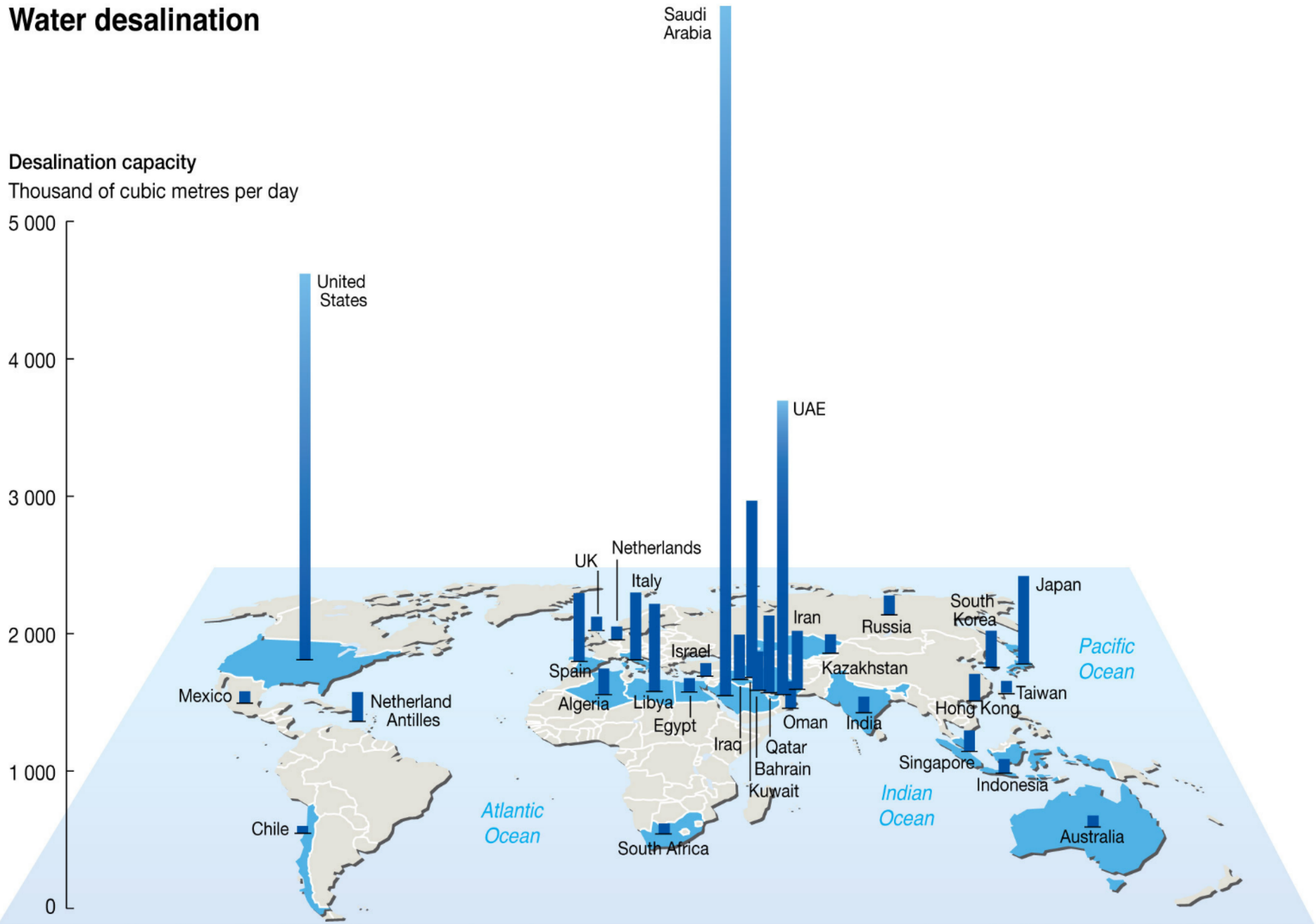
El problema del agua



+97%

agua de mar

Water desalination



Note: only countries with more than 70 000 cubic metres per day are shown.

Sources: Pacific Institute, The World's Water, 2009.

Los dos principales tipos de tecnologías en desalación

Separación con membranas

Destilación térmica

55%

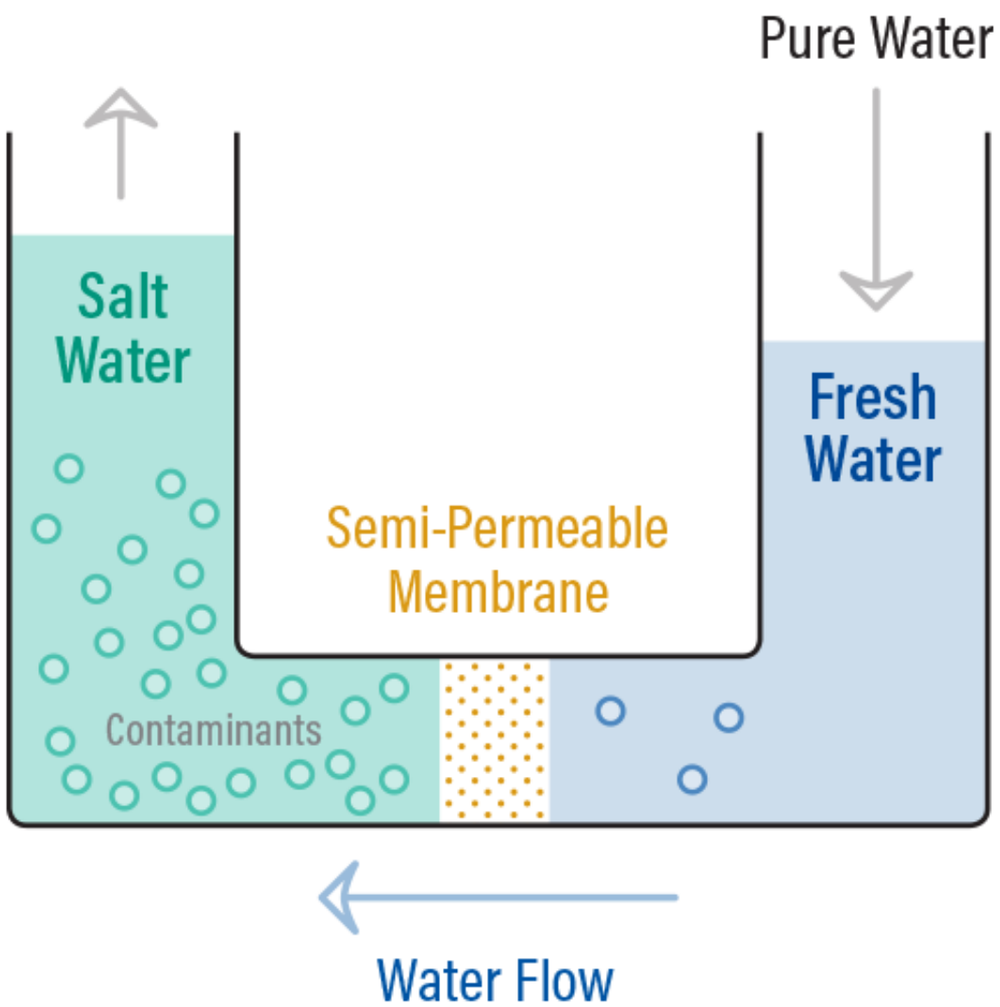
de la capacidad global instalada

Ósmosis Inversa

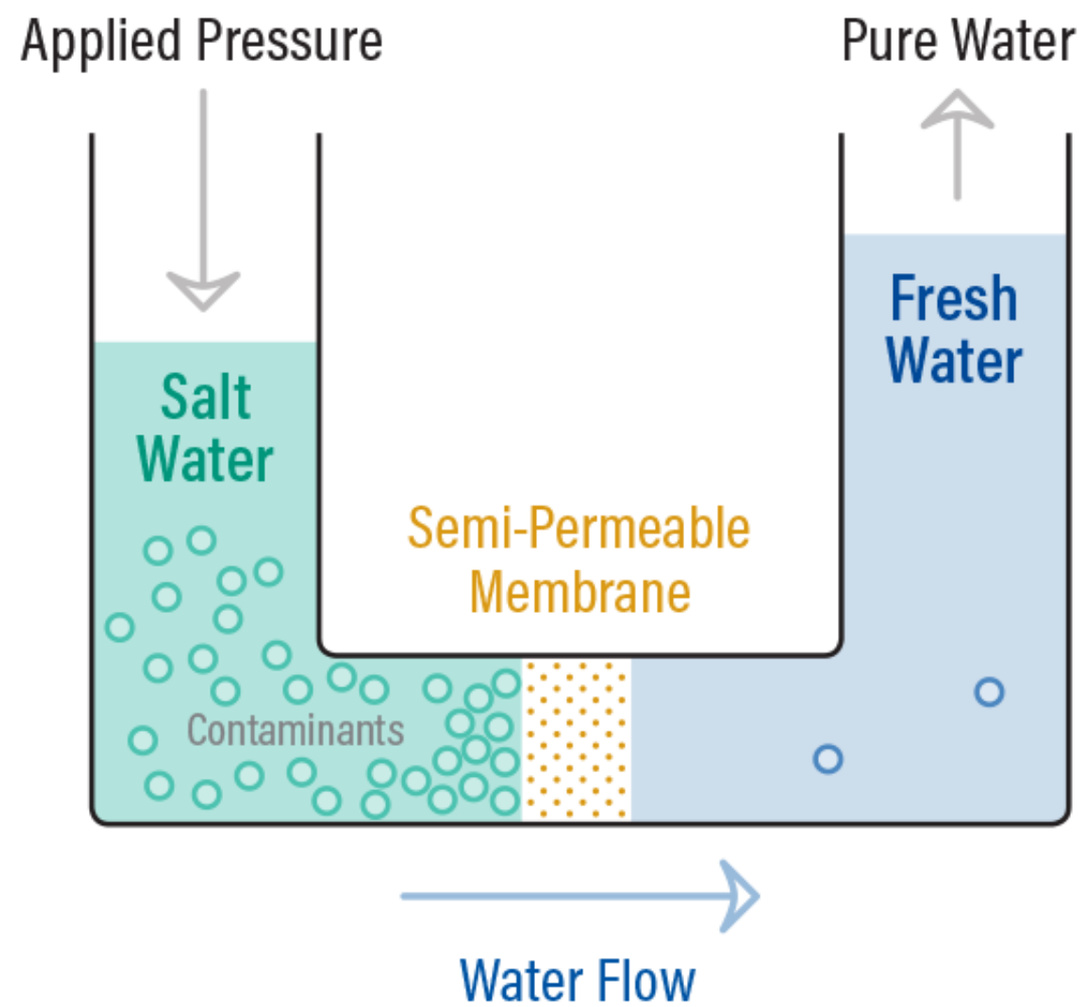
45%

Otras tecnologías

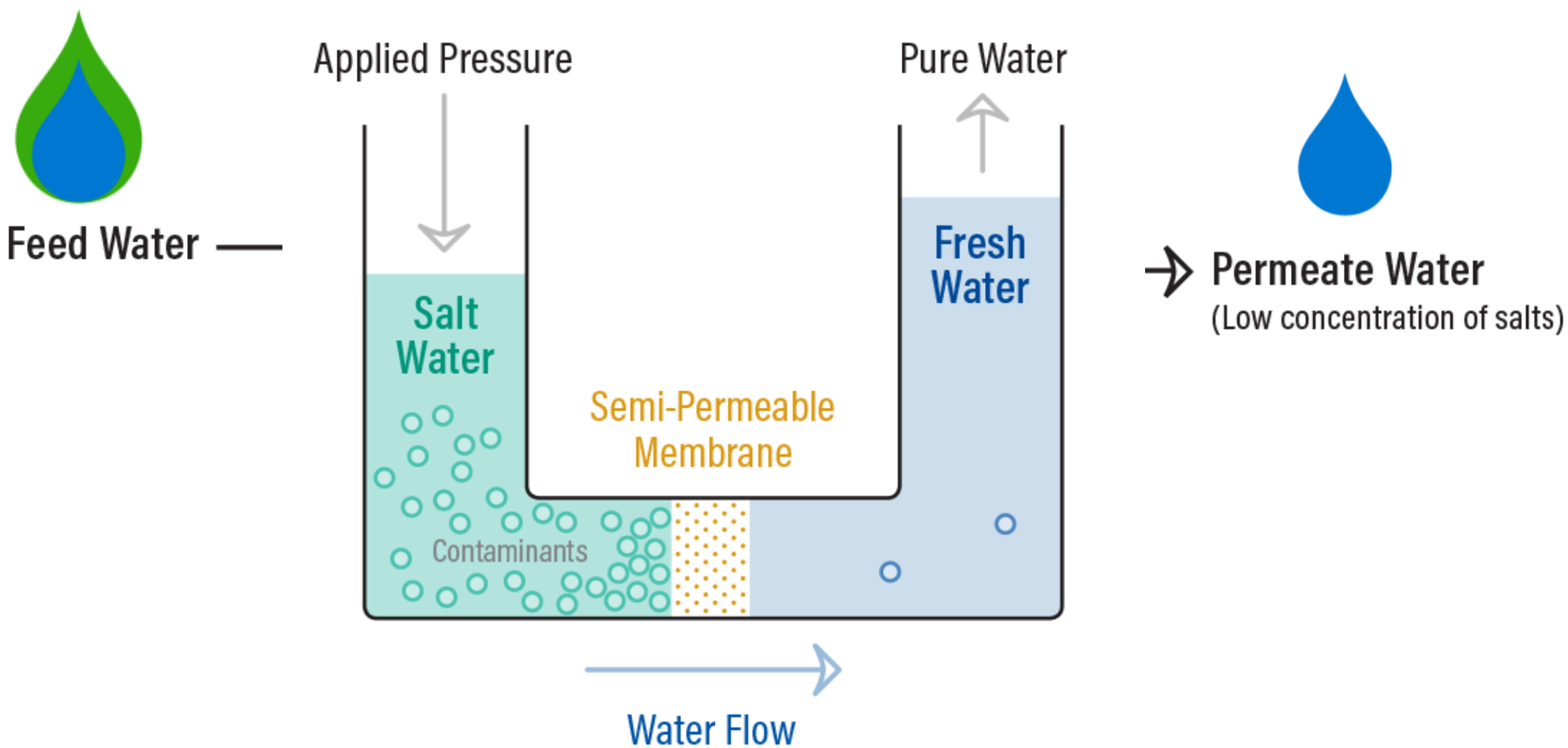
Osmosis



Reverse Osmosis



Reverse Osmosis



Problemas

Energía

Coste

Contaminación

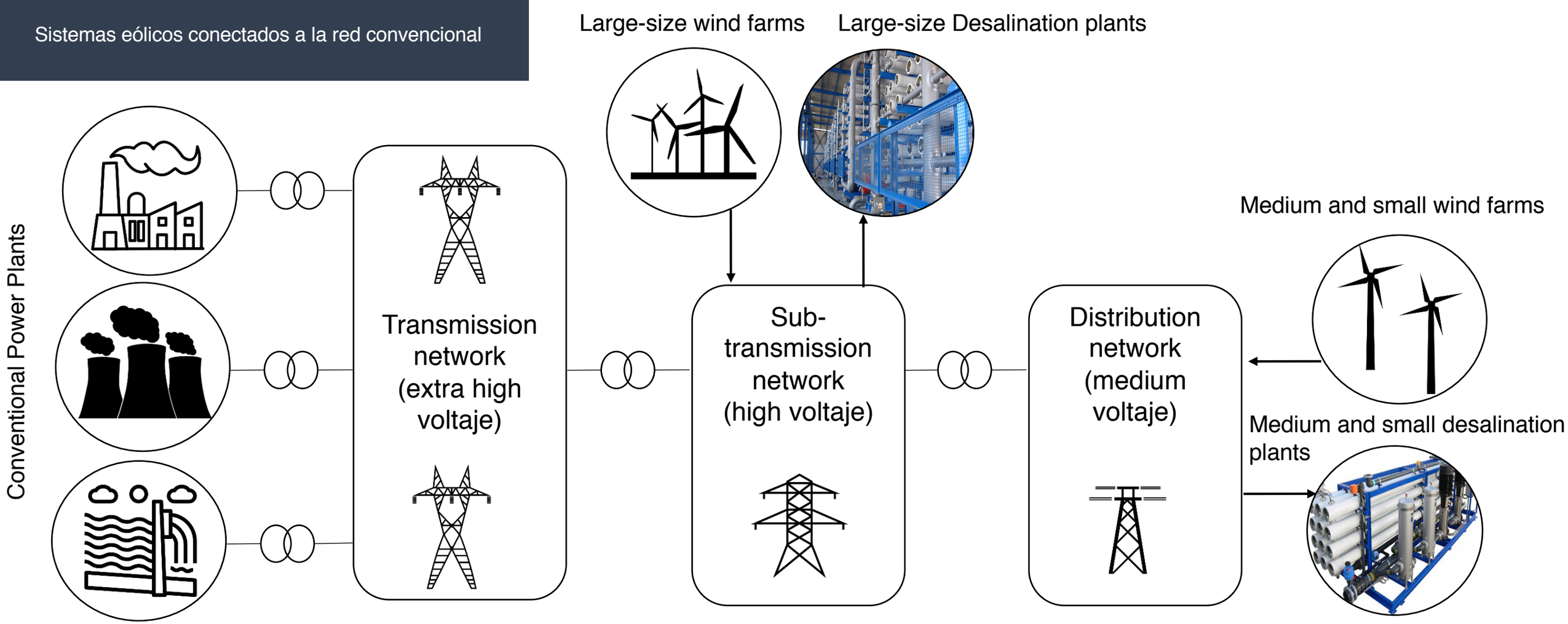
Sistemas de desalación accionados con energía eólica

Sistemas eólicos conectados a la red

Sistemas eólicos aislados de la red convencional

Sistemas de desalación accionados con energía eólica

Sistemas eólicos conectados a la red convencional



Sistemas de desalación accionados con energía eólica

Sistemas eólicos conectados a la red

Sistemas eólicos aislados de la red convencional

Sistemas eólicos autónomos

Sistemas híbridos

Sistemas de desalación accionados con energía eólica

Sistemas eólicos conectados a la red

Sistemas eólicos aislados de la red convencional

Sistemas eólicos autónomos

Sistemas híbridos

Electrical interface

Without energy storage systems

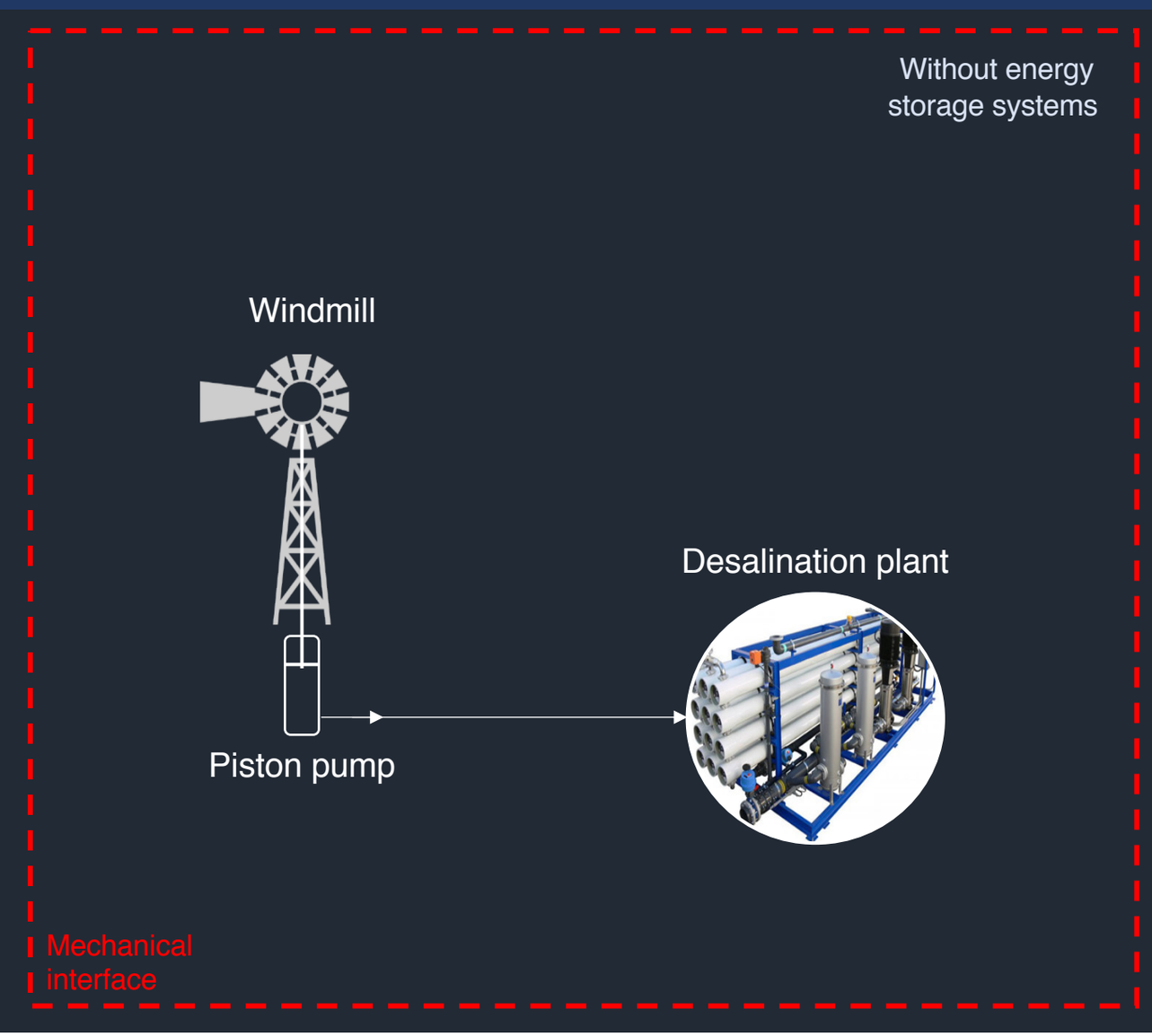
With energy storage systems

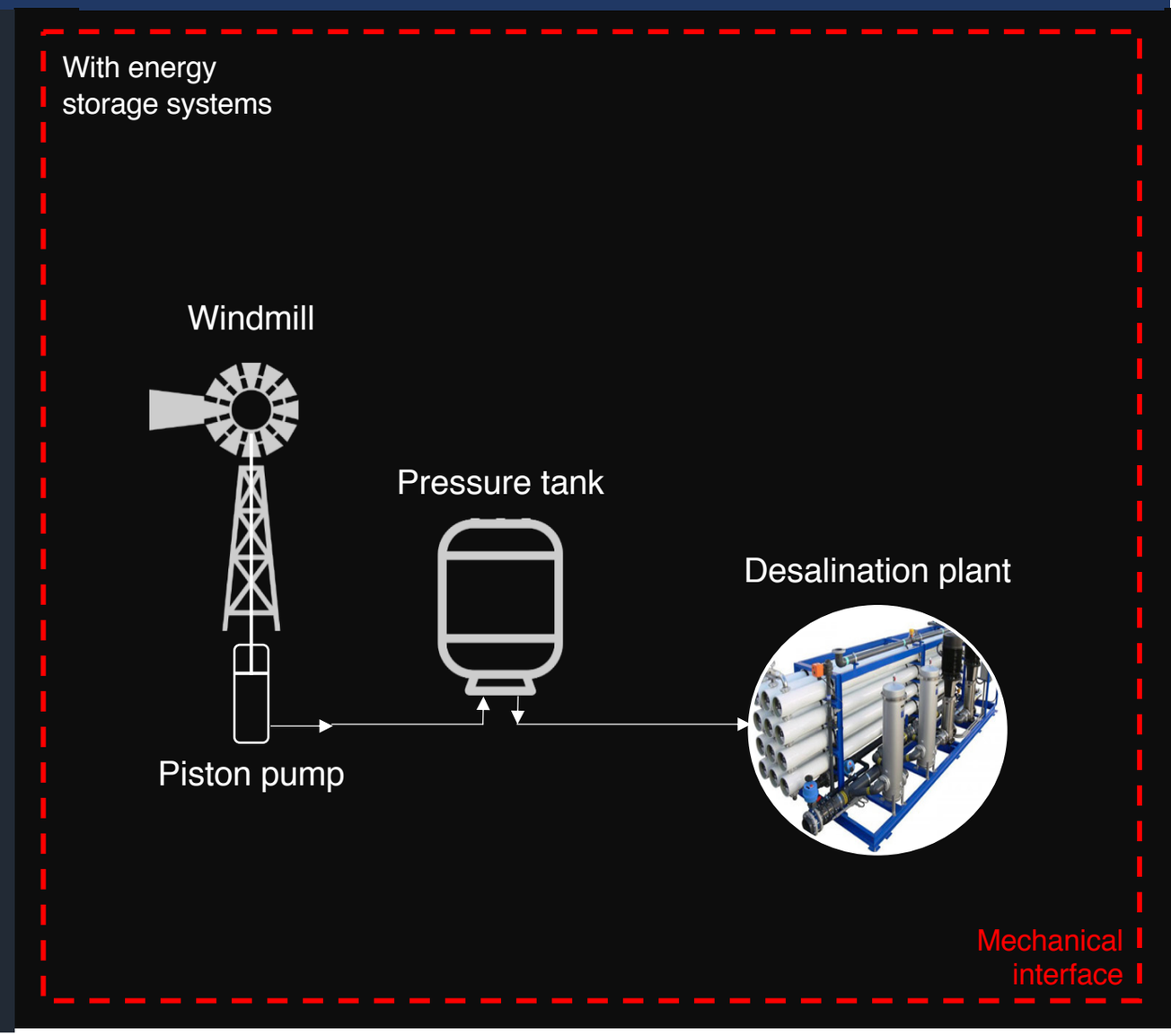
Mechanical interface

Sistemas de desalación accionados con energía eólica

Sistemas eólicos desconectados de la red convencional

Sistemas autónomos

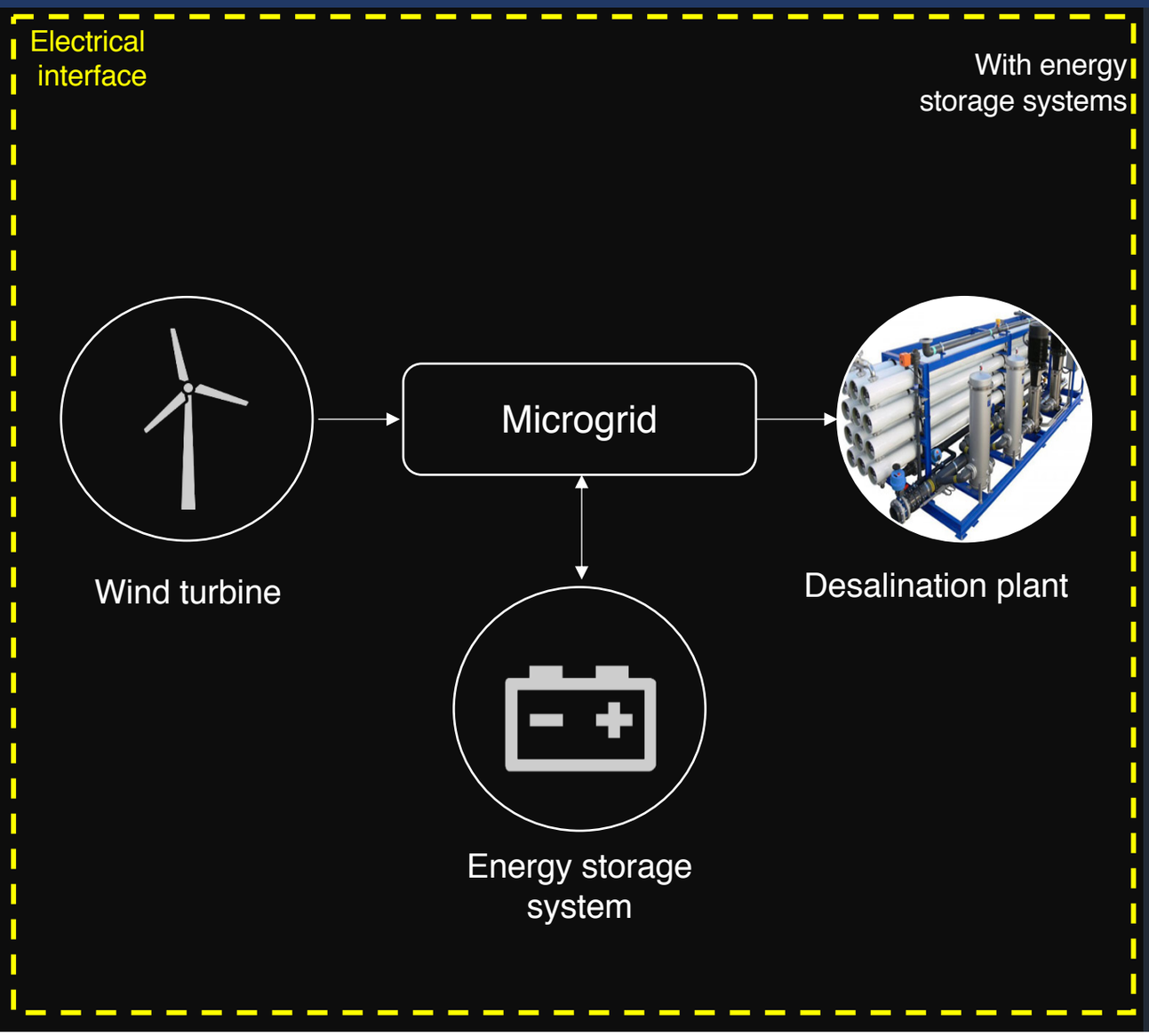


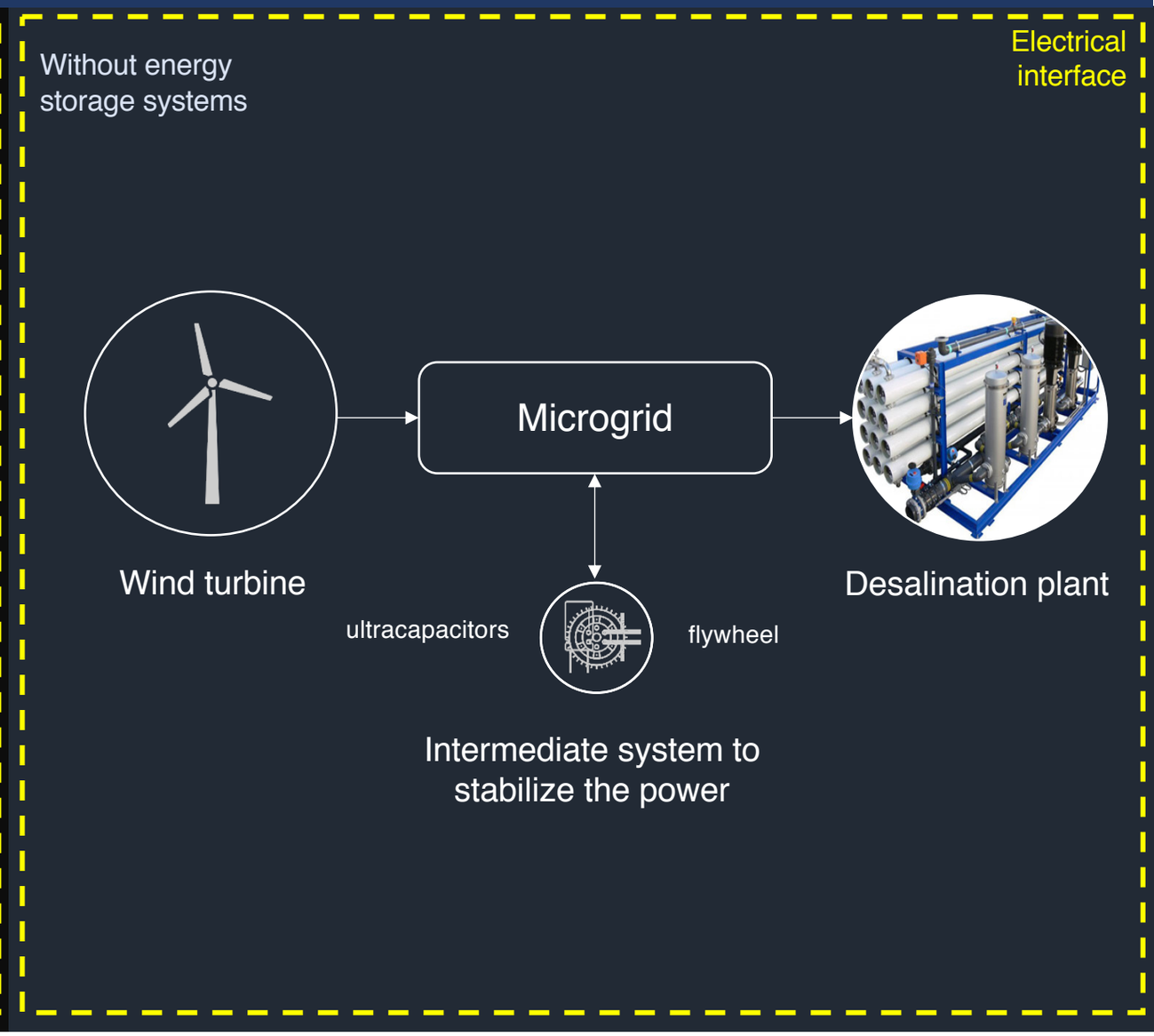


Sistemas de desalación accionados con energía eólica

Sistemas eólicos desconectados de la red convencional

Sistemas autónomos

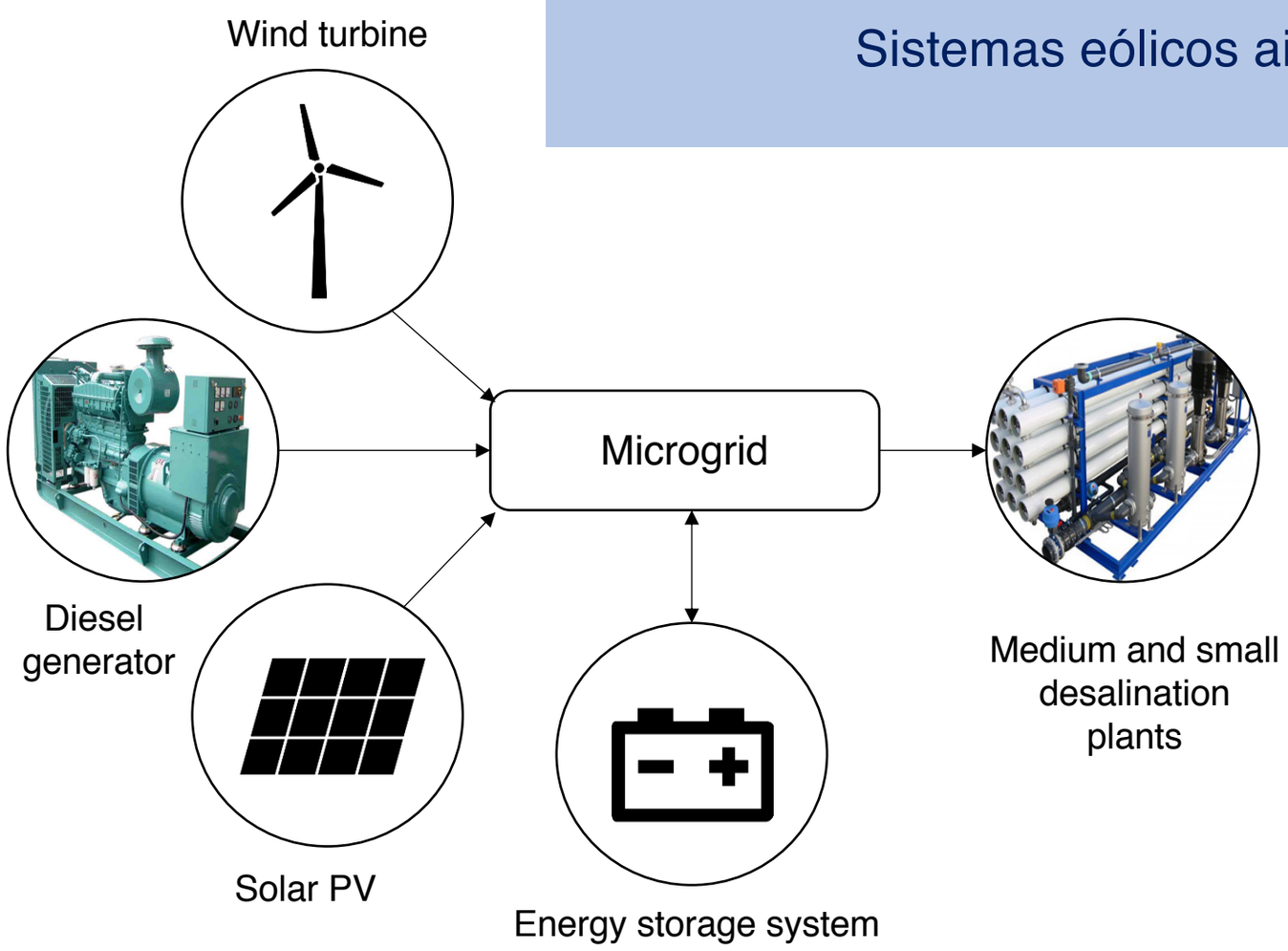




Sistemas de desalación accionados con energía eólica

Sistemas eólicos aislados de la red eléctrica

Sistemas híbridos

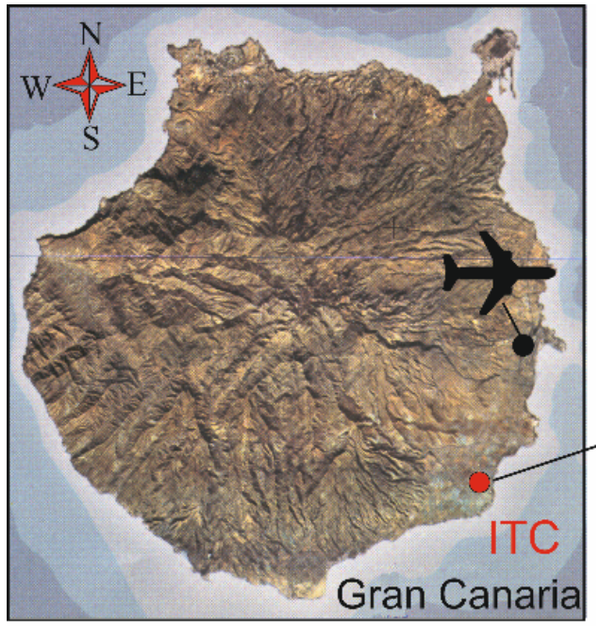


Objetivos generales

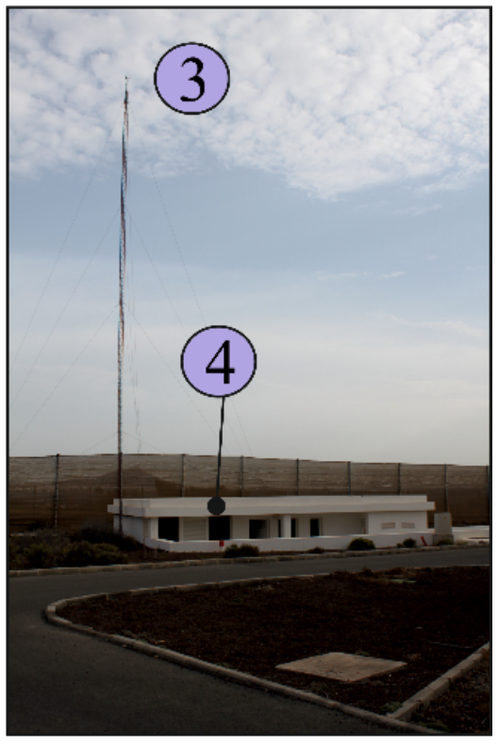
Incrementar la flexibilidad de operación de la planta desalinizadora

Incrementar el uso de Energías Renovables en Desalación

Prototipo



Latitude north: 27º49'4''
Longitude west: 15º25'27''

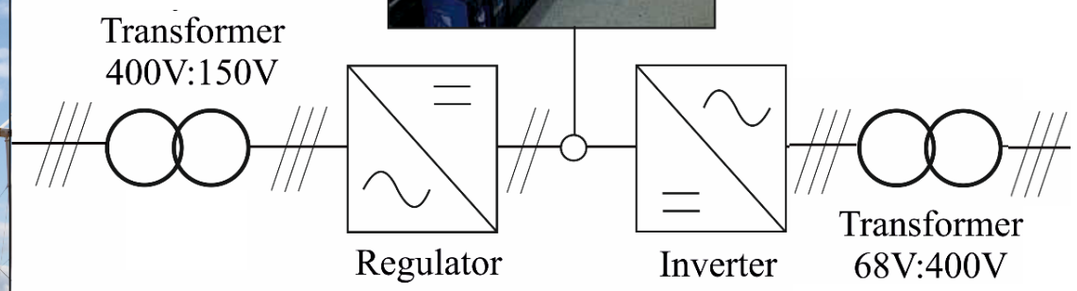


(1) Pumping center. (2) Product water reservoir. (3) Anemometer and wind vane. (4) Desalination plant house.

Materiales de partida (Proyecto AEROGEDESA)

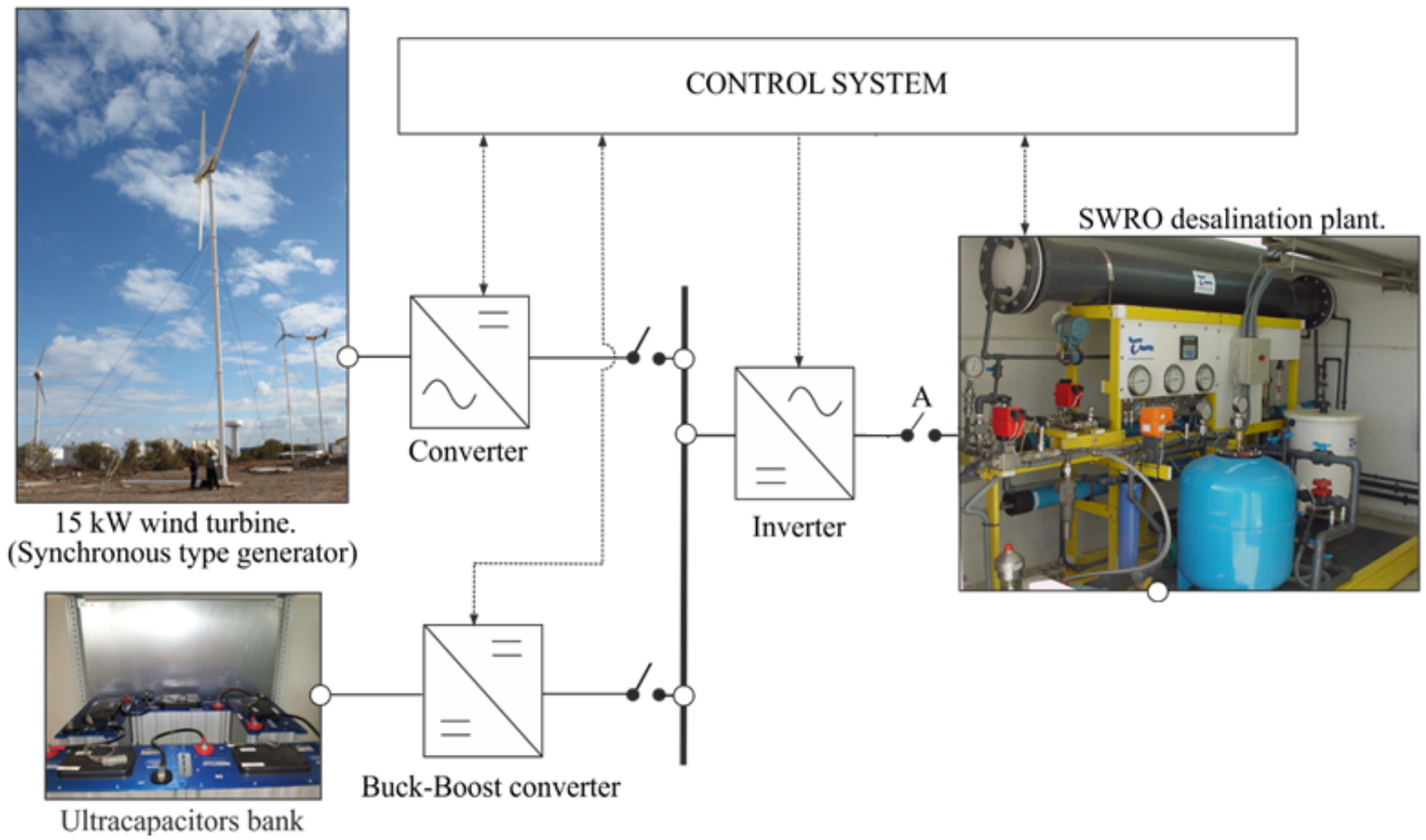
15 kW wind turbine.
(Asynchronous type generator)

Batteries (120 V. 190Ah)

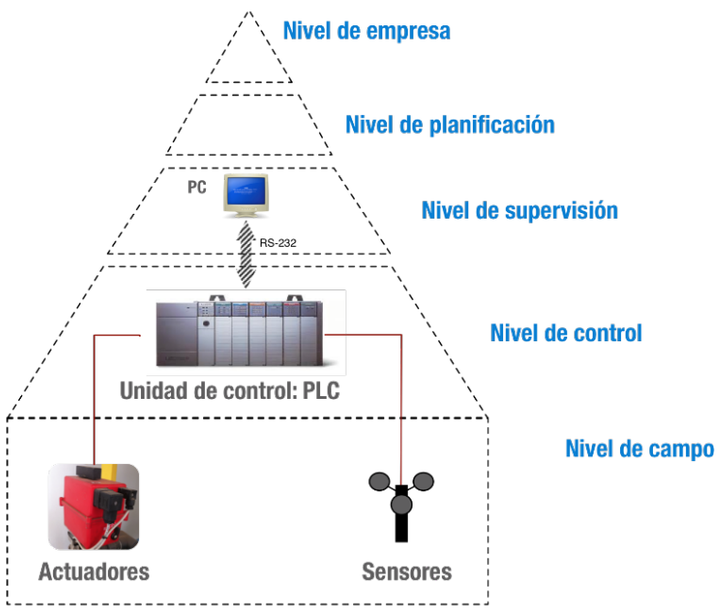


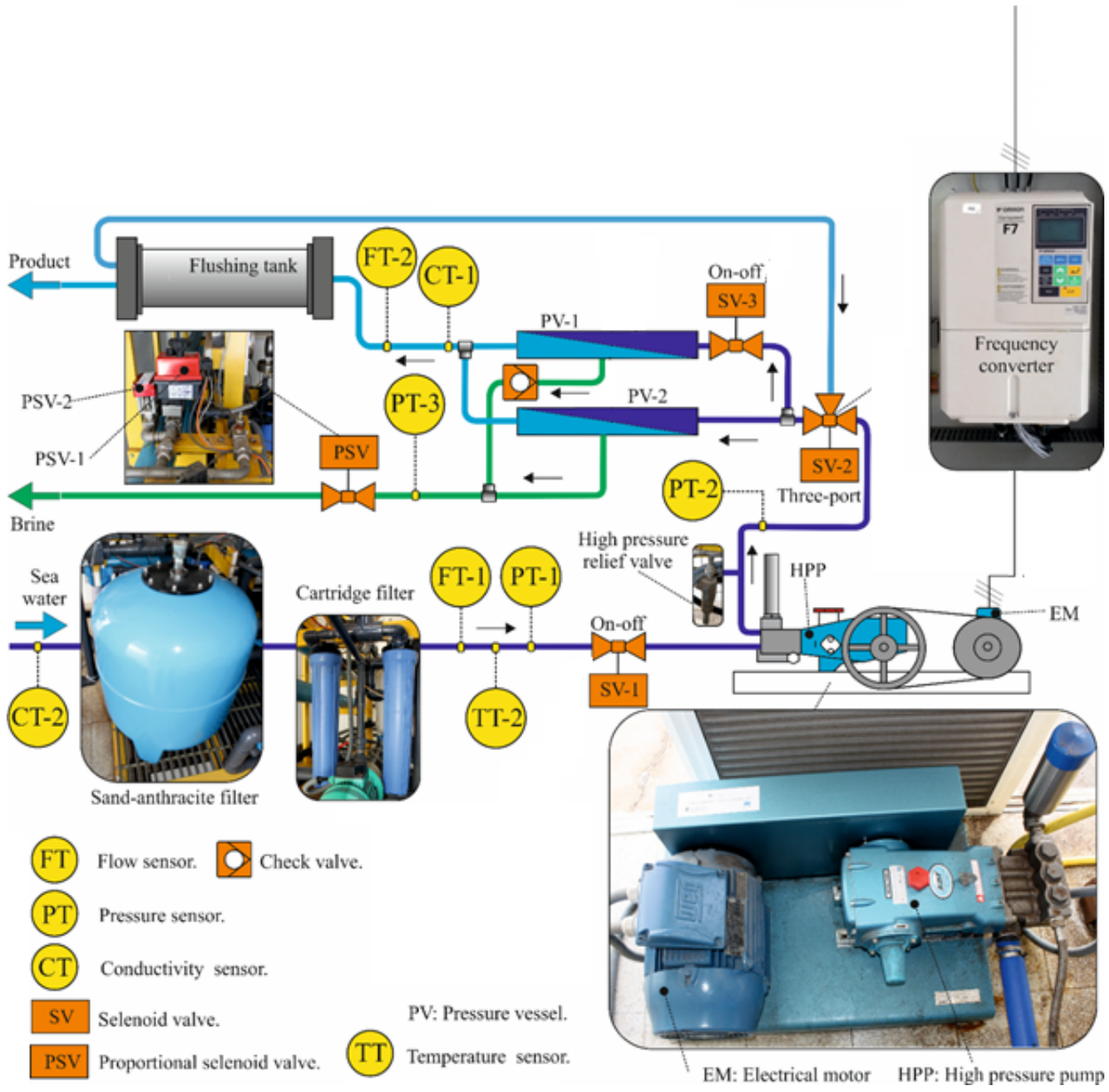
SWRO desalination plant. (18 m^3/day)

Nueva idea de prototipo

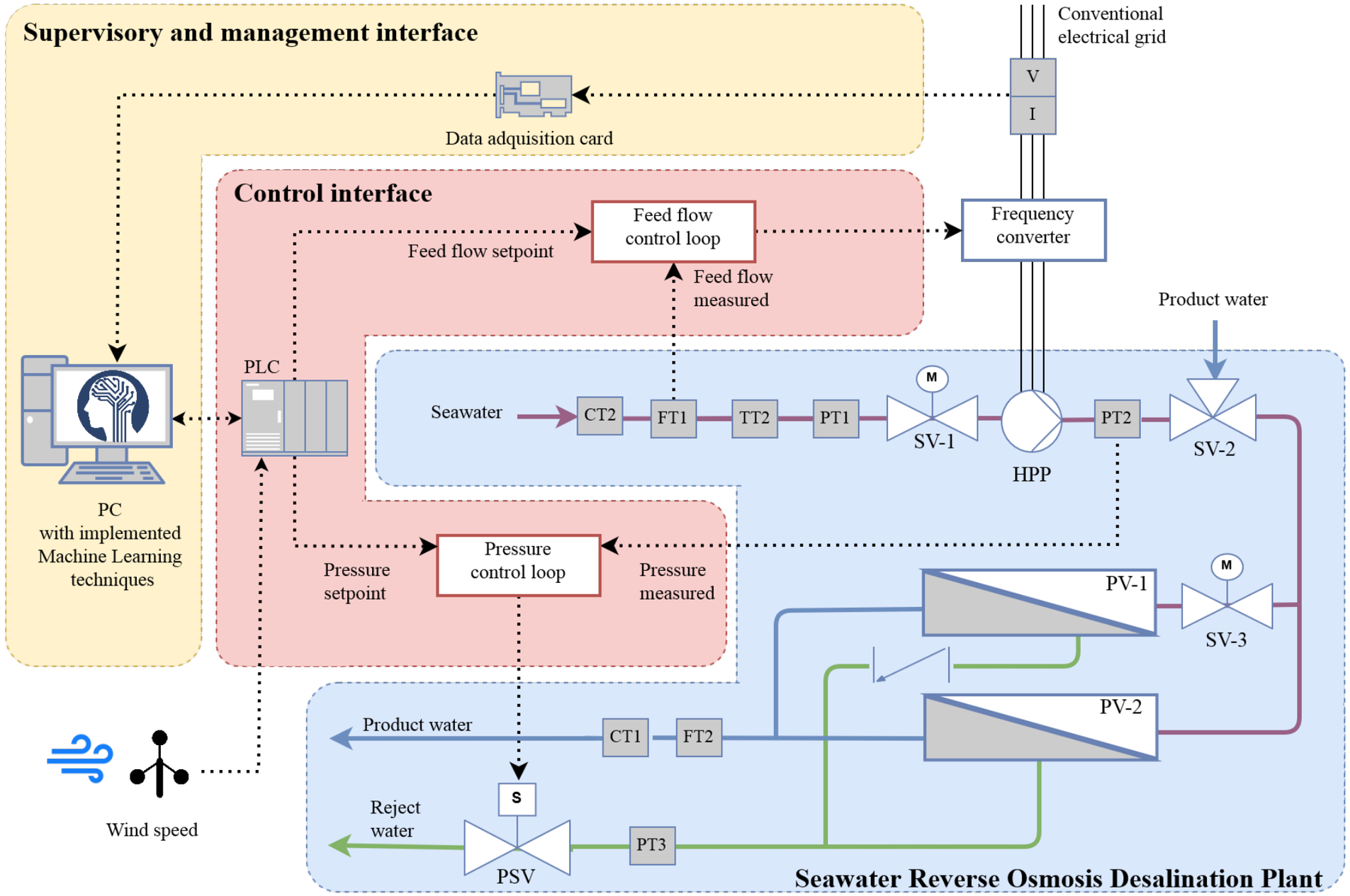


Configuración hidráulica y nuevos equipos para la planta desaladora





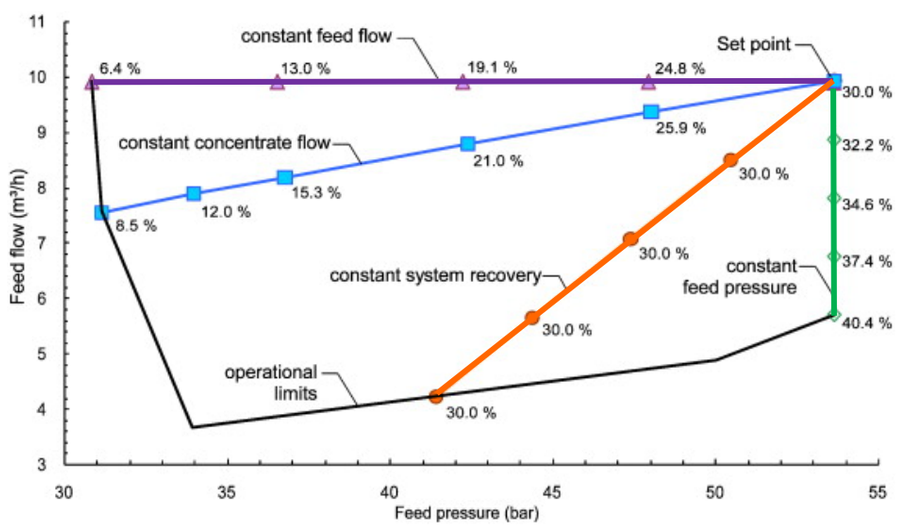
El sistema de control



Sistemas de desalación accionados con energía eólica

Sistemas eólicos desconectados de la red convencional

Sistemas autónomos



Pohl et al. [1] propose different operating strategies:

(a) constant feed pressure / variable feed seawater flow rate

(b) constant feed seawater flow rate / variable feed pressure

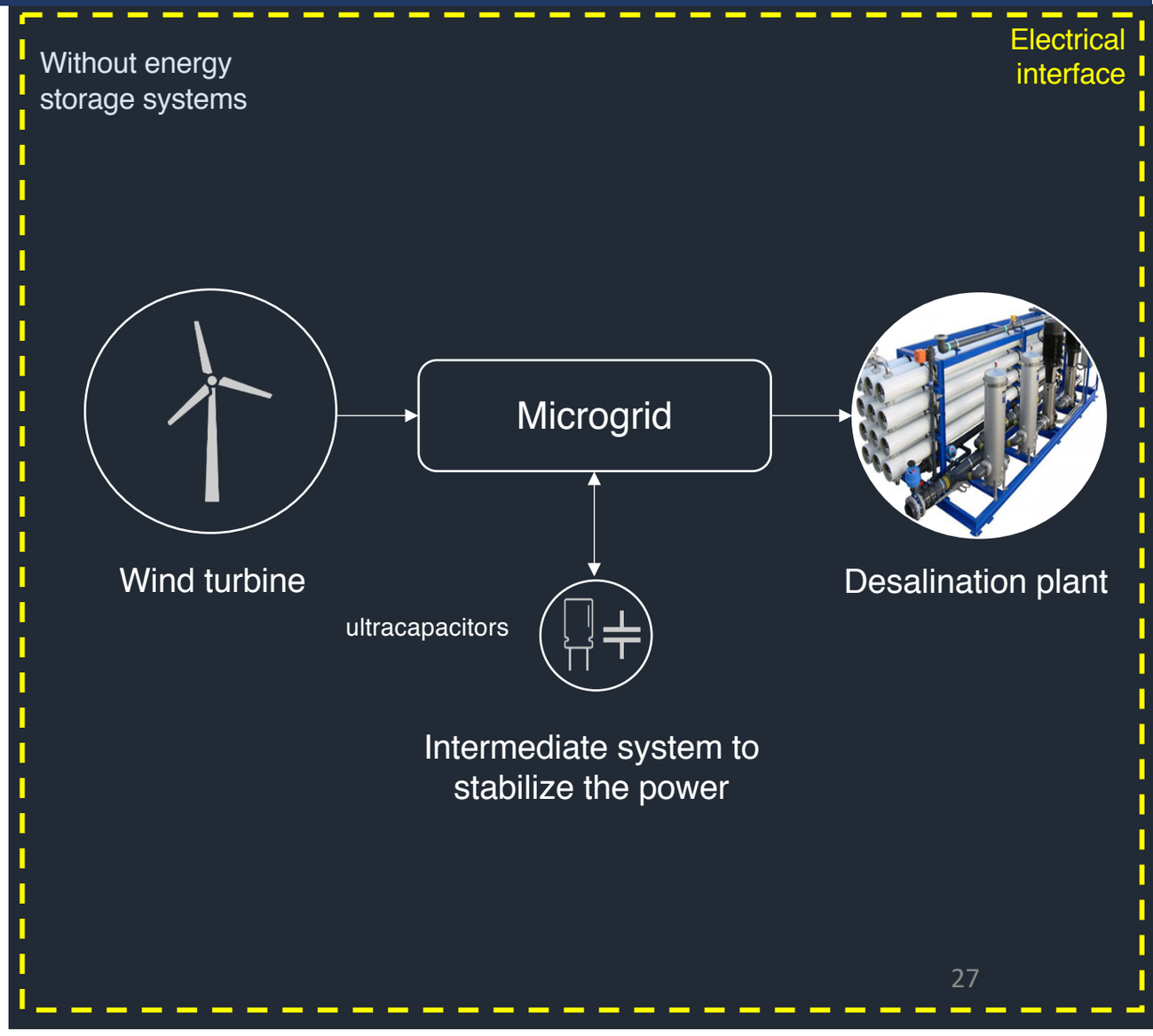
(c) variable pressure and feed flow rate / constant *recovery* rate

$$P_{wt} = P_{RO} = \frac{p_f Q_f}{\eta}$$

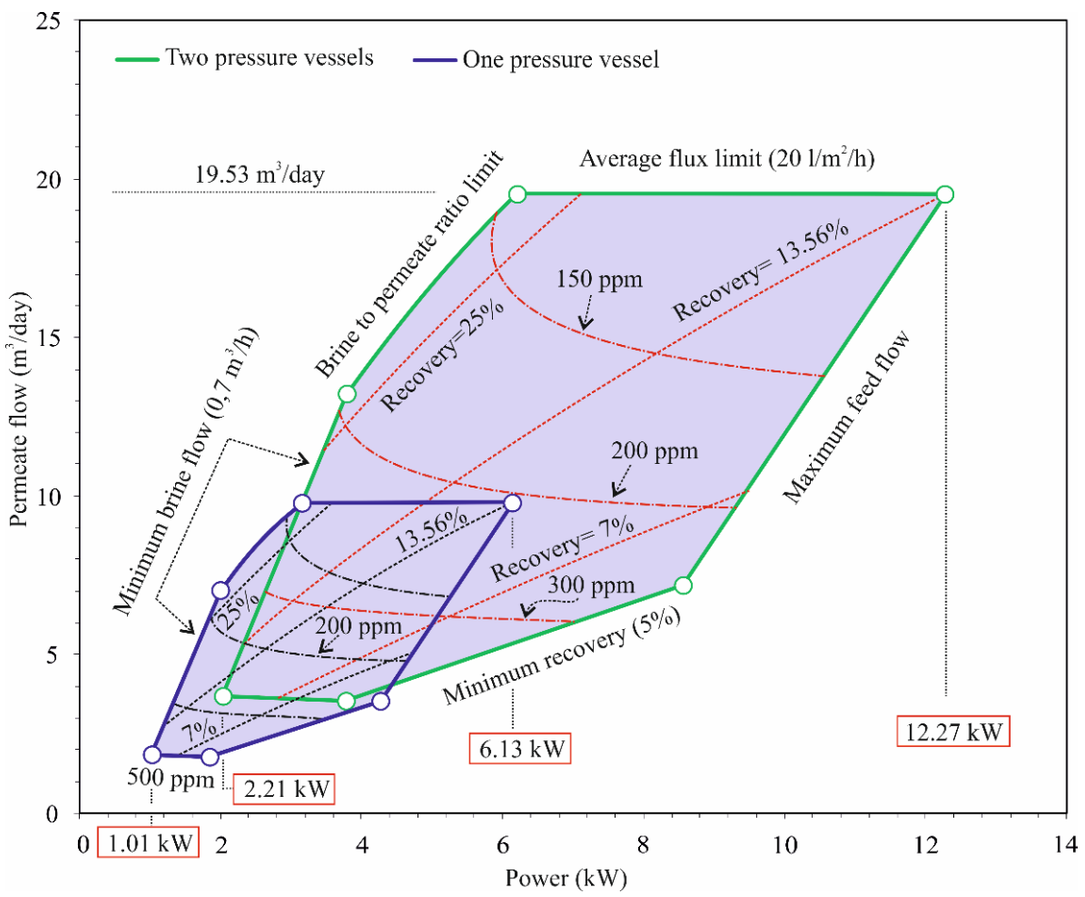
feed pressure — p_f; *feed seawater flow rate* — Q_f; *efficiency* — η

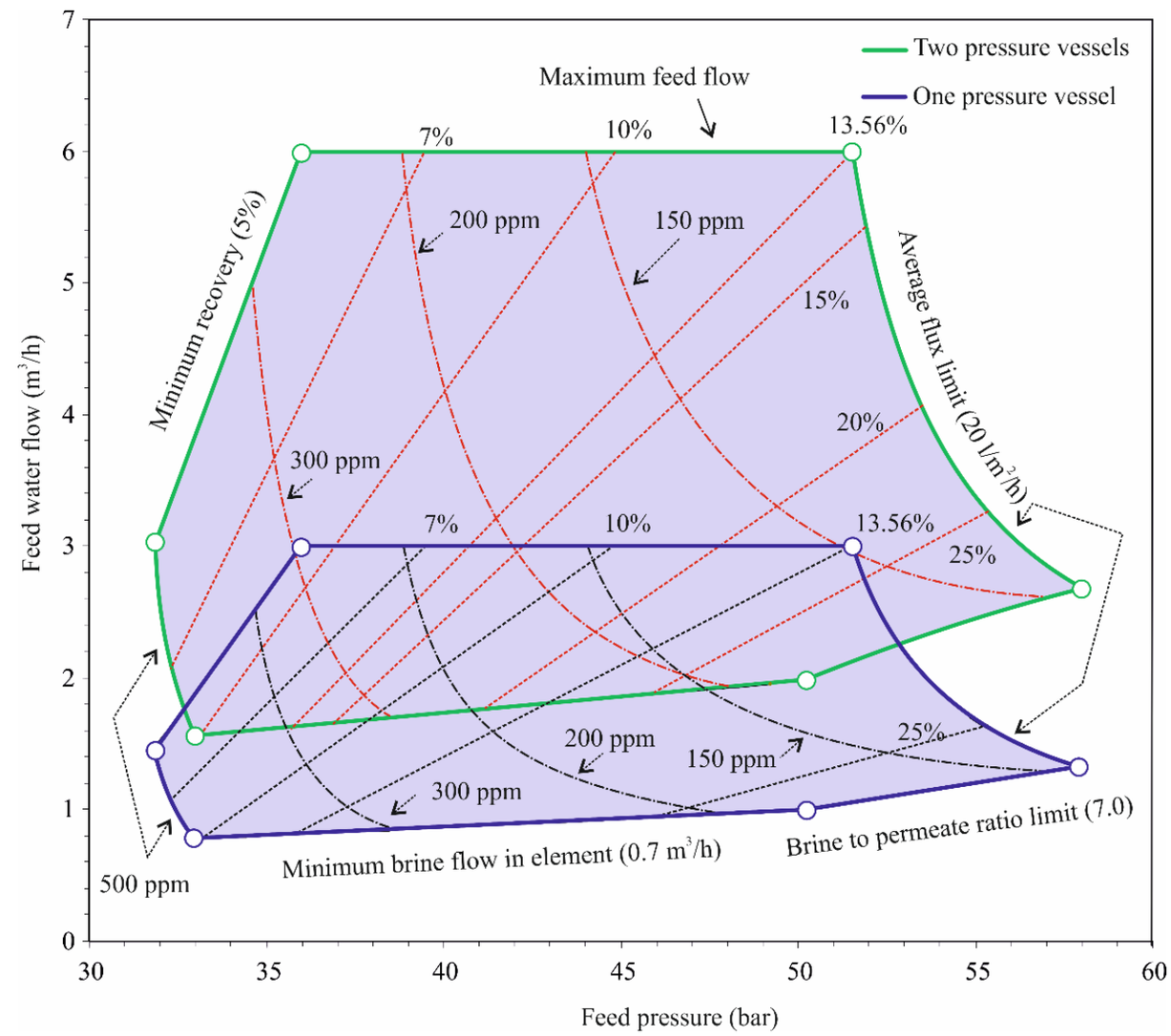
$$Recovery\ rate = \frac{Q_{out}}{Q_{input}}$$

[1] Pohl R, Kaltschmitt M, Holländer R. *Investigation of different operational strategies for the variable operation of a simple reverse osmosis unit*. Desalination 2009;249:1280–7.



Determinación de los límites teóricos de operación admisibles para la planta desalinizadora





Estrategia de operación en la planta desaladora

$$Recuperación = \frac{Q_{out}}{Q_{input}}$$

$$P_{wt} = P_{RO} = \frac{p_f Q_f}{\eta}$$

p_f: *feed pressure*

Q_f: *feed seawater flow rate*

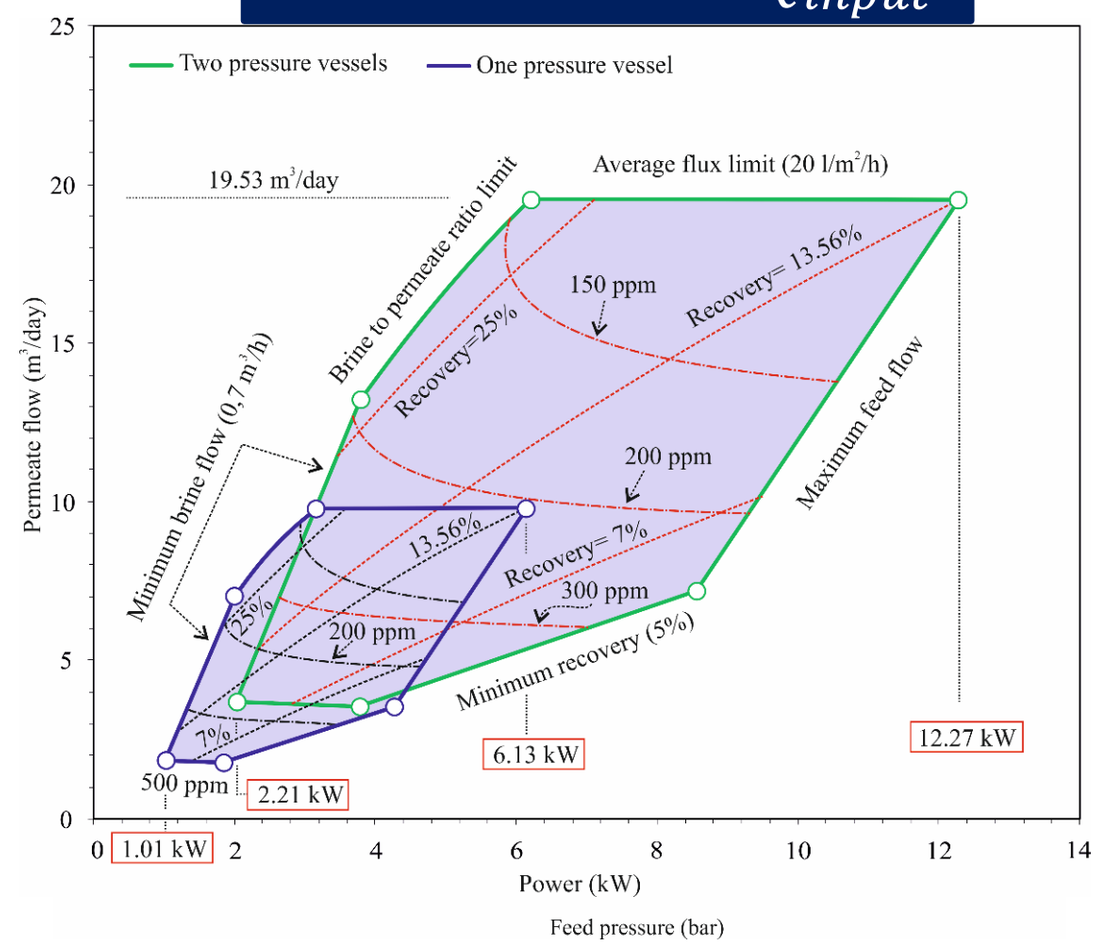
η: *efficiency*

Pohl et al. [1] propose different operating strategies:

(a) constant feed pressure / variable feed seawater flow rate,

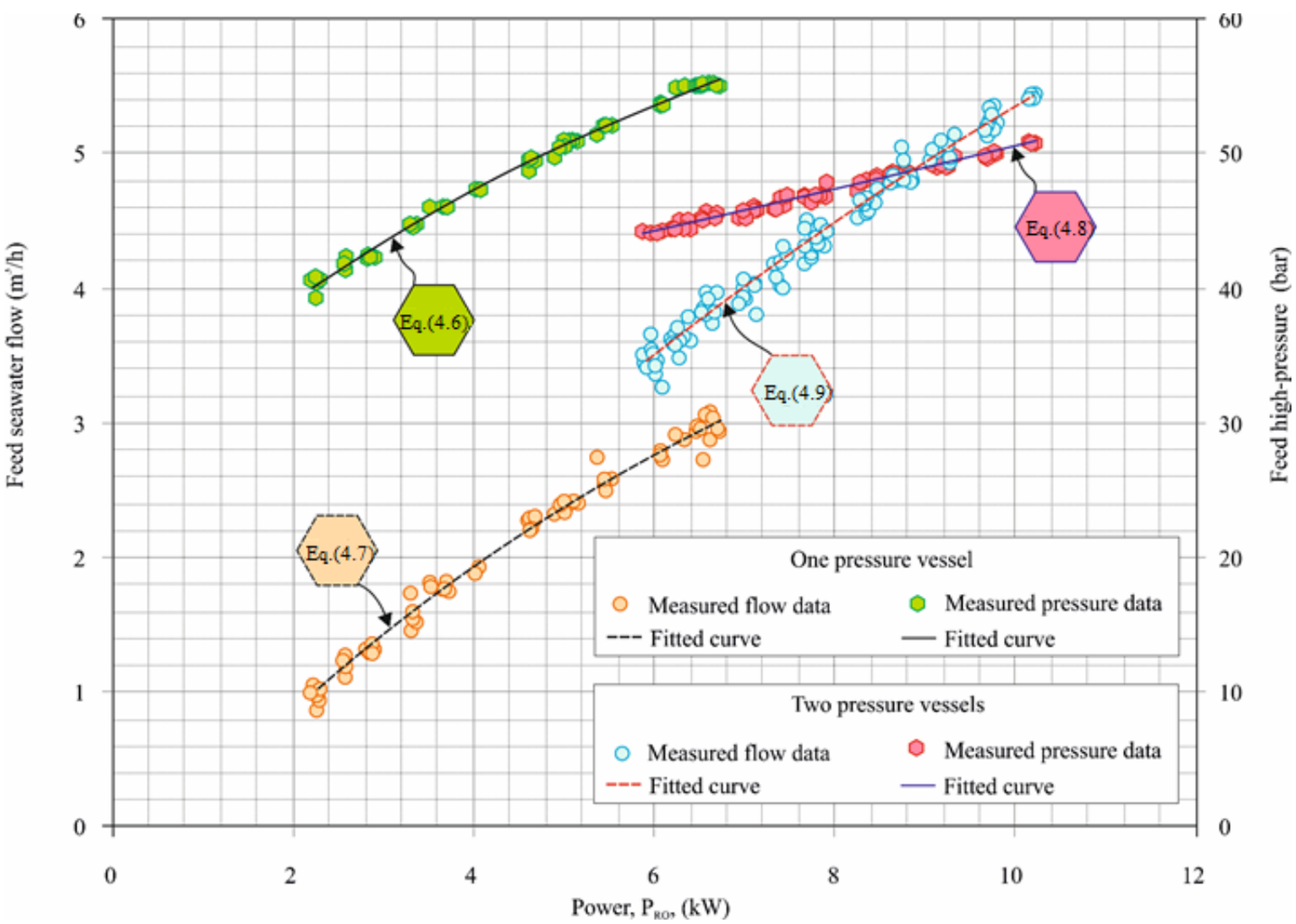
(b) constant feed seawater flow rate / variable feed pressure,

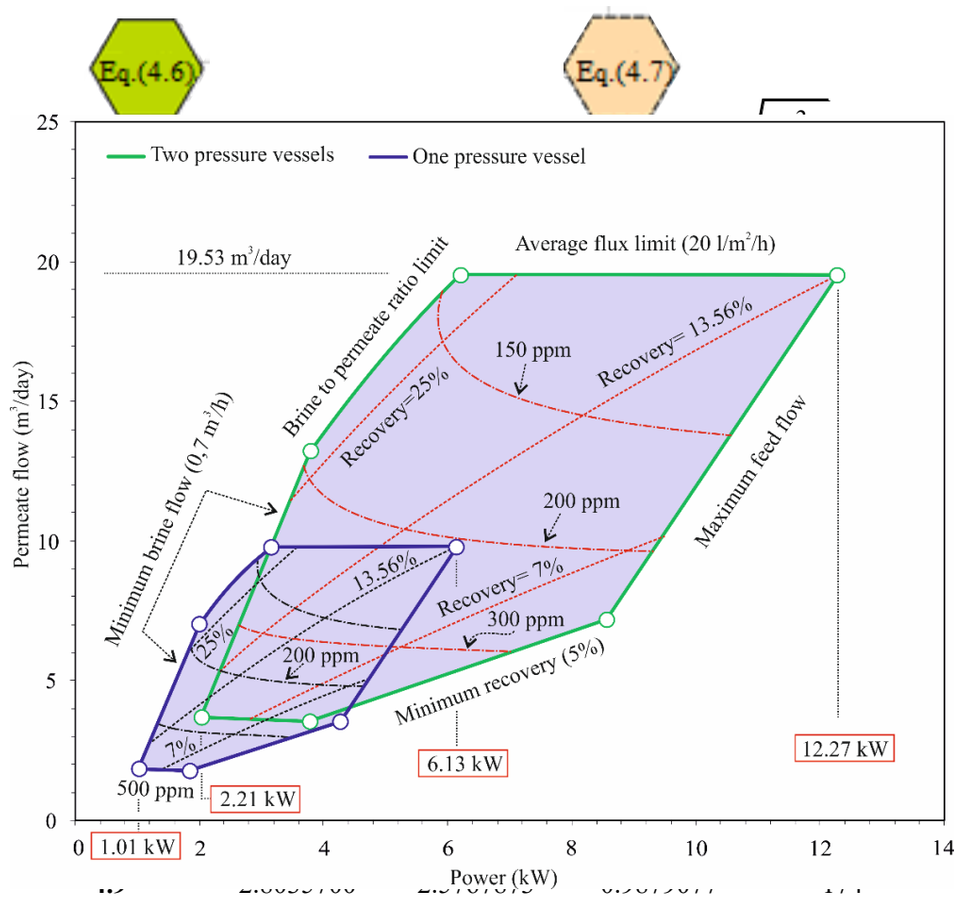
(c) variable pressure and feed flow rate / constant *recovery* rate



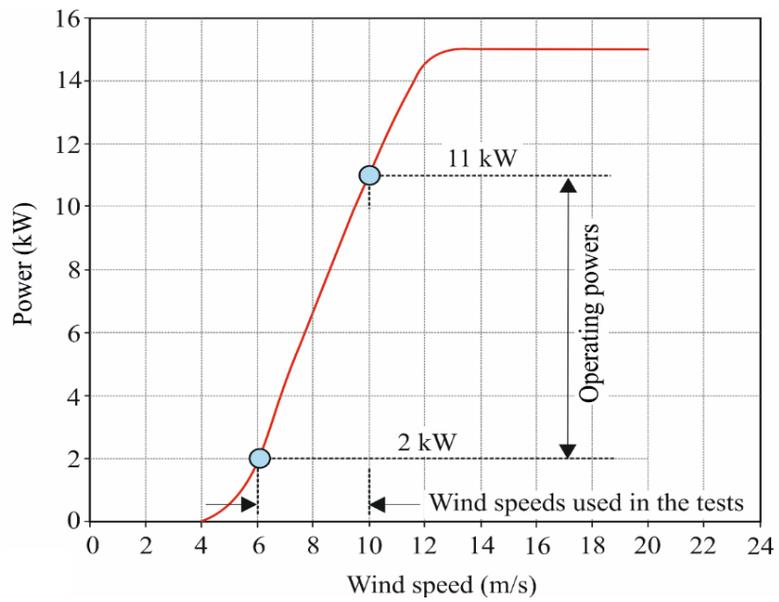
[1] Pohl R, Kaltschmitt M, Holländer R. *Investigation of different operational strategies for the variable operation of a simple reverse osmosis unit*. Desalination 2009;249:1280–7.

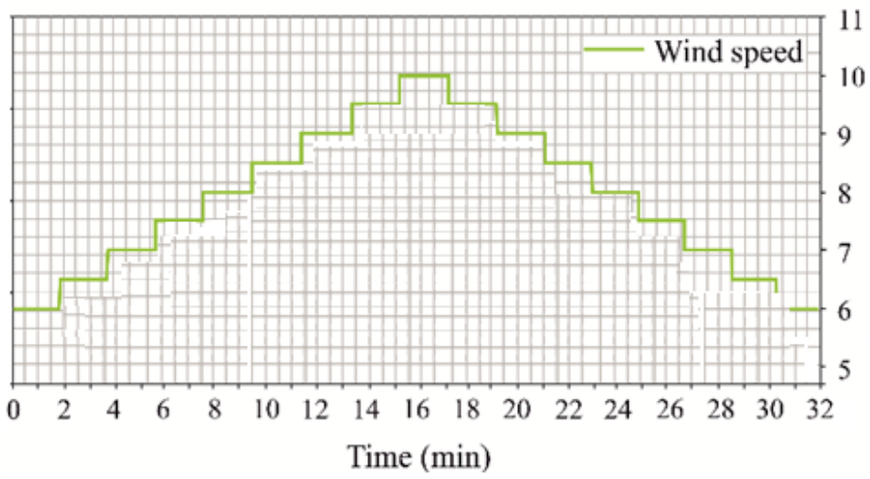
Experimental determination of reference pressures and flow rates

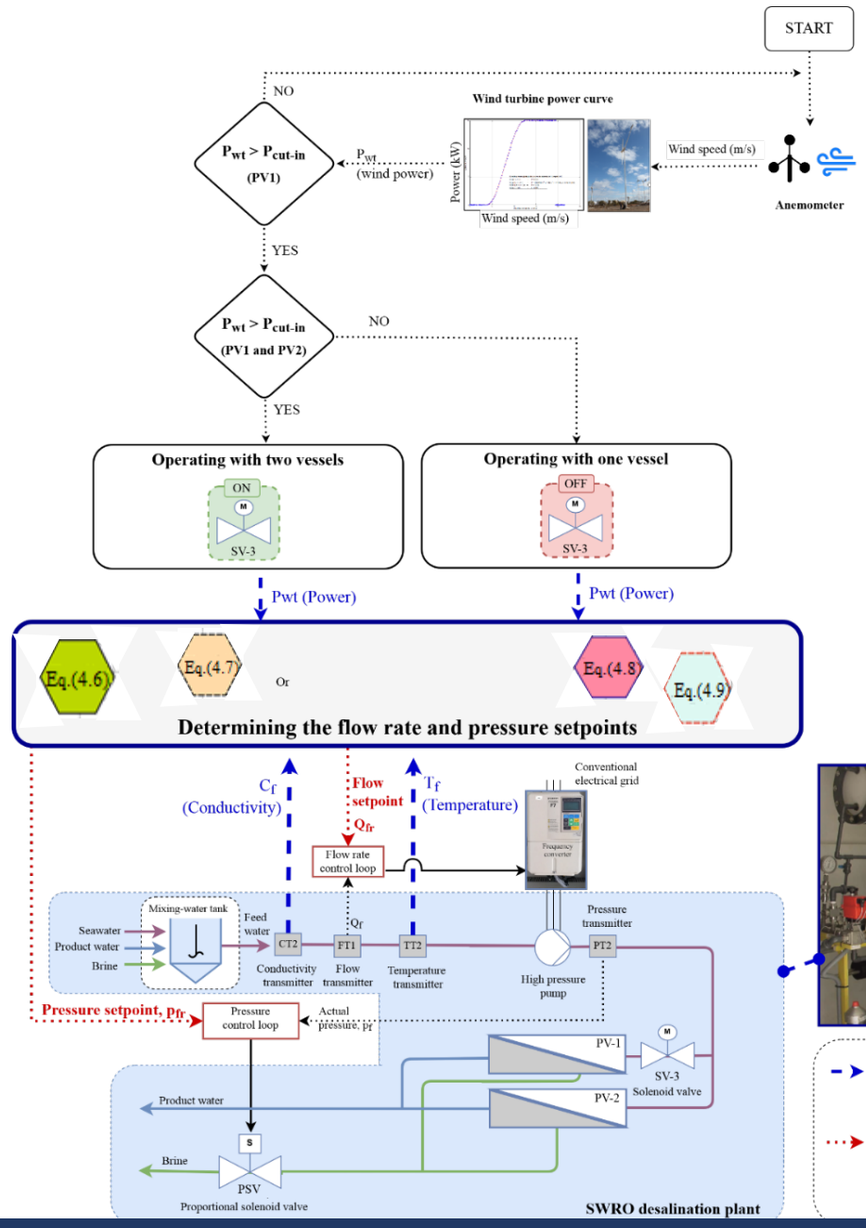




Prueba de la operación de la planta en condiciones variables

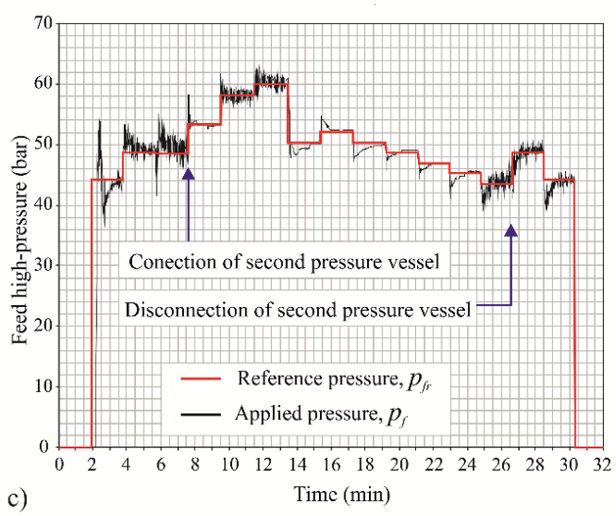




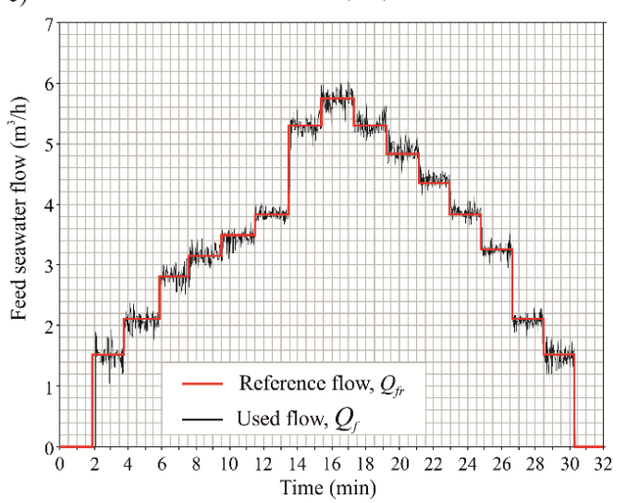


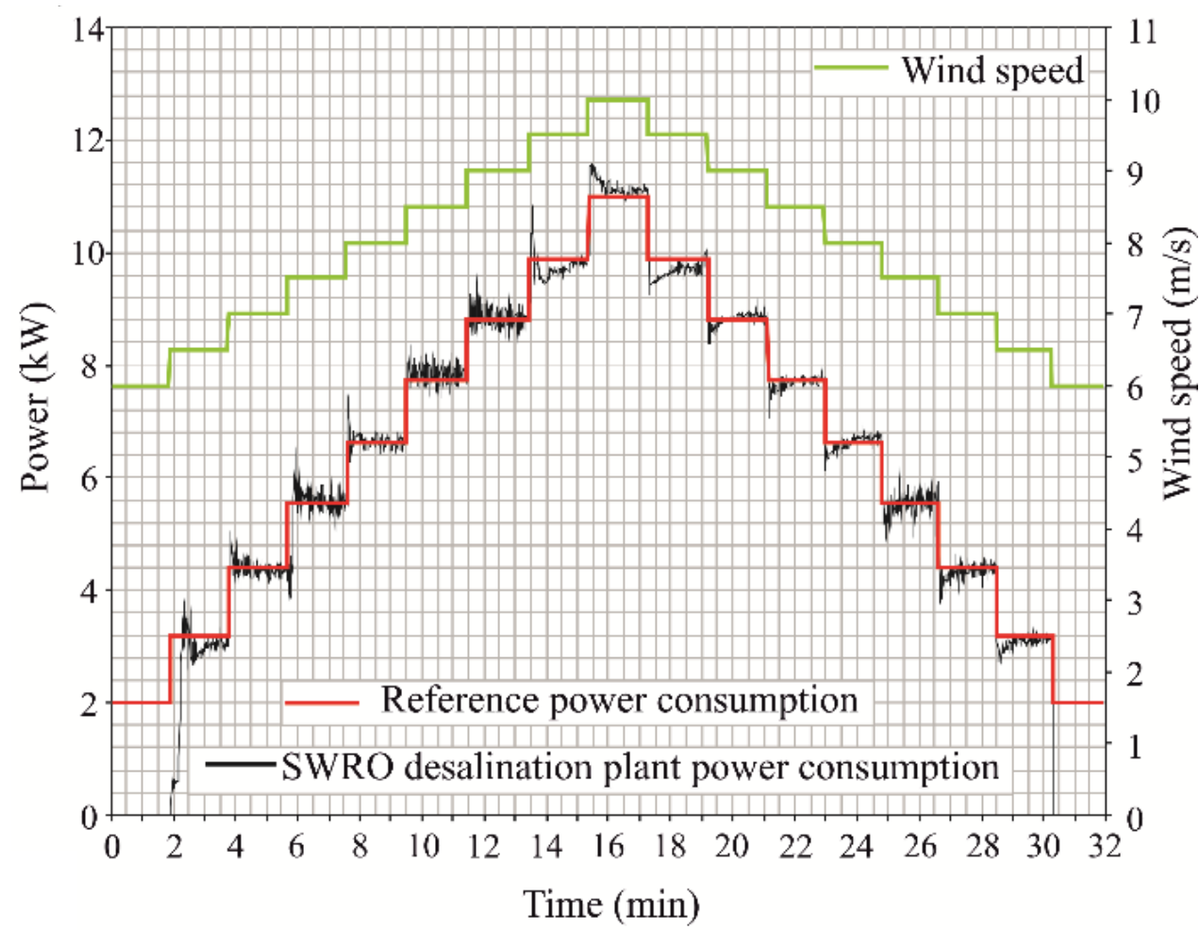
Resultados

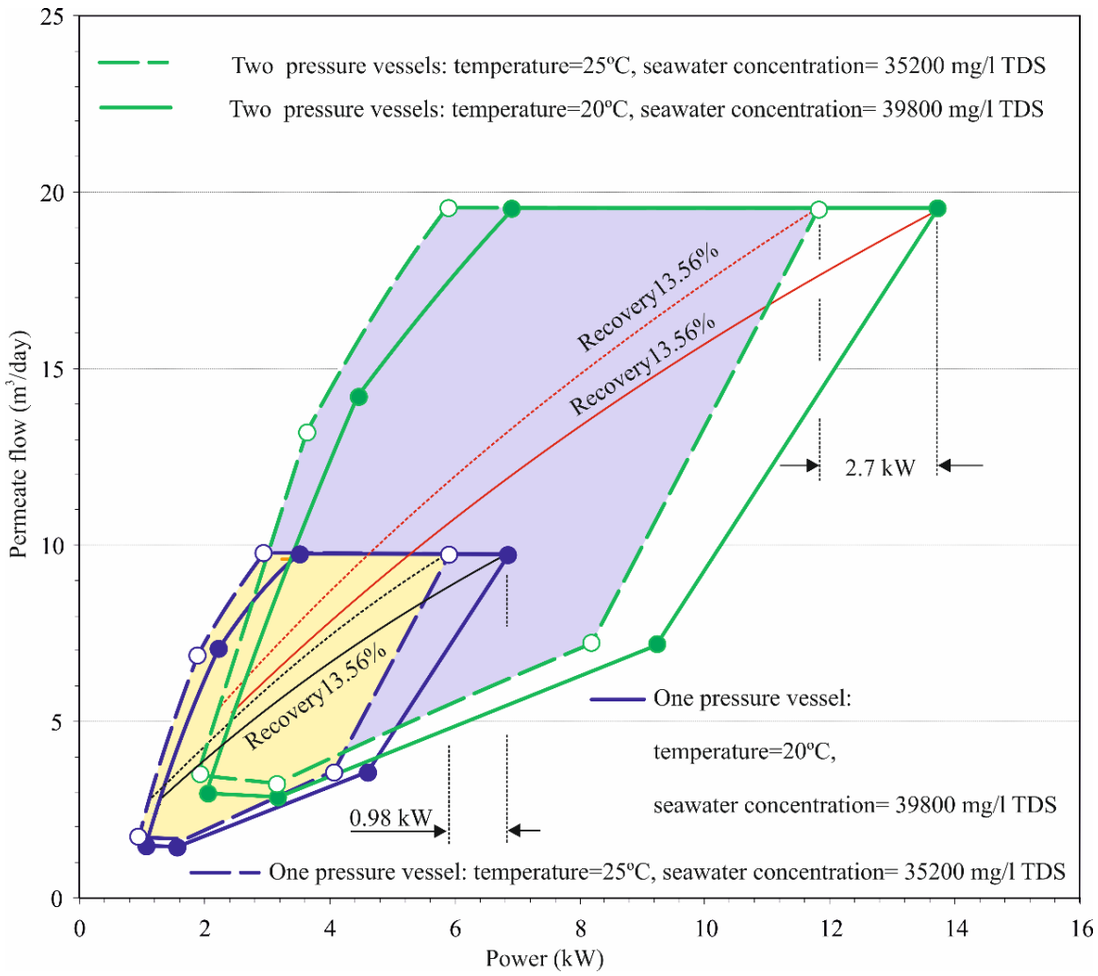
Después de la operación de la planta desaladora bajo condiciones variables

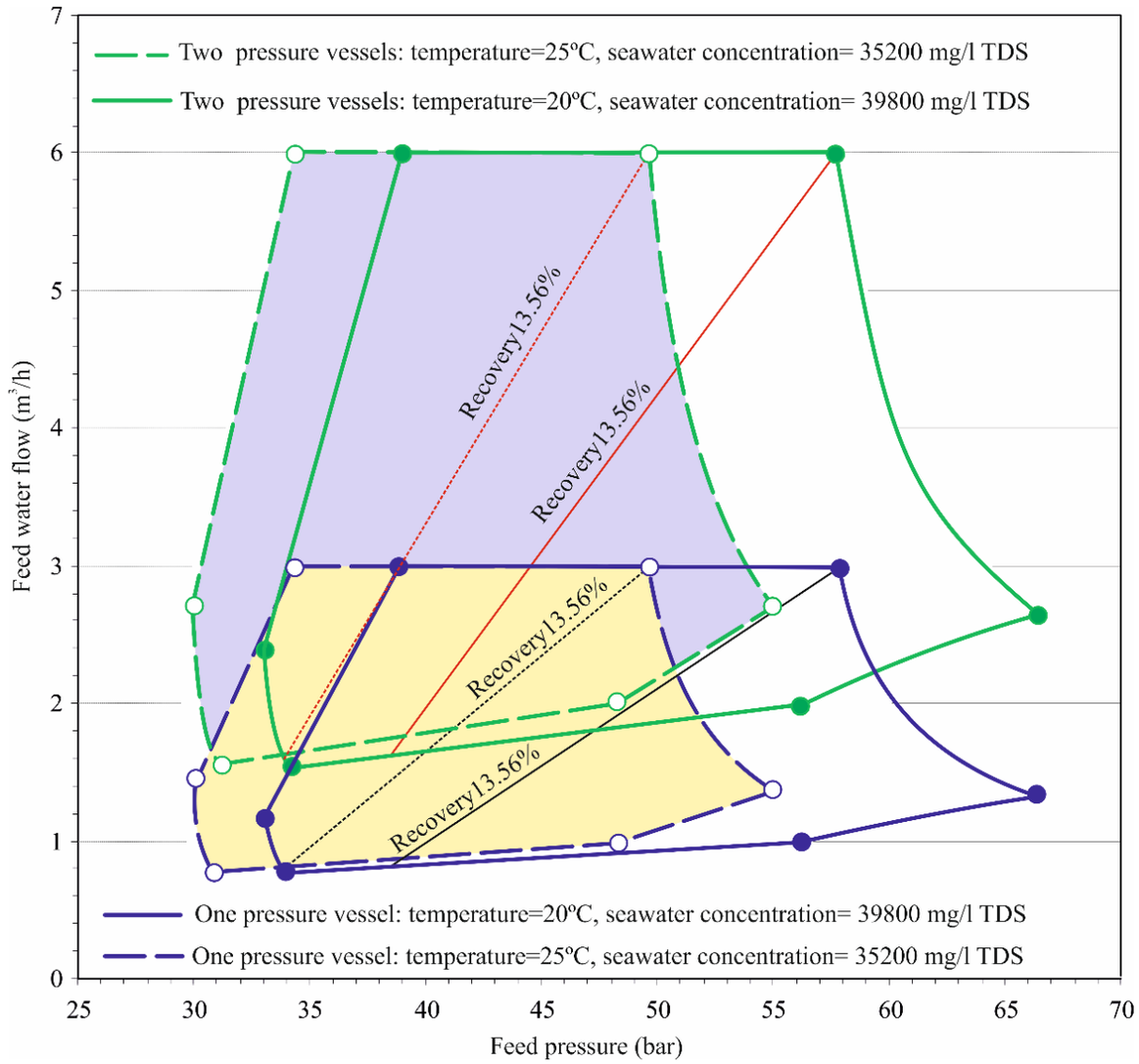


c)






Two pressure vessels: temperature=25ºC, seawater concentration= 35200 mg/l TDS
Two pressure vessels: temperature=20ºC, seawater concentration= 39800 mg/l TDS
Recovery13.56%
Recovery13.56%
Recovery13.56%
2.7 kW
0.98 kW
One pressure vessel:
temperature=20ºC,
seawater concentration= 39800 mg/l TDS
One pressure vessel: temperature=25ºC, seawater concentration= 35200 mg/l TDS
Permeate flow (m³/day)
Power (kW)
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16


Two pressure vessels: temperature=25ºC, seawater concentration= 35200 mg/l TDS
Two pressure vessels: temperature=20ºC, seawater concentration= 39800 mg/l TDS
Recovery13.56%
Recovery13.56%
Recovery13.56%
Recovery13.56%
One pressure vessel: temperature=20ºC, seawater concentration= 39800 mg/l TDS
One pressure vessel: temperature=25ºC, seawater concentration= 35200 mg/l TDS
Feed water flow (m³/h)
Feed pressure (bar)
0
1
2
3
4
5
6
7
25
30
35
40
45
50
55
60
65
70

¿Qué es la Inteligencia Artificial?

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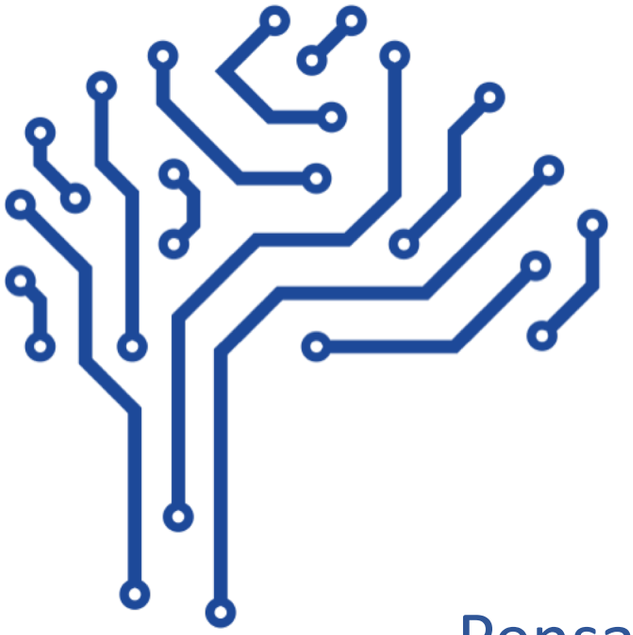
John McCarthy

«la ciencia e ingenio de hacer máquinas inteligentes, especialmente programas de cómputo inteligentes» (1956)

Actuar como los humanos

Pensar como los humanos



Actuar racionalmente

Pensar racionalmente

2016-12-27 16:01:27 114km/h
BLACKVUE DR650S-2CH/FHD-HD

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¿Cómo se consigue esto?

¿Cómo se puede aplicar a la desalación?

WEB
MOBILE
FLICKR
MEDIA
SEARCH
LIKE
MONEY
NEWS
SOCIAL
DATA
RADIO
ONLINE
SHARE
CONTENT
PEOPLE
COMMUNITY
INFORMATION
NETWORK
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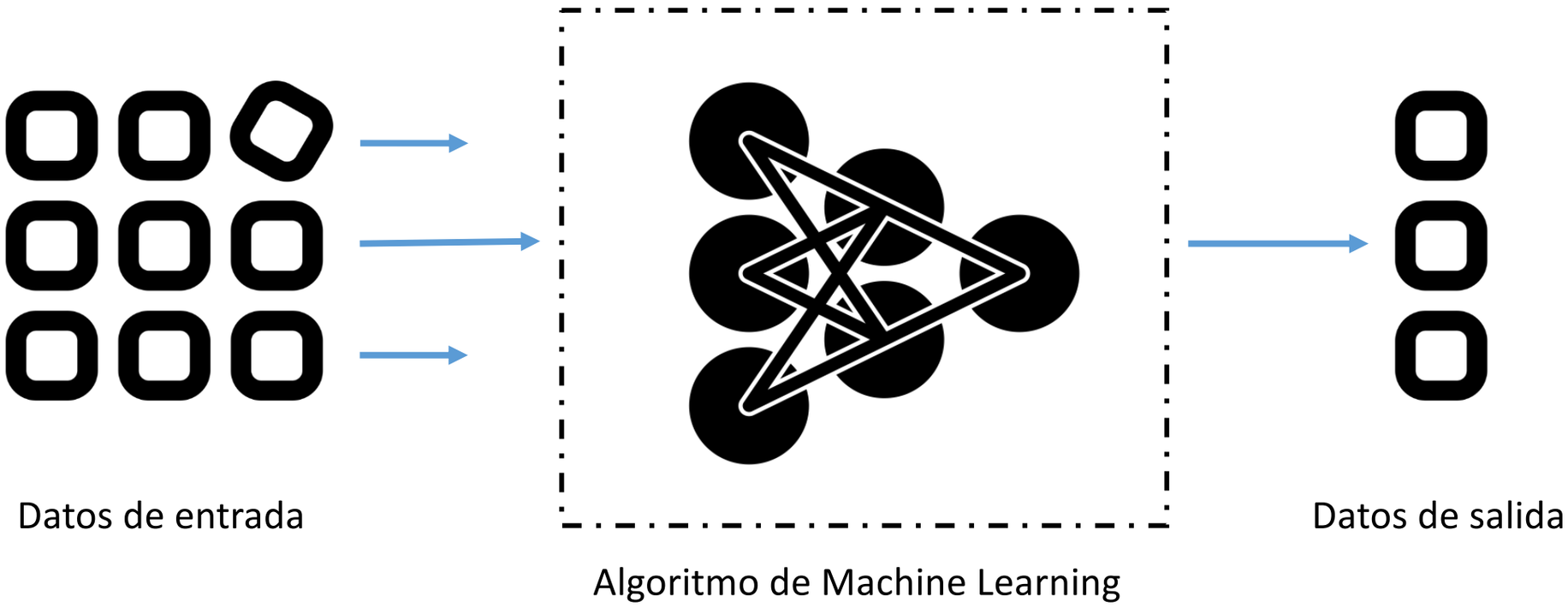
GLOBAL
LINKEDIN
PINTEREST
INTERNET

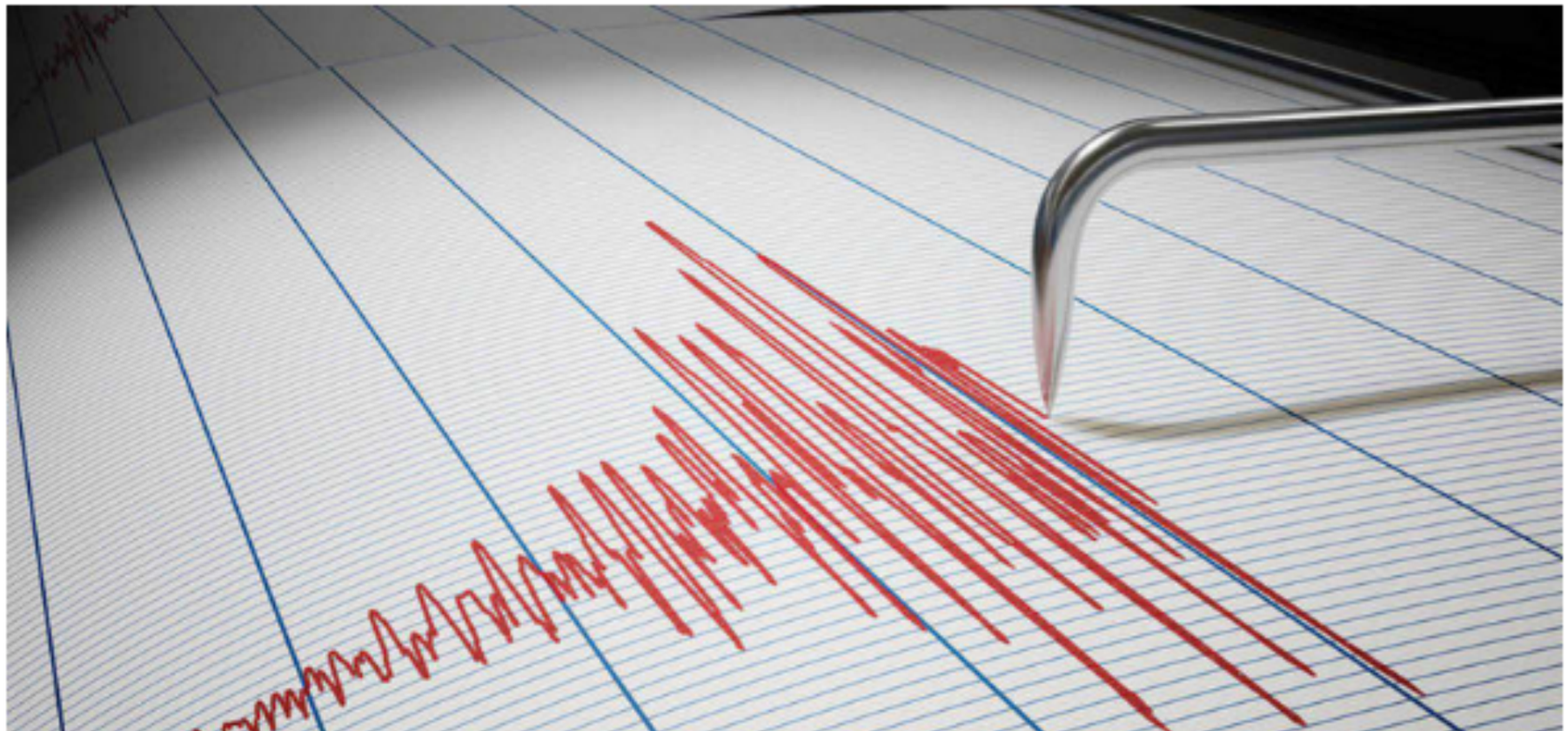


Pedro Cabrera

Inteligencia artificial para detectar denuncias falsas a la policía

- Un equipo investigador ha desarrollado Veripol, que determina la veracidad de las declaraciones de robo
- Tiene una tasa de éxito del 91%, 15 puntos superiores a la de agentes expertos

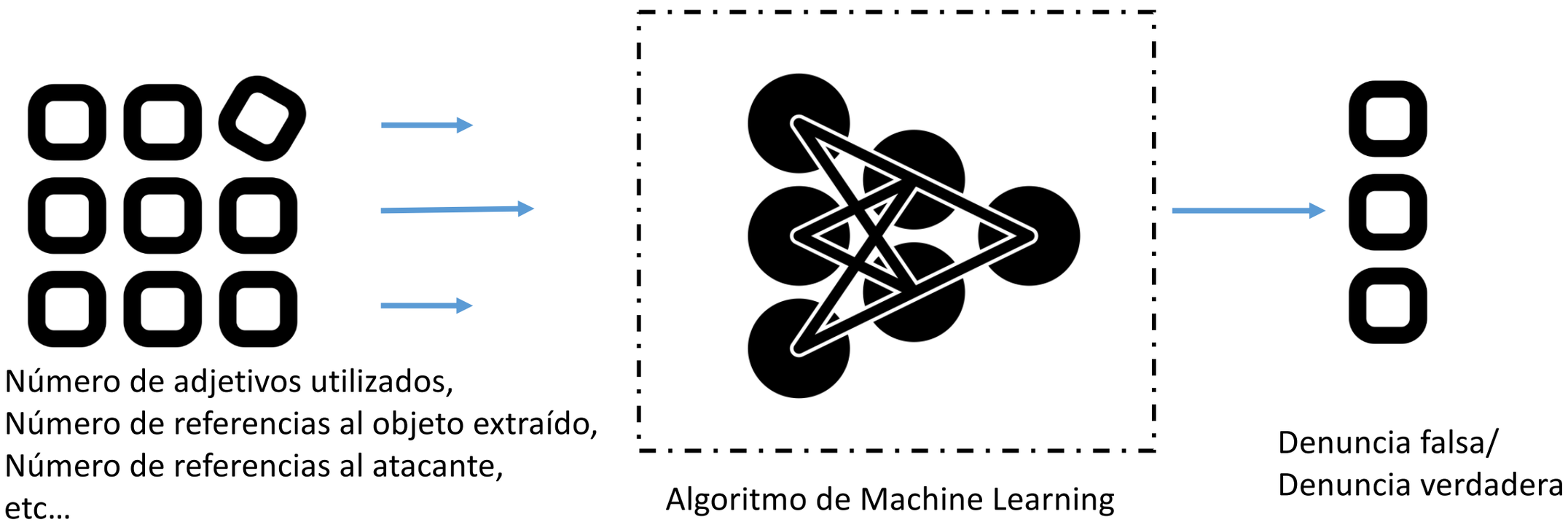
18.09.2018 | actualización 15:06 horas Por AGENCIA SINC



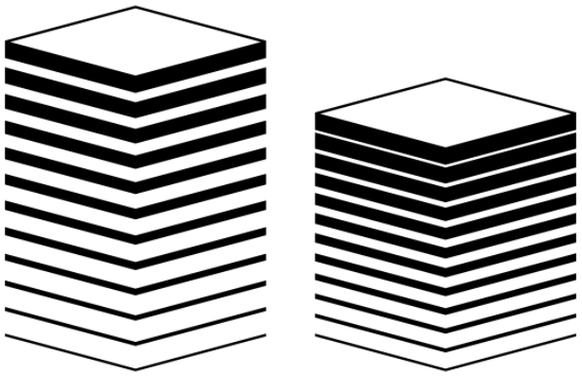
Pedro Cabrera

Análisis lingüístico

Por ejemplo, se sabe que en los casos de robo, las declaraciones verdaderas se presentan más detalles, descripciones e información personal, **frente a la insistencia exclusiva en el objeto extraído y la omisión de detalles sobre el atacante o cómo sucedió el incidente de las falsas**. A partir de este análisis lingüístico, Veripol es capaz de crear un patrón eficaz.



Paso 1:

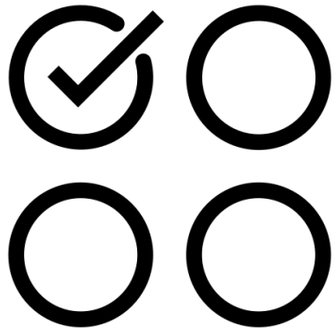


Entrenamiento humano

Paso 2:

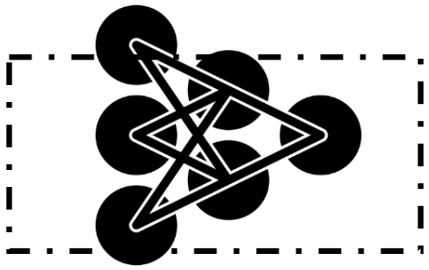
Extracción de información

Paso 3:



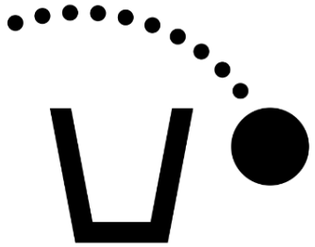
Selección de variables

Paso 4:



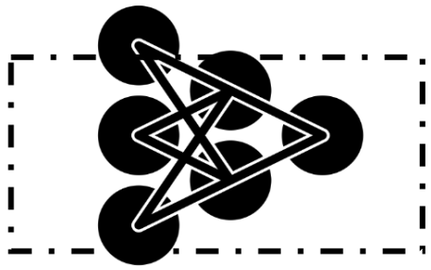
Entrenamiento del algoritmo con entradas y salidas conocidas

Paso 5:



Cálculo del error cometido

Paso 6:



Uso del algoritmo con nuevas entradas

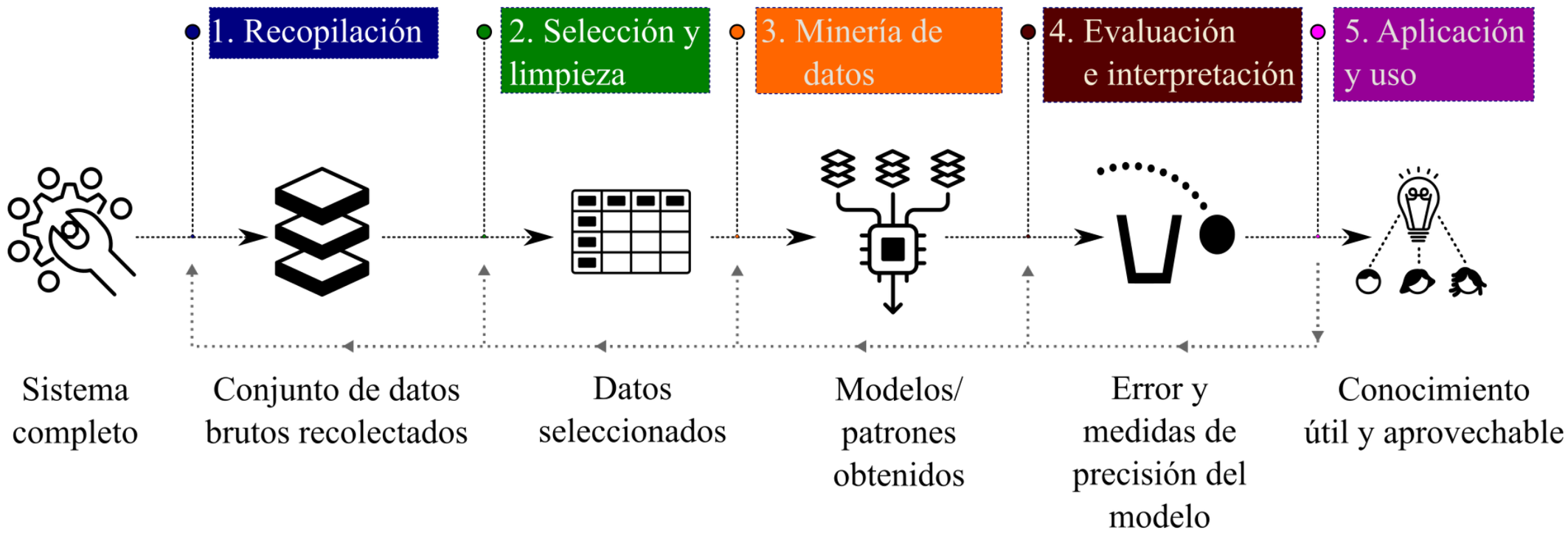
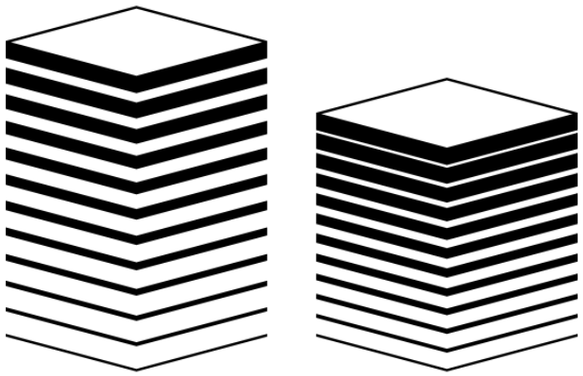
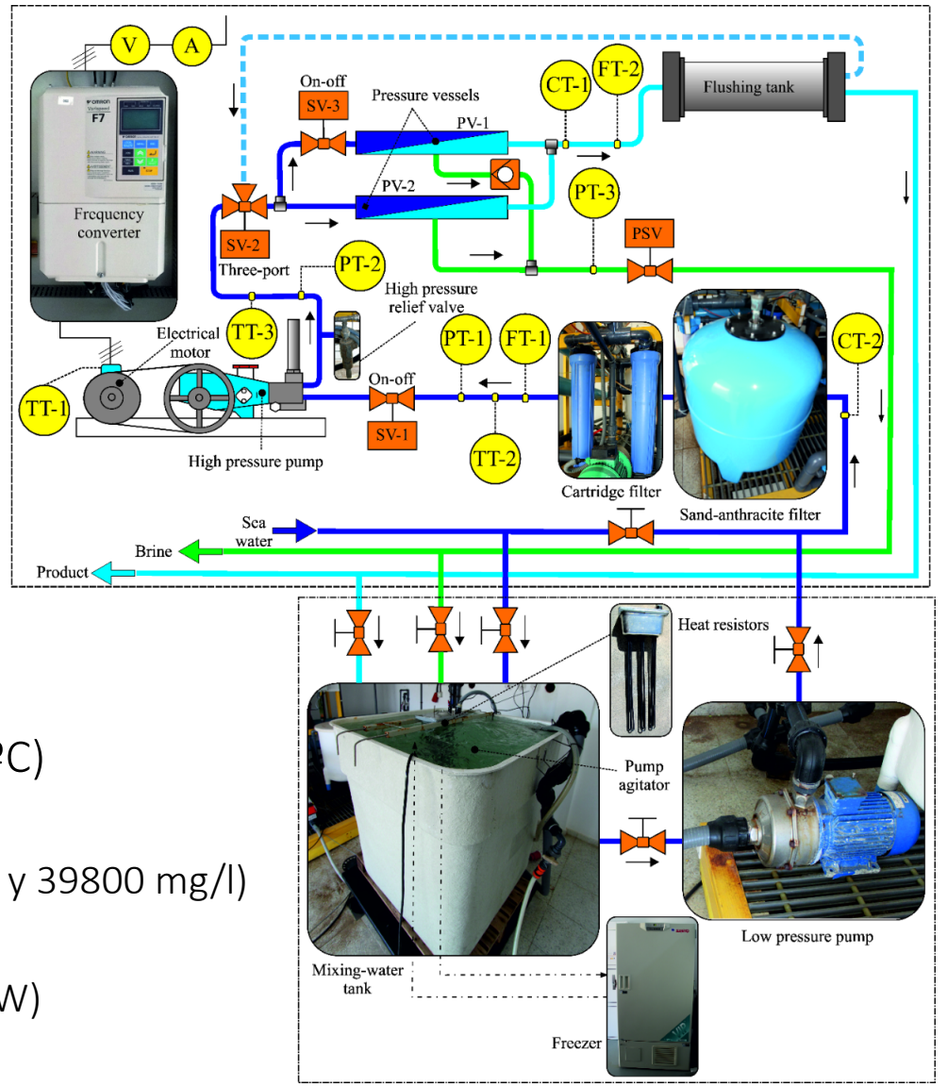


Figura. Esquema general del proceso de extracción del conocimiento (inspirado en los modelos propuestos por Hernández-Orallo et al. y Fayyad et al.).

Paso 1:



Entrenamiento humano



1 Establecimiento de Temperatura a un valor (entre 20ºC – 25ºC)

2 Ensayo del sistema a distintas conductividades (entre 35200 y 39800 mg/l)

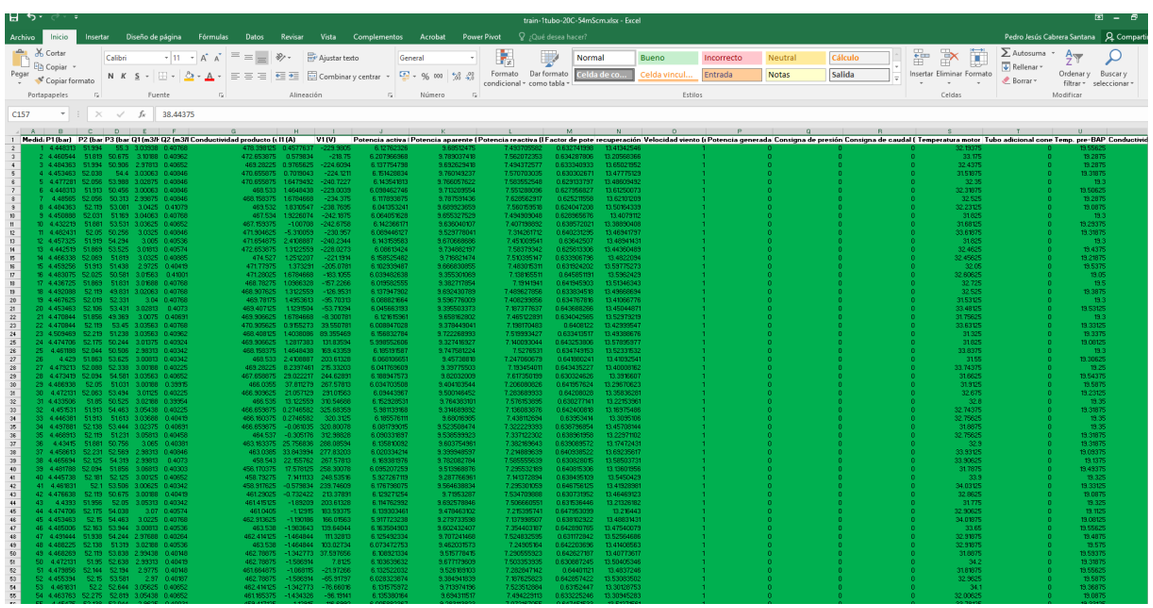
3 Ensayo del sistema a distintas potencias (entre 1 y 12 kW)

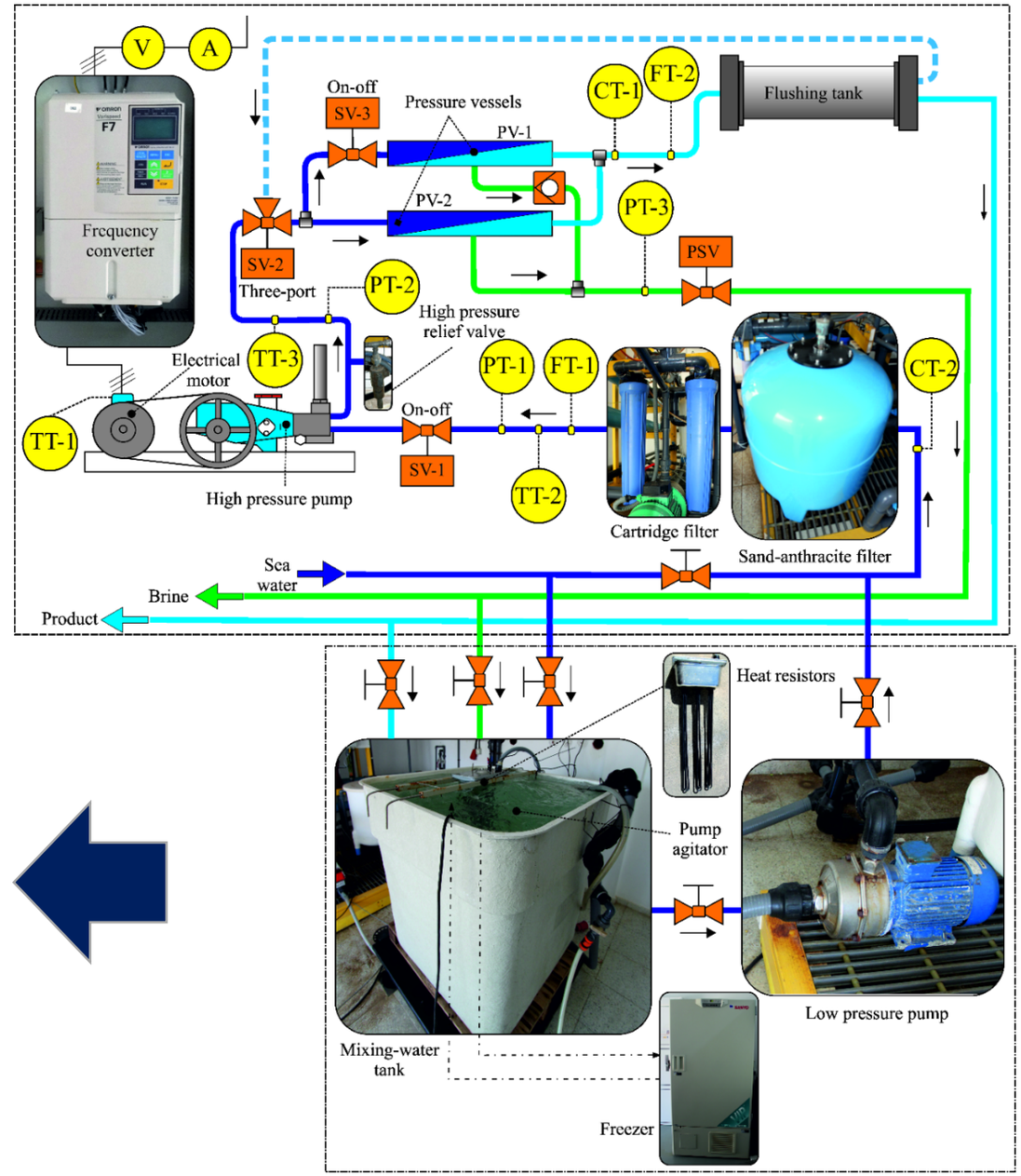
→ (situando distintos valores de caudal y presión)

Paso 2:

Extracción de información

Recopilación: donde se recopilan, registran o integran datos procedentes de distintas fuentes, sensores, ensayos o análisis.

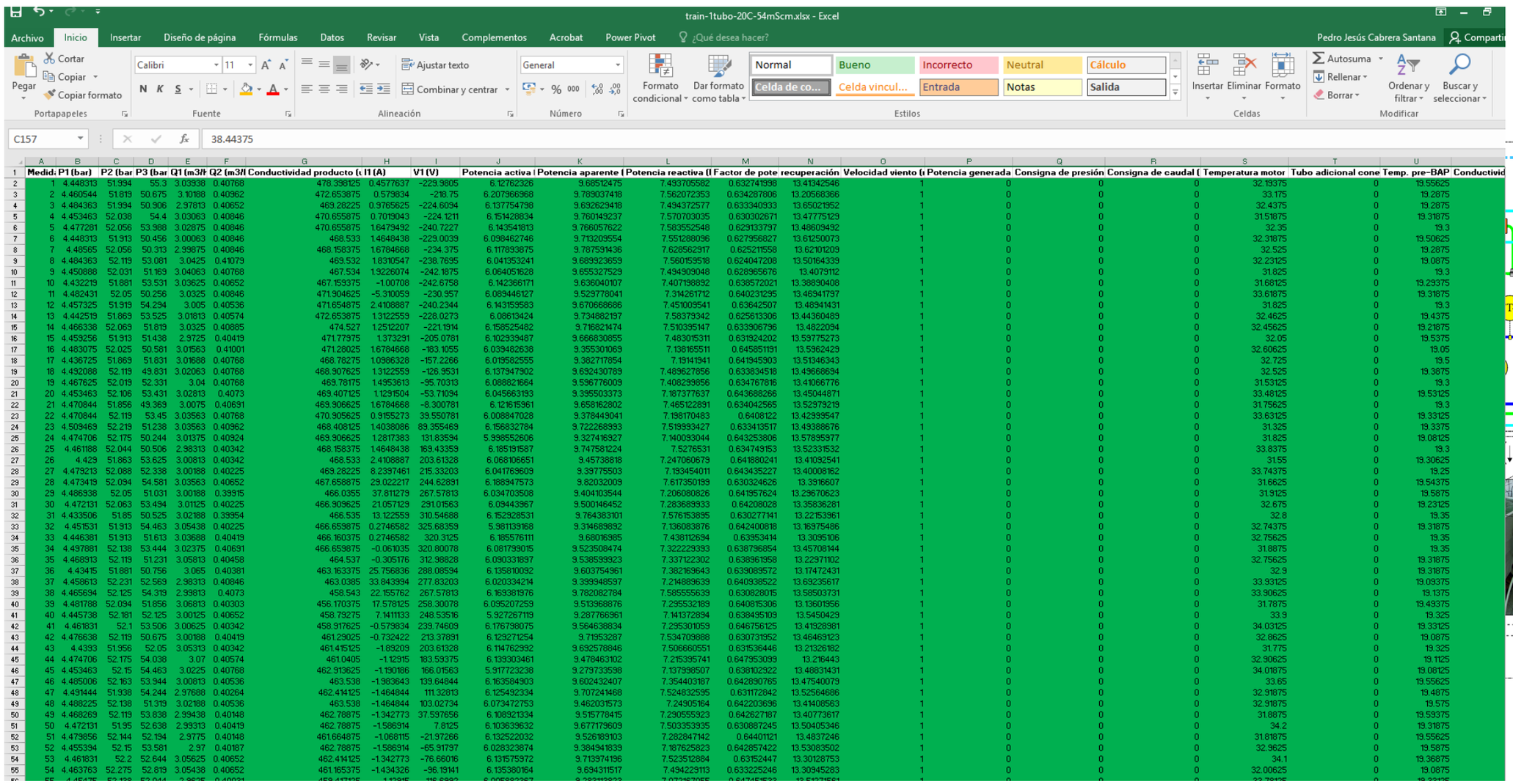




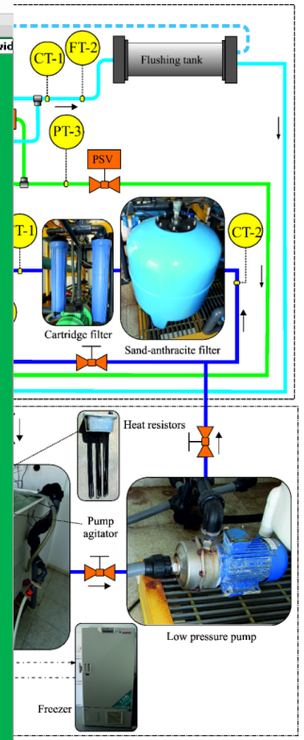
Paso 2:

Extracción de información

Recopilación: donde se recopilan, registran o integran datos procedentes de distintas fuentes, sensores, ensayos o análisis.



	Medid	P1 (bar)	P2 (bar	P3 (bar	Q1 (m3/h	Q2 (m3/h	Conductividad producto (µ	I1 (A)	V1 (V)	Potencia activa	Potencia aparente (	Potencia reactiva (I	Factor de pote	recuperación	Velocidad viento (r	Potencia generada	Consigna de presión	Consigna de caudal (	Temperatura motor	Tubo adicional cone	Temp. pre-BAP	Conductivid
2	1	4.448313	51.994	55.3	3.03938	0.40768	478.398125	0.4577637	-229.9805	6.12762326	9.68512475	7.433705582	0.632741998	13.41342546	1	0	0	0	32.19375	0	19.55625	
3	2	4.460544	51.819	50.675	3.10188	0.40962	472.653875	0.579834	-218.75	6.207966968	9.789037418	7.562072353	0.634287806	13.20568366	1	0	0	0	33.175	0	19.2875	
4	3	4.484363	51.994	50.906	2.97813	0.40652	469.28225	0.9765625	-224.6094	6.137754798	9.692629418	7.494372577	0.633340933	13.65021952	1	0	0	0	32.4375	0	19.2875	
5	4	4.453463	52.038	54.4	3.03063	0.40846	470.655875	0.7019043	-224.1211	6.151428834	9.760149237	7.570703035	0.630302671	13.47775129	1	0	0	0	31.51875	0	19.31875	
6	5	4.477281	52.056	53.988	3.02875	0.40846	470.655875	1.6479492	-240.7227	6.143541813	9.766057622	7.583552548	0.629133797	13.48609492	1	0	0	0	32.35	0	19.3	
7	6	4.448313	51.913	50.456	3.00063	0.40846	468.533	1.4648438	-229.0039	6.098462746	9.713209554	7.551288096	0.627956827	13.61250073	1	0	0	0	32.31875	0	19.50625	
8	7	4.48565	52.056	50.313	2.99875	0.40846	468.158375	1.6784668	-234.375	6.117893875	9.787531436	7.628562317	0.625211558	13.62101209	1	0	0	0	32.525	0	19.2875	
9	8	4.484363	52.119	53.081	3.0425	0.41079	469.532	1.8310547	-238.7695	6.041353241	9.689923659	7.560159518	0.624047208	13.50164339	1	0	0	0	32.23125	0	19.0875	
10	9	4.450888	52.031	51.169	3.04063	0.40768	467.534	1.9226074	-242.1875	6.064051628	9.655327529	7.434909048	0.628965676	13.4079112	1	0	0	0	31.825	0	19.3	
11	10	4.432219	51.881	53.531	3.03625	0.40652	467.159375	-1.00708	-242.6758	6.142366171	9.636040107	7.407198892	0.638572021	13.38830408	1	0	0	0	31.68125	0	19.29375	
12	11	4.482431	52.05	50.256	3.0325	0.40846	471.904625	-5.310059	-230.957	6.083446127	9.529778041	7.314261712	0.640231295	13.46941797	1	0	0	0	33.61875	0	19.31875	
13	12	4.457325	51.919	54.294	3.005	0.40536	471.654875	2.4108887	-240.2344	6.143159583	9.670668686	7.451003541	0.63642507	13.48941431	1	0	0	0	31.825	0	19.3	
14	13	4.442519	51.869	53.525	3.01813	0.40574	472.653875	1.3122559	-228.0273	6.08613424	9.734882197	7.58379342	0.625613306	13.44360489	1	0	0	0	32.4625	0	19.4375	
15	14	4.466338	52.069	51.819	3.0325	0.40885	474.527	1.2512207	-221.1914	6.158525482	9.716821474	7.510395147	0.633906796	13.4822094	1	0	0	0	32.45625	0	19.21875	
16	15	4.459256	51.913	51.438	2.9725	0.40419	471.77975	1.373291	-205.0781	6.102939487	9.666830855	7.483015311	0.631924202	13.59775273	1	0	0	0	32.05	0	19.5375	
17	16	4.483075	52.025	50.581	3.01563	0.41001	471.28025	1.6784668	-183.1055	6.039482638	9.3553010169	7.138165511	0.645851191	13.5362429	1	0	0	0	32.60625	0	19.05	
18	17	4.436725	51.869	51.831	3.01688	0.40768	468.78275	1.0986328	-157.2266	6.019582555	9.382717854	7.19141941	0.641945903	13.51346343	1	0	0	0	32.725	0	19.5	
19	18	4.432088	52.119	49.831	3.02063	0.40768	468.907625	1.3122559	-126.9531	6.137947902	9.692430789	7.489627856	0.633834518	13.49668694	1	0	0	0	32.525	0	19.3875	
20	19	4.467625	52.019	52.331	3.04	0.40768	469.78175	1.4953613	-95.70313	6.088821664	9.596776009	7.408299856	0.634767816	13.41066776	1	0	0	0	31.53125	0	19.3	
21	20	4.453463	52.106	53.431	3.02813	0.4073	469.407125	1.1291504	-53.71094	6.045663193	9.395503373	7.187377637	0.643688266	13.45044871	1	0	0	0	33.48125	0	19.53125	
22	21	4.470844	51.856	49.369	3.0075	0.40691	469.906625	1.6784668	-8.300781	6.121615961	9.658162802	7.465122831	0.634042565	13.52979219	1	0	0	0	31.75625	0	19.3	
23	22	4.470844	52.119	53.45	3.03563	0.40768	470.905625	0.9155273	39.550781	6.008847028	9.378449041	7.198170483	0.6408122	13.42999547	1	0	0	0	33.63125	0	19.33125	
24	23	4.509469	52.219	51.238	3.03563	0.40962	468.408125	1.4038086	89.355469	6.156832784	9.722268993	7.519993427	0.633413517	13.49388676	1	0	0	0	31.325	0	19.3375	
25	24	4.474706	52.175	50.244	3.01375	0.40324	469.906625	1.2817383	131.83594	5.998552606	9.327416327	7.140093044	0.643253806	13.57895977	1	0	0	0	31.825	0	19.08125	
26	25	4.461188	52.044	50.506	2.98313	0.40342	468.158375	1.4648438	169.43359	6.165191587	9.747581224	7.5276531	0.634749153	13.52331532	1	0	0	0	33.8375	0	19.3	
27	26	4.429	51.863	53.625	3.00813	0.40342	468.533	2.4108887	203.61328	6.068106651	9.45738818	7.247060679	0.641880241	13.41032541	1	0	0	0	31.55	0	19.30625	
28	27	4.479213	52.088	52.338	3.00188	0.40225	469.28225	8.2397461	215.33203	6.041769609	9.39775503	7.193454011	0.643435227	13.40008162	1	0	0	0	33.74375	0	19.25	
29	28	4.473419	52.094	54.581	3.03563	0.40652	467.658875	29.022217	244.62891	6.188947573	9.82032009	7.617350199	0.630324626	13.3916607	1	0	0	0	31.6625	0	19.54375	
30	29	4.486938	52.05	51.031	3.00188	0.39915	466.0355	37.811279	267.57813	6.034703508	9.404103544	7.206080826	0.641957624	13.29670623	1	0	0	0	31.9125	0	19.5875	
31	30	4.472131	52.063	53.494	3.01125	0.40225	466.909625	21.057129	291.01563	6.09443967	9.500146452	7.283689933	0.64208028	13.35836281	1	0	0	0	32.675	0	19.23125	
32	31	4.433506	51.85	50.525	3.02188	0.39954	466.535	13.122559	310.54688	6.152928531	9.764383101	7.576153895	0.630277141	13.22153961	1	0	0	0	32.8	0	19.35	
33	32	4.451531	51.913	54.463	3.05438	0.40225	466.653875	0.2746582	325.68359	5.981139168	9.314683832	7.136083876	0.642400818	13.16975486	1	0	0	0	32.74375	0	19.31875	
34	33	4.446381	51.913	51.613	3.03688	0.40419	466.160375	0.2746582	320.3125	6.185576111	9.68016985	7.438112694	0.63953414	13.3095106	1	0	0	0	32.75625	0	19.35	
35	34	4.497881	52.138	53.444	3.02375	0.40691	466.653875	-0.061035	320.80078	6.081799015	9.523508474	7.322229393	0.638796854	13.45708144	1	0	0	0	31.8875	0	19.35	
36	35	4.468913	52.119	51.231	3.05813	0.40458	464.537	-0.305176	312.98828	6.090331897	9.538599323	7.337122302	0.638961958	13.22971102	1	0	0	0	32.75625	0	19.31875	
37	36	4.43415	51.881	50.756	3.065	0.40381	463.163375	25.756836	288.08594	6.135810032	9.603754961	7.382169643	0.639089572	13.17472431	1	0	0	0	32.9	0	19.31875	
38	37	4.458613	52.231	52.569	2.98313	0.40846	463.0385	33.843994	277.83203	6.020334214	9.399498597	7.214889639	0.640938522	13.69235617	1	0	0	0	33.93125	0	19.09375	
39	38	4.465634	52.125	54.319	2.99813	0.4073	458.543	22.155762	267.57813	6.169381976	9.782082784	7.585555639	0.630828015	13.58503731	1	0	0	0	33.90625	0	19.1375	
40	39	4.481788	52.094	51.856	3.06813	0.40303	456.170375	17.578125	258.30078	6.095207259	9.513968876	7.295532189	0.640815306	13.13601956	1	0	0	0	31.7875	0	19.49375	
41	40	4.445738	52.181	52.125	3.00125	0.40652	458.79275	7.1411133	248.53516	5.927267119	9.287766961	7.141372894	0.638495109	13.5450429	1	0	0	0	33.9	0	19.325	
42	41	4.461831	52.1	53.506	3.00625	0.40342	458.917625	-0.579834	239.74609	6.176798075	9.564638834	7.295301059	0.646756125	13.41928981	1	0	0	0	34.03125	0	19.33125	
43	42	4.476638	52.119	50.675	3.00188	0.40419	461.29025	-0.732422	213.37891	6.123271254	9.71953287	7.534709888	0.630731952	13.46469123	1	0	0	0	32.8625	0	19.0875	
44	43	4.4393	51.956	52.05	3.05313	0.40342	461.415125	-1.89209	203.61328	6.114762392	9.692578846	7.506660551	0.631536446	13.21326182	1	0	0	0	31.775	0	19.325	
45	44	4.474706	52.175	54.038	3.07	0.40574	461.0405	-1.12915	183.59375	6.139303461	9.478463102	7.215395741	0.647953039	13.216443	1	0	0	0	32.90625	0	19.1125	
46	45	4.453463	52.15	54.463	3.0225	0.40768	462.913625	-1.190186	166.01563	5.917723238	9.279733538	7.137998507	0.638102922	13.48831431	1	0	0	0	34.01875	0	19.08125	
47	46	4.485006	52.163	53.944	3.00813	0.40536	463.538	-1.983643	139.64844	6.163584903	9.602432407	7.354403187	0.642890765	13.47540079	1	0	0	0	33.65	0	19.55625	
48	47	4.491444	51.938	54.244	2.97688	0.40264	462.414125	-1.464844	111.32813	6.125492334	9.707241468	7.524832595	0.631172842	13.52564686	1	0	0	0	32.91875	0	19.4875	
49	48	4.488225	52.138	51.319	3.02188	0.40536	463.538	-1.464844	103.02734	6.073472753	9.462031573	7.24905164	0.642203696	13.41408563	1	0	0	0	32.91875	0	19.575	
50	49	4.468269	52.119	53.838	2.99438	0.40148	462.78875	-1.342773	37.597656	6.108921334	9.515778415	7.230555923	0.642627187	13.40773617	1	0	0	0	31.8875	0	19.59375	
51	50	4.472131	51.95	52.638	2.99313	0.40419	462.78875	-1.586914	7.8125	6.103639632	9.677179609	7.503353935	0.630887245	13.50405346	1	0	0	0	34.2	0	19.31875	
52	51	4.479856	52.144	52.194	2.9775	0.40148	461.664875	-1.068115	-21.97266	6.132522032	9.526189103	7.282847142	0.64401121	13.4837246	1	0	0	0	31.81875	0	19.55625	
53	52	4.455394	52.15	53.581	2.97	0.40187	462.78875	-1.586914	-65.91797	6.028323874	9.384941839	7.187625823	0.642857422	13.53083502	1	0	0	0	32.9625	0	19.5875	
54	53	4.461831	52.2	52.644	3.05625	0.40652	462.414125	-1.342773	-76.66016	6.131575972	9.713974196	7.523512884	0.63152447	13.30128753	1	0	0	0	34.1	0	19.36875	
55	54	4.463763	52.275	52.819	3.05438	0.40652	461.165375	-1.434326	-96.19141	6.135380164	9.694311517	7.494229113	0.633225246	13.30945283	1	0	0	0	32.00625	0	19.0875	

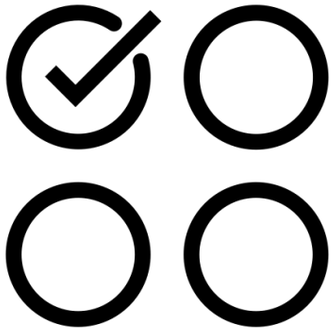


Paso 3:

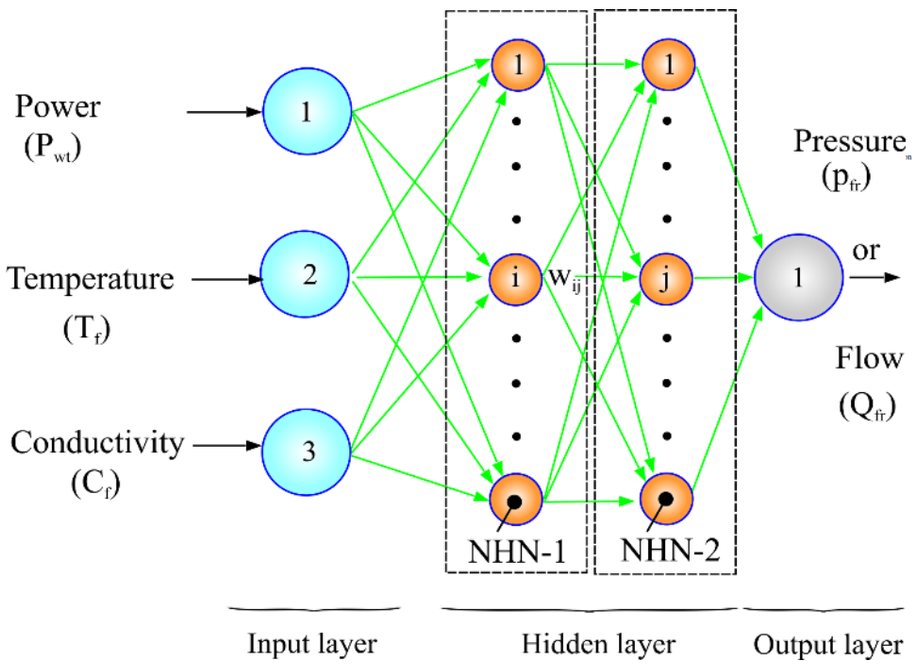
Table 1
Sample of data recorded when operating the SWRO desalination plant with one and two pressure vessels. These data are used to carry out the training, validation and testing of the ANN models(*)

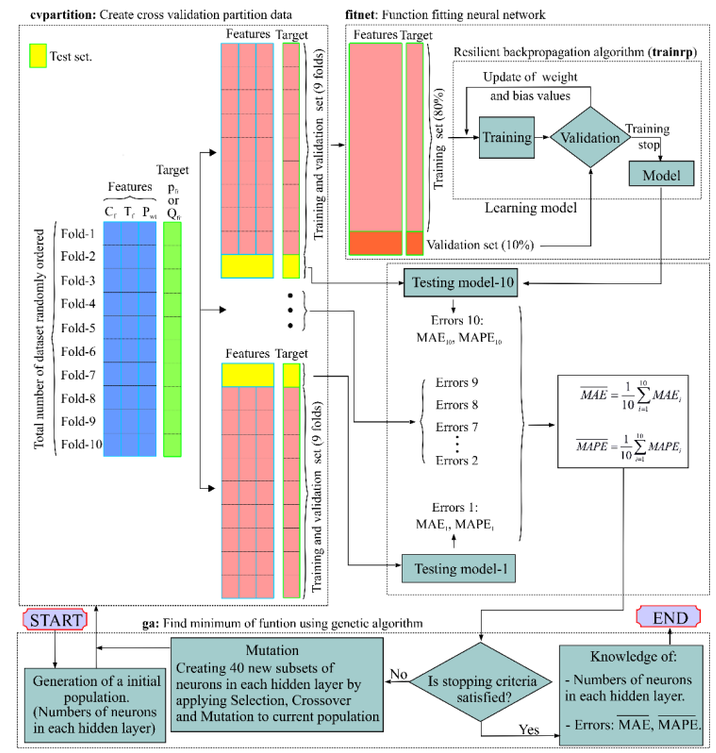
One pressure vessel						Two pressure vessels					
Row number	Conduct. (μS/cm)	Temp. (°C)	Power (kW)	Pressure (bar)	Flow rate (m^3/h)	Row number	Conduct. (μS/cm)	Temp. (°C)	Power (kW)	Pressure (bar)	Flow rate (m^3/h)
1	47645	23.45	**1.84**	33.43	1.05	1	47798	21.29	**4.11**	36.35	3.06
2	**45032**	20.91	1.84	33.34	0.97	2	47251	24.93	4.12	**35.25**	3.07
3	47763	23.44	1.85	33.38	1.04	3	46688	23.28	4.19	35.55	**3.04**
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
9	47645	23.54	1.87	**33.27**	0.98	171	55360	20.39	5.77	43.31	3.53
10	47645	23.43	1.87	33.33	1.04	172	**55626**	20.56	5.78	43.33	3.51
11	51611	23.98	1.87	34.08	1.00	173	47557	23.32	5.79	38.70	4.10
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
32	51241	26.45	2.09	38.11	**0.96**	318	51667	**19.88**	7.53	44.60	4.54
33	53732	24.36	2.09	38.57	1.07	319	47167	24.89	7.55	40.65	5.04
34	53813	24.11	2.09	37.76	1.01	320	54781	21.06	7.56	46.15	4.52
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
76	47298	**20.61**	2.63	37.13	1.50	383	53215	**26.18**	8.36	45.43	5.07
77	50507	21.45	2.68	39.47	1.49	384	53215	25.89	8.36	45.19	5.03
78	50668	21.28	2.69	39.76	1.52	385	52824	25.81	8.36	45.41	5.05
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
100	51206	**26.70**	2.83	40.38	1.50	550	46935	22.79	9.86	45.08	6.08
101	53132	26.18	2.83	40.33	1.50	551	**46395**	22.71	9.87	44.83	5.97
102	51206	26.38	2.84	40.38	1.51	552	47323	22.81	9.87	44.92	6.02
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
110	52875	26.23	2.88	40.16	1.46	682	53523	20.66	10.96	50.68	**6.13**
111	51133	26.23	2.90	40.20	1.47	683	52832	20.93	10.96	50.40	6.05
112	**54180**	20.75	2.98	42.33	1.49	684	53523	21.14	10.96	**50.79**	6.08
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
503	53655	21.21	6.21	52.83	3.03	690	52832	20.72	11.05	50.59	6.07
504	53239	21.09	6.22	**53.09**	**3.07**	691	52832	20.99	11.06	50.63	6.07
505	53239	21.11	**6.22**	52.77	2.97	692	52832	20.96	**11.07**	50.41	6.07

(*)Numbers in bold indicate the minimum and maximum recorded of the five variables.

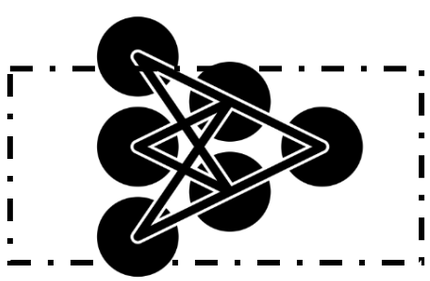


Selección de variables



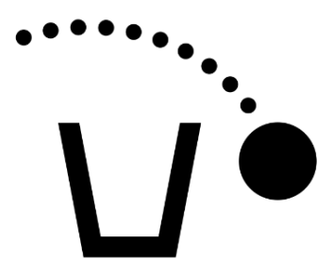


Paso 4:



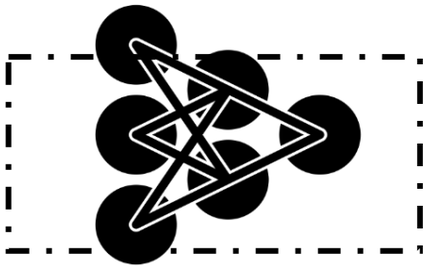
Entrenamiento del algoritmo con entradas y salidas conocidas

Paso 5:

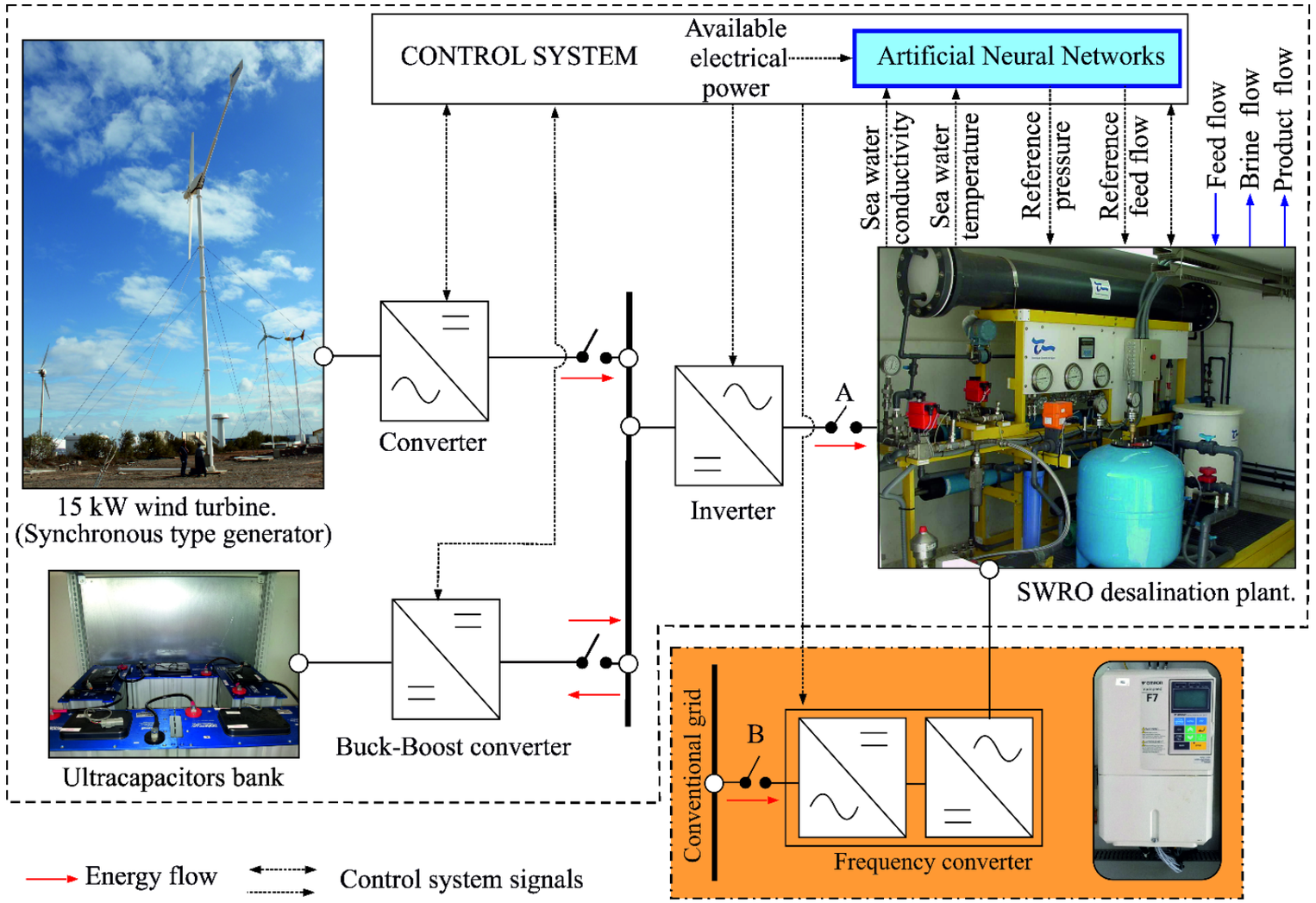


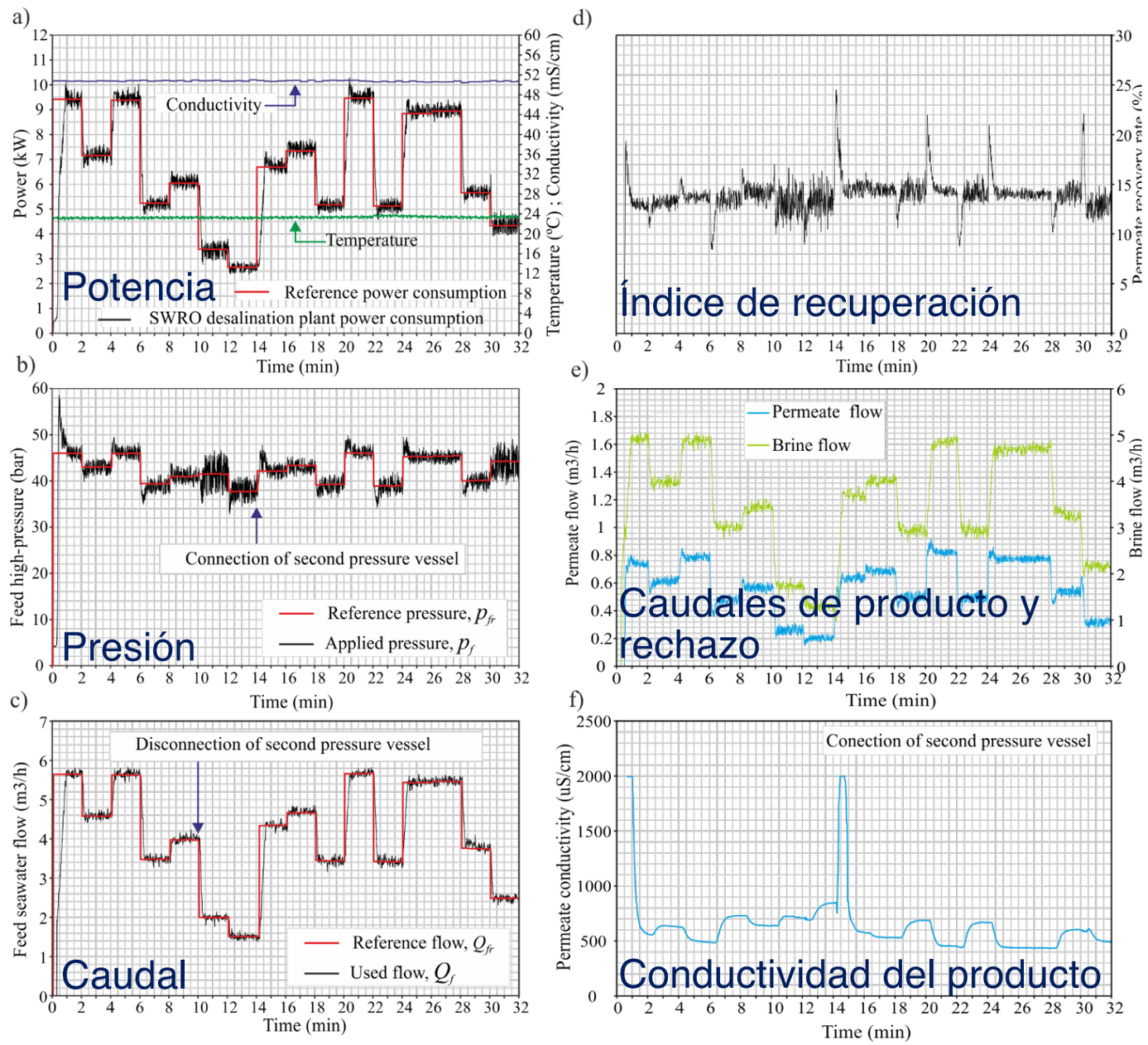
Cálculo del error cometido

Paso 6:

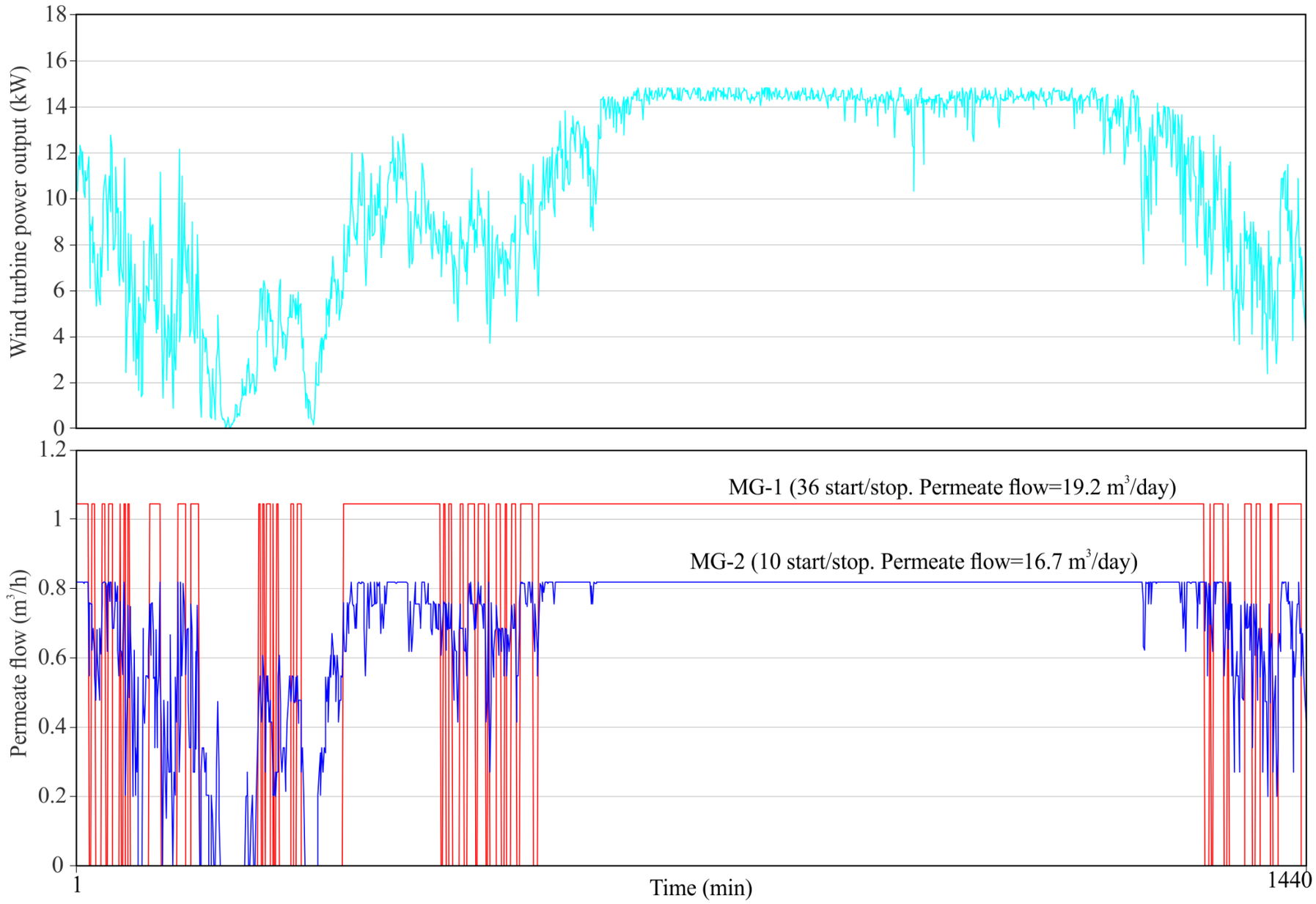


Uso del algoritmo con nuevas entradas

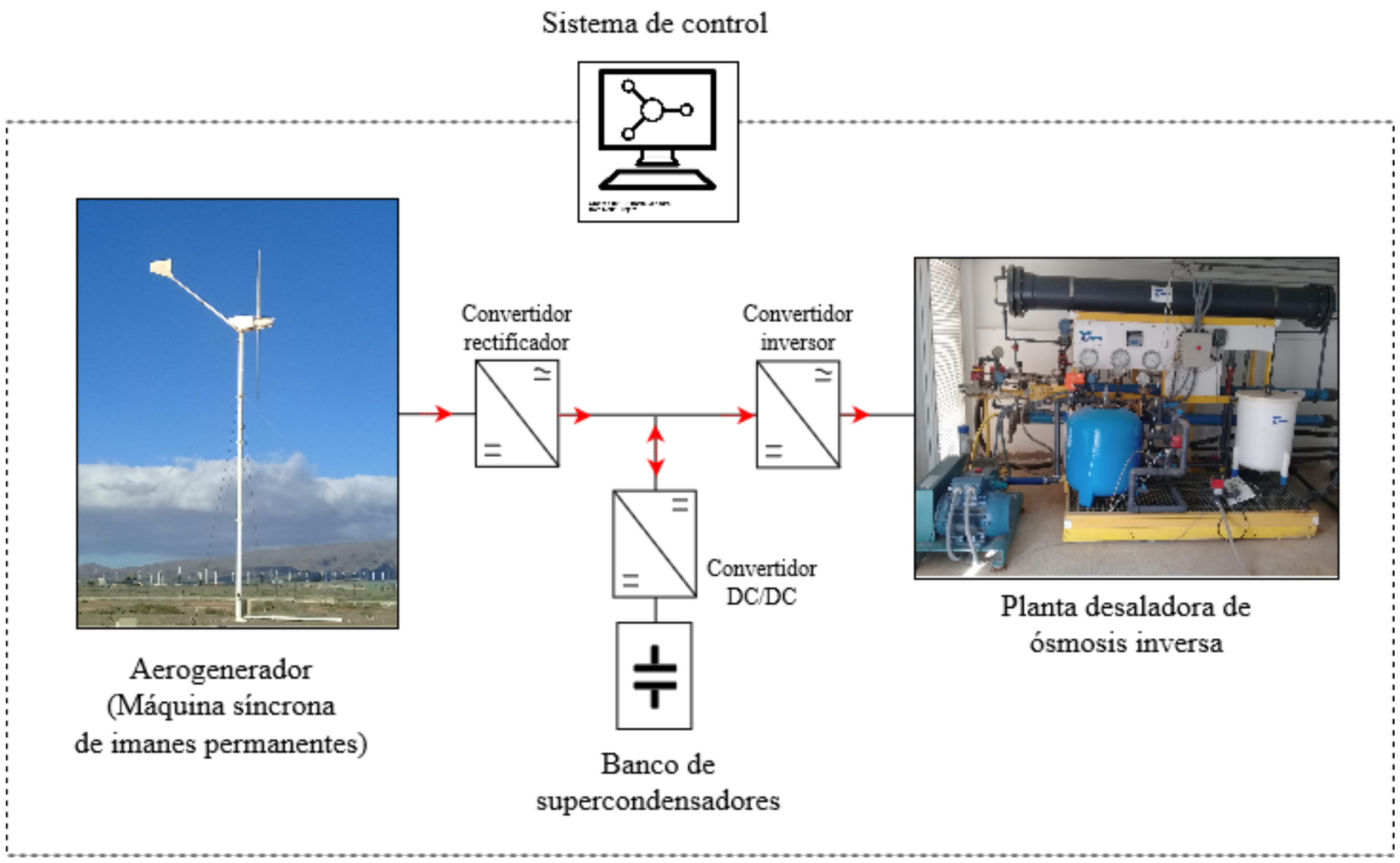



a)
Power (kW)
Temperature (ºC) ; Conductivity (mS/cm)
Conductivity
Temperature
Potencia
Reference power consumption
SWRO desalination plant power consumption
Time (min)
b)
Feed high-pressure (bar)
Connection of second pressure vessel
Reference pressure, p_{fr}
Applied pressure, p_f
Presión
Time (min)
c)
Feed seawater flow (m3/h)
Disconnection of second pressure vessel
Reference flow, Q_{fr}
Used flow, Q_f
Caudal
Time (min)
d)
Permeate recovery rate (%)
Índice de recuperación
Time (min)
e)
Permeate flow (m3/h)
Brine flow (m3/h)
Permeate flow
Brine flow
Caudales de producto y rechazo
Time (min)
f)
Permeate conductivity (uS/cm)
Conection of second pressure vessel
Conductividad del producto
Time (min)

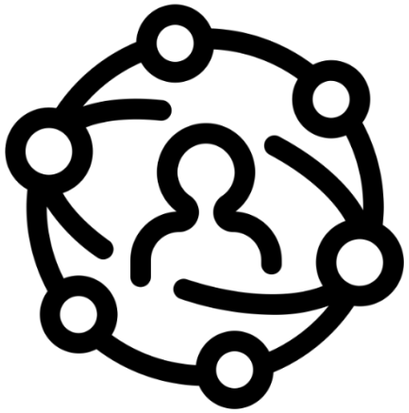
Results


Wind turbine power output (kW)
18
16
14
12
10
8
6
4
2
0
Permeate flow (m³/h)
1.2
1
0.8
0.6
0.4
0.2
0
MG-1 (36 start/stop. Permeate flow=19.2 m³/day)
MG-2 (10 start/stop. Permeate flow=16.7 m³/day)
1
1440
Time (min)

...the authors were able the combine the ANN and the engineering to a level that deserve publication ***as one of the first steps towards optimal operation of membrane systems****. For this they deserve a real applause.*

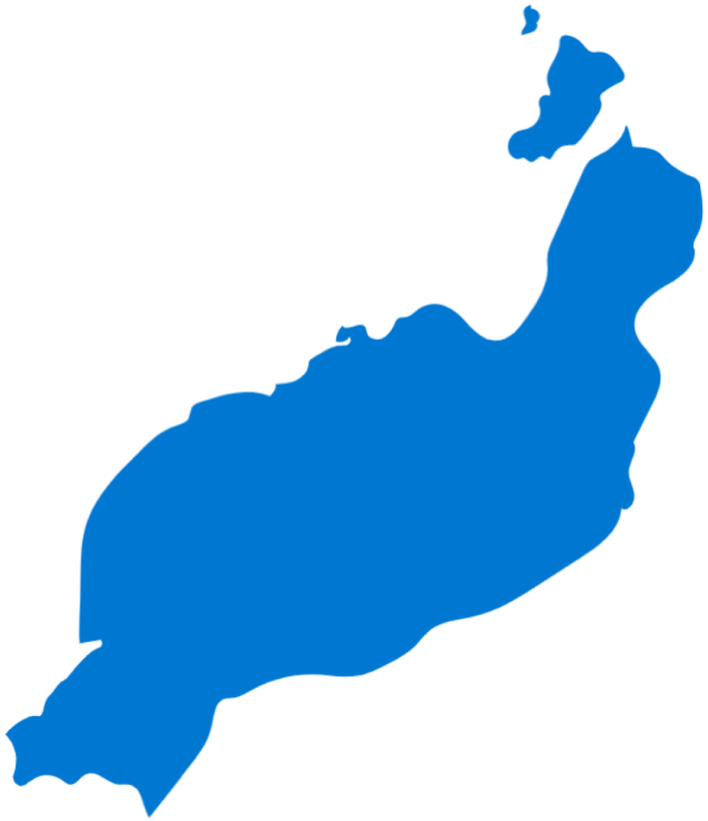

Sistema de control
Convertidor rectificador
Convertidor inversor
Convertidor DC/DC
Aerogenerador (Máquina síncrona de imanes permanentes)
Banco de supercondensadores
Planta desaladora de ósmosis inversa

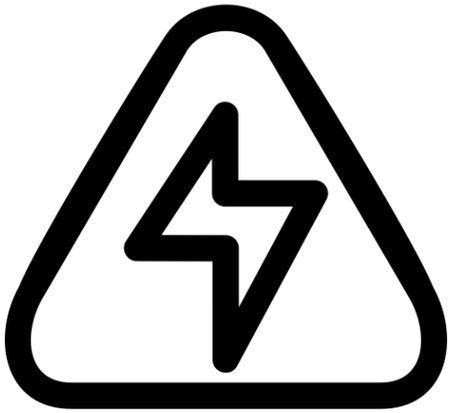
Por otra parte:



Comunicaciones

Transporte



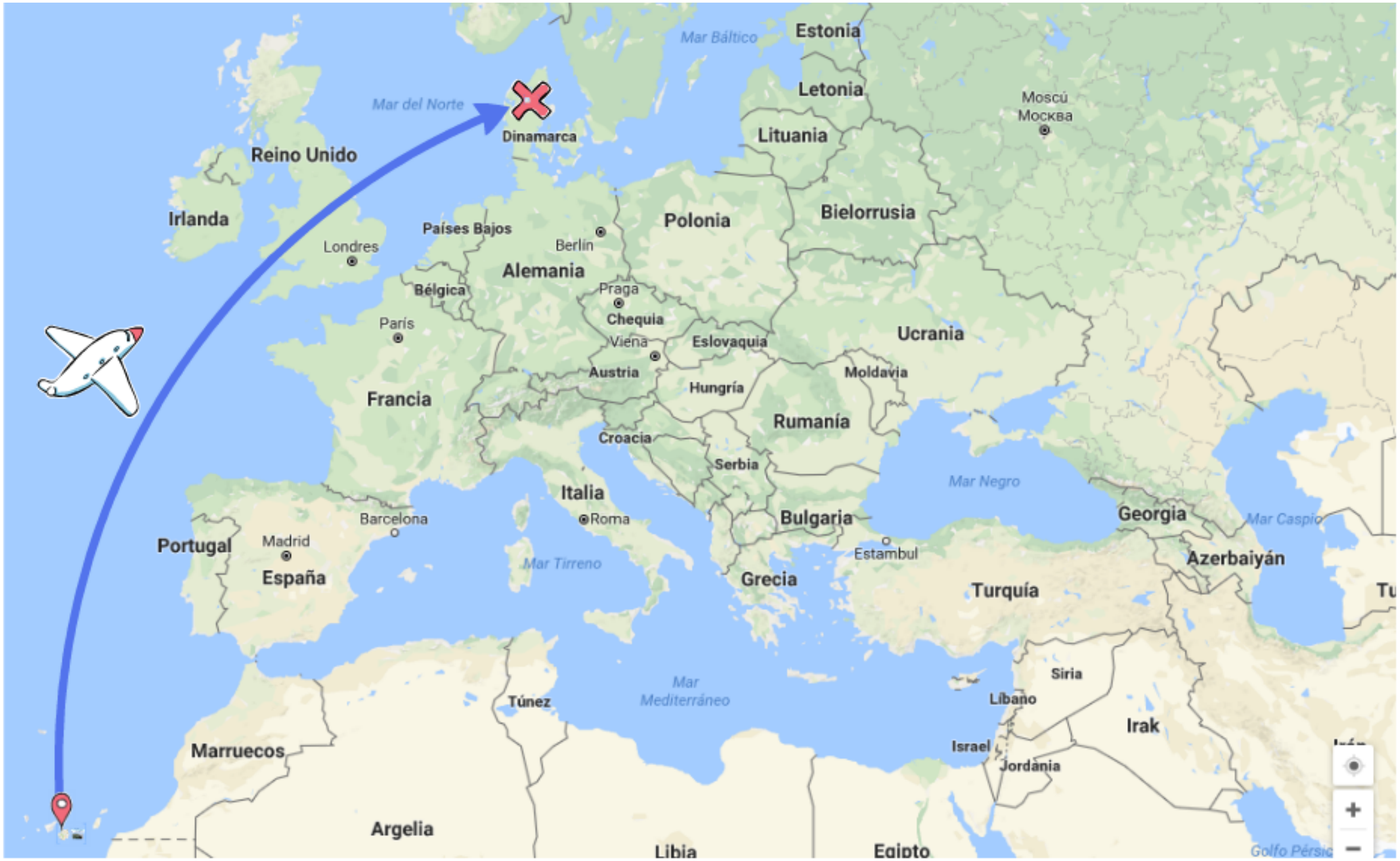


Energía

Research question

¿Sería posible incrementar la integración de Energías Renovables en un sistema aislado como Lanzarote gestionando la desalación?

Método


Mar Báltico
Estonia
Letonia
Lituania
Moscú
Москва
Mar del Norte
Dinamarca
Reino Unido
Irlanda
Polonia
Bielorrusia
Países Bajos
Londres
Berlín
Alemania
Bélgica
Praga
Chequia
París
Viena
Eslovaquia
Ucrania
Austria
Moldavia
Hungría
Francia
Rumanía
Croacia
Serbia
Mar Negro
Italia
Roma
Barcelona
Bulgaria
Georgia
Mar Caspio
Portugal
Madrid
España
Estambul
Azerbaiyán
Mar Tirreno
Grecia
Turquía
Siria
Mar Mediterráneo
Túnez
Líbano
Irak
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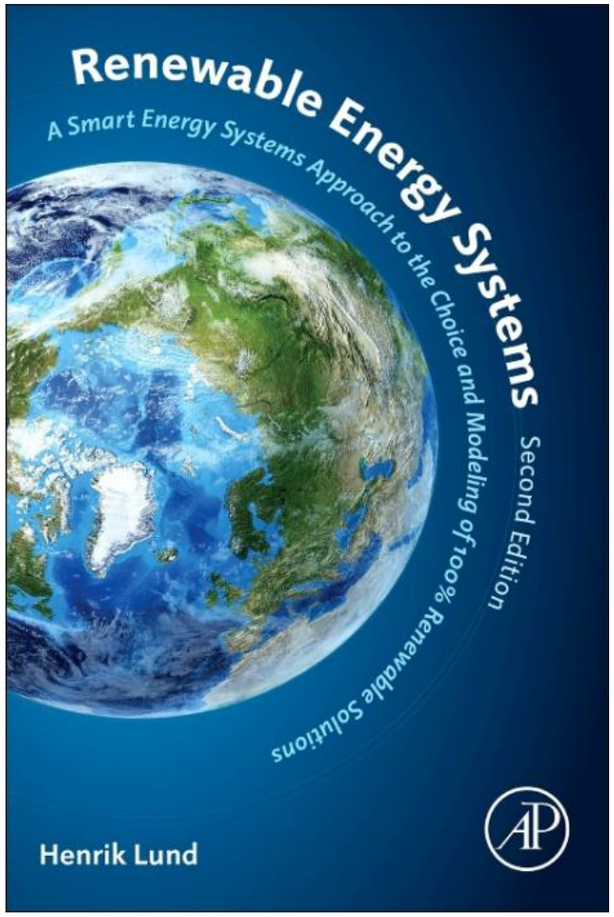
Jordania
Marruecos
Argelia
Libia
Egipto
Golfo Pérsico



- Teoría de la elección consciente
- Smart Energy Systems

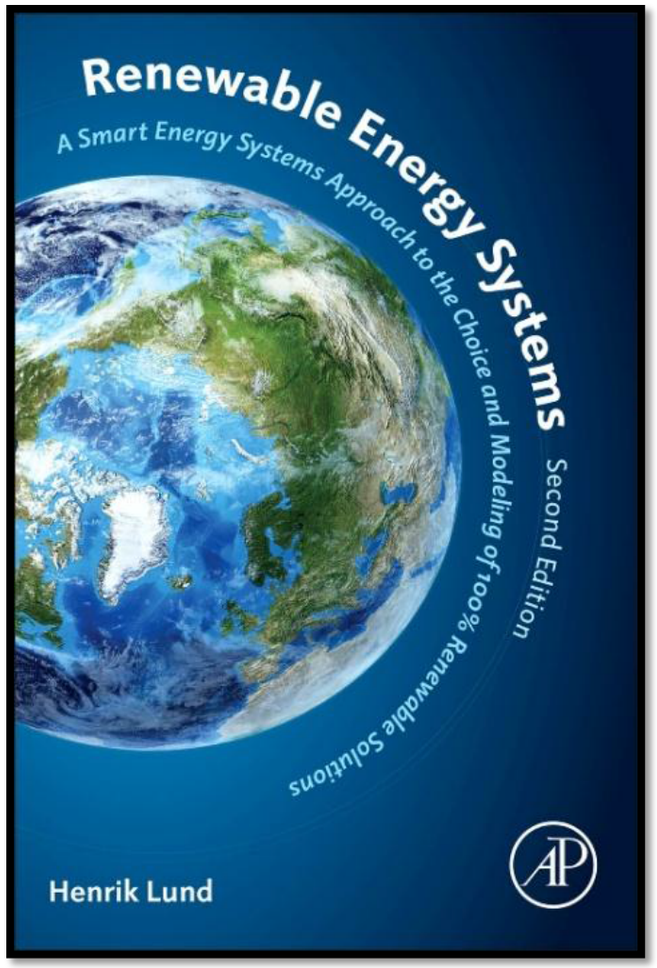
Henrik Lund

Sustainable Energy Planning Research Group

Social projects Aalborg komune

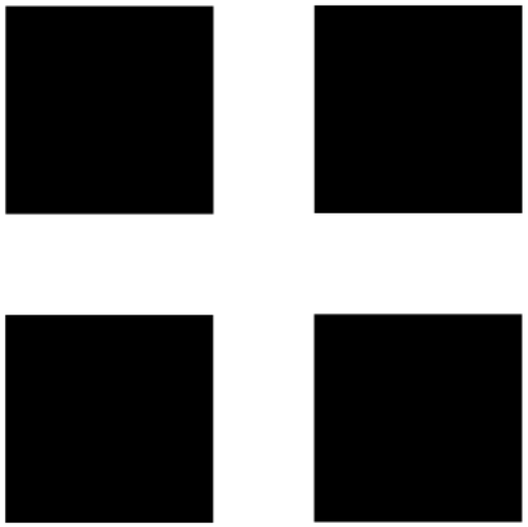
Gotemburgo, Suecia

El concepto Smart Energy System aplicado a islas



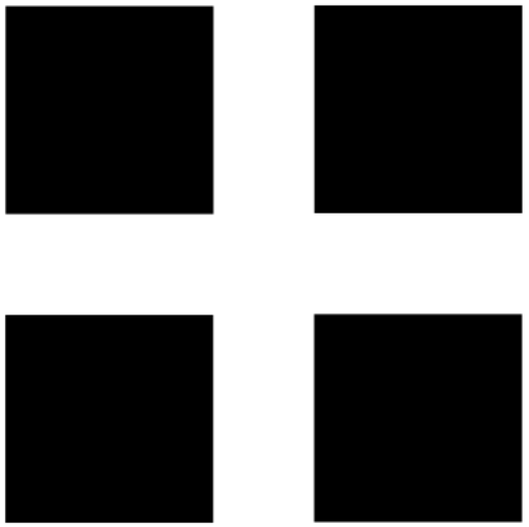
¿Smart Energy System?

Los sectores de un Sistema energético se consideran independientemente

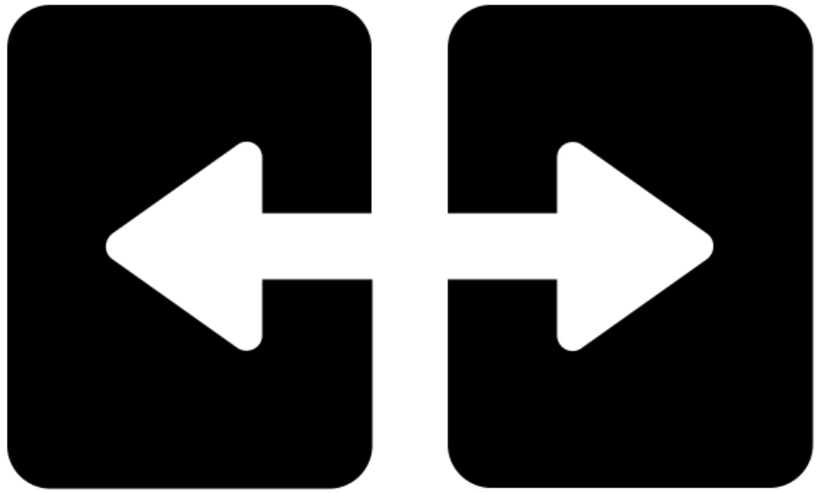


¿Smart Energy System?

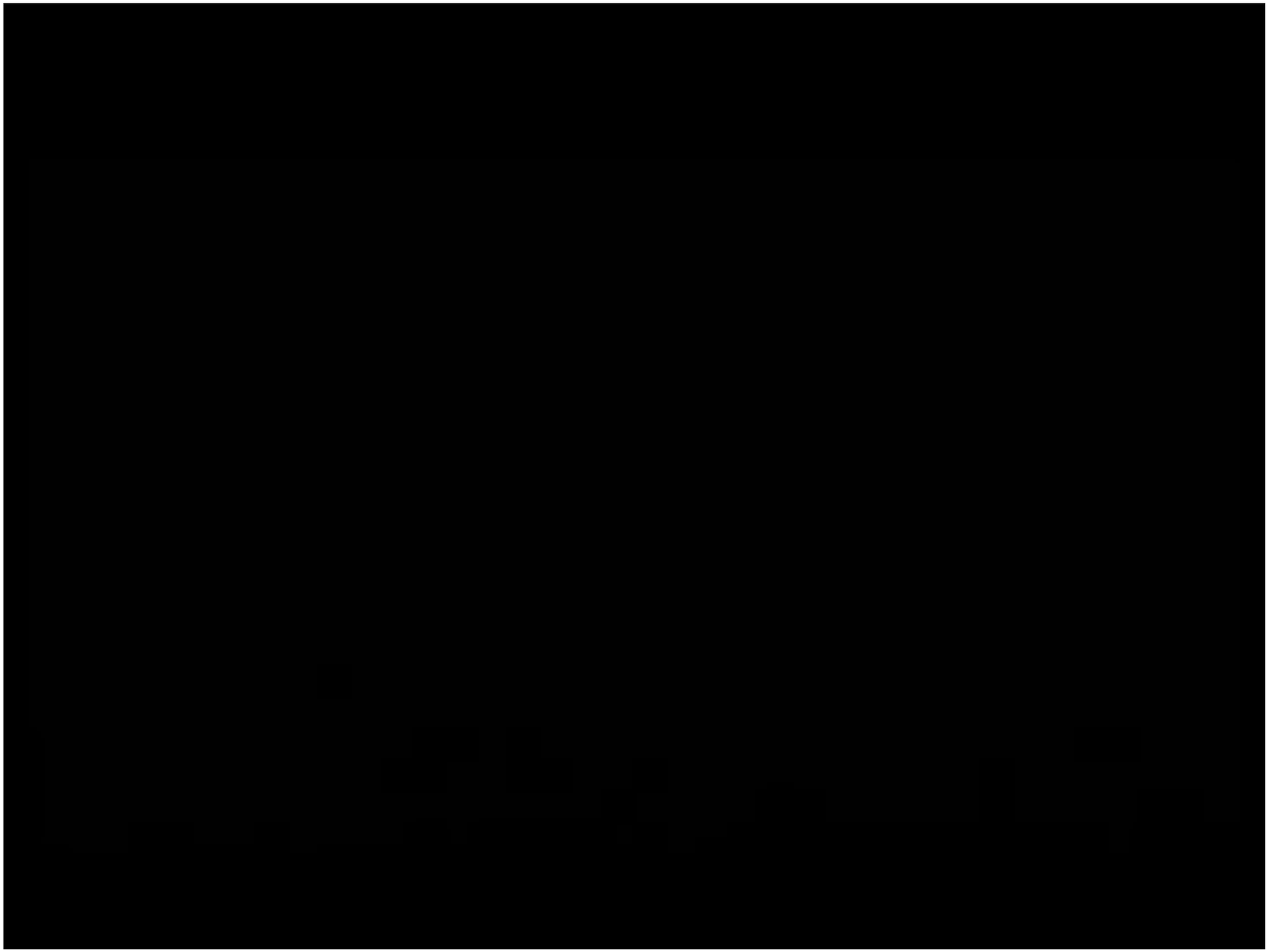
Los sectores de un Sistema energético se consideran independientemente

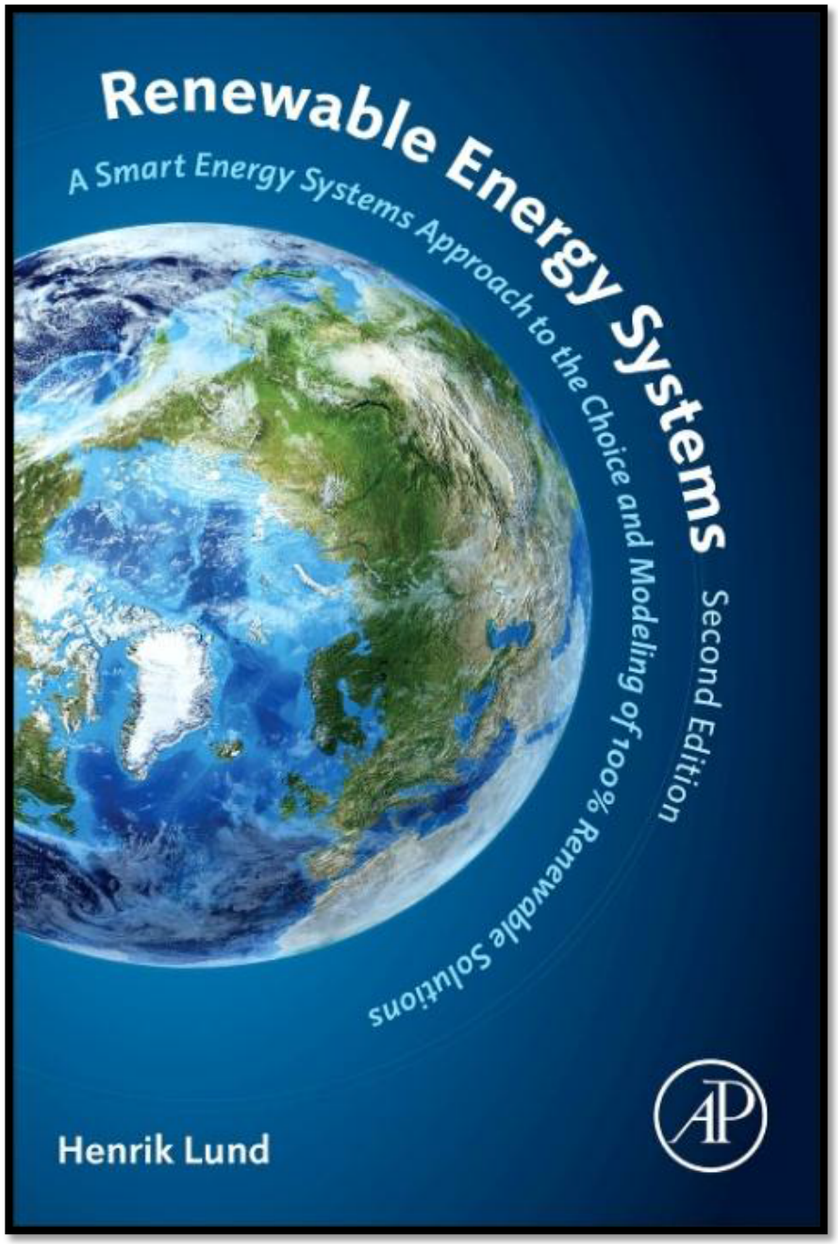


Sin embargo si estos se integran y colaboran entre sí, se optienen mejores soluciones

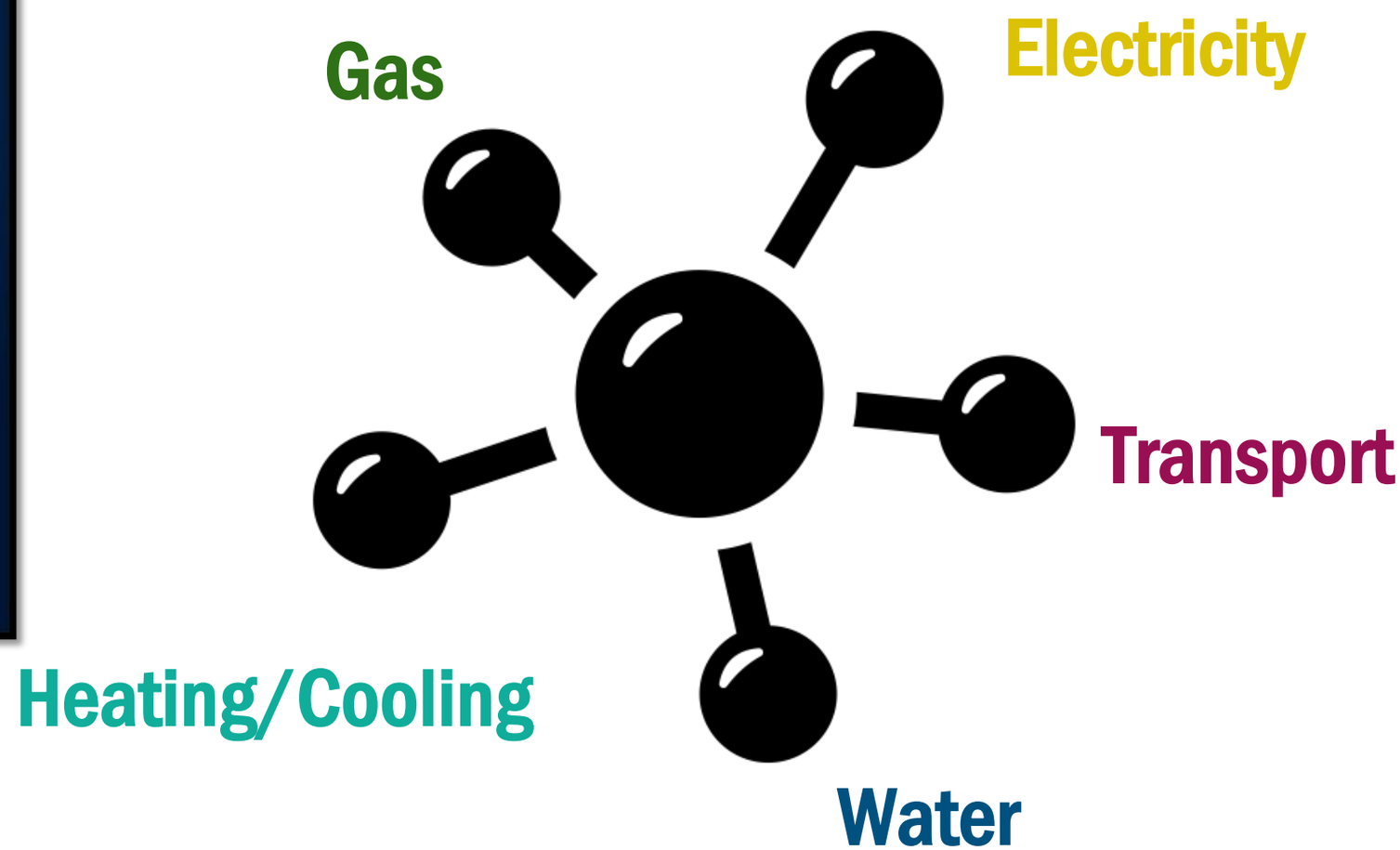


¿Smart Energy System?





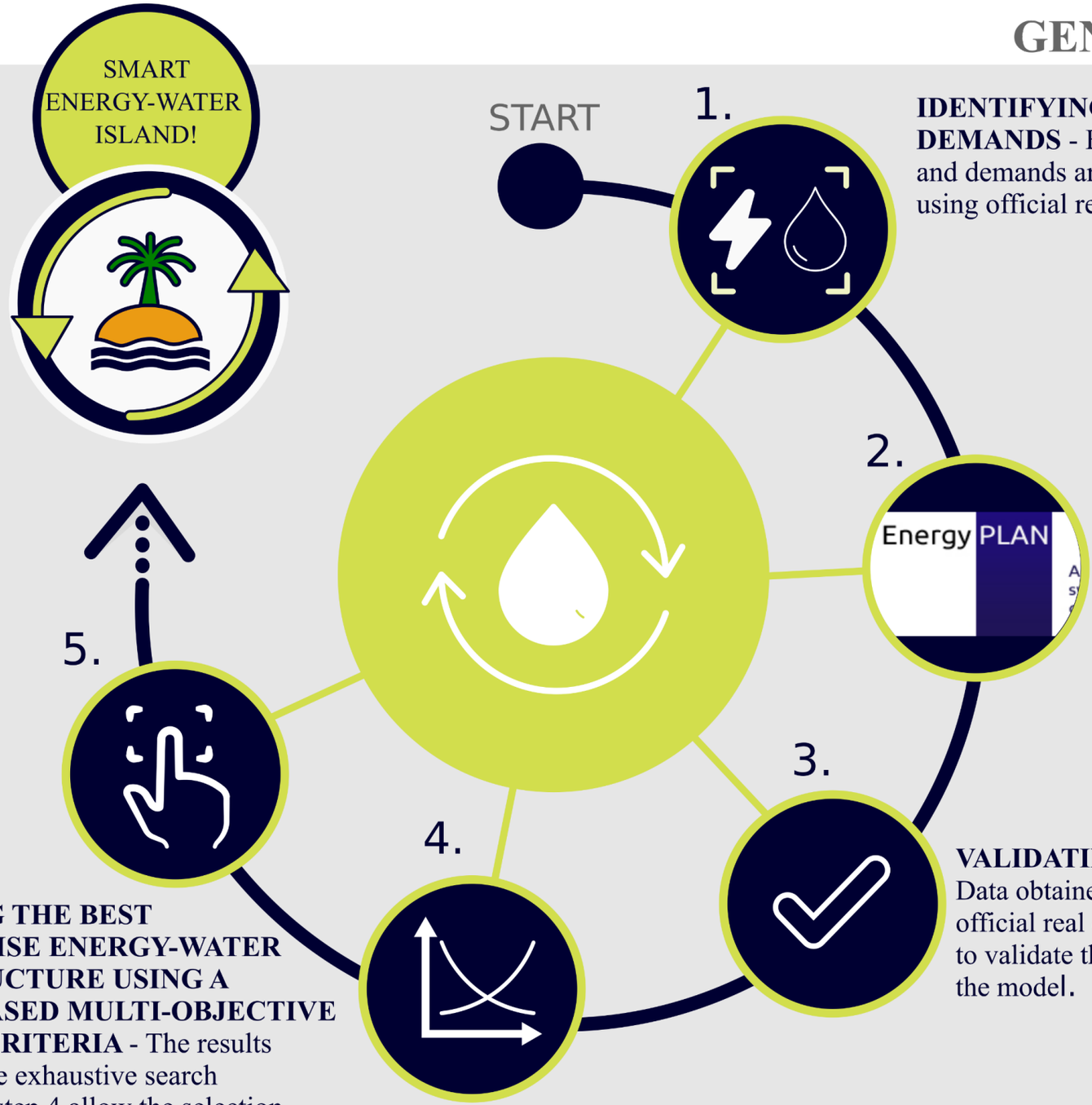
Smart Energy System



Aplicación a la isla de Lanzarote como caso de estudio

©Quolo

GENERAL METHOD



IDENTIFYING RESOURCES AND DEMANDS - Energy-Water resources and demands are identified on the island using official records.

MODELLING REFERENCE SCENARIO - A known reference scenario is modelled using the EnergyPLAN tool.

VALIDATING REFERENCE SCENARIO - Data obtained from EnergyPLAN and official real data are cross-crecked to validate the results obtained from the model.

GENERATING THE POPULATION OF FEASIBLE ENERGY-WATER SYSTEMS USING AN *EXHAUSTIVE SEARCH* - An exhaustive search of water infrastructures and optimal renewable configurations is made to generate a set of optimal energy-water feasible solutions to be analysed in the following step..

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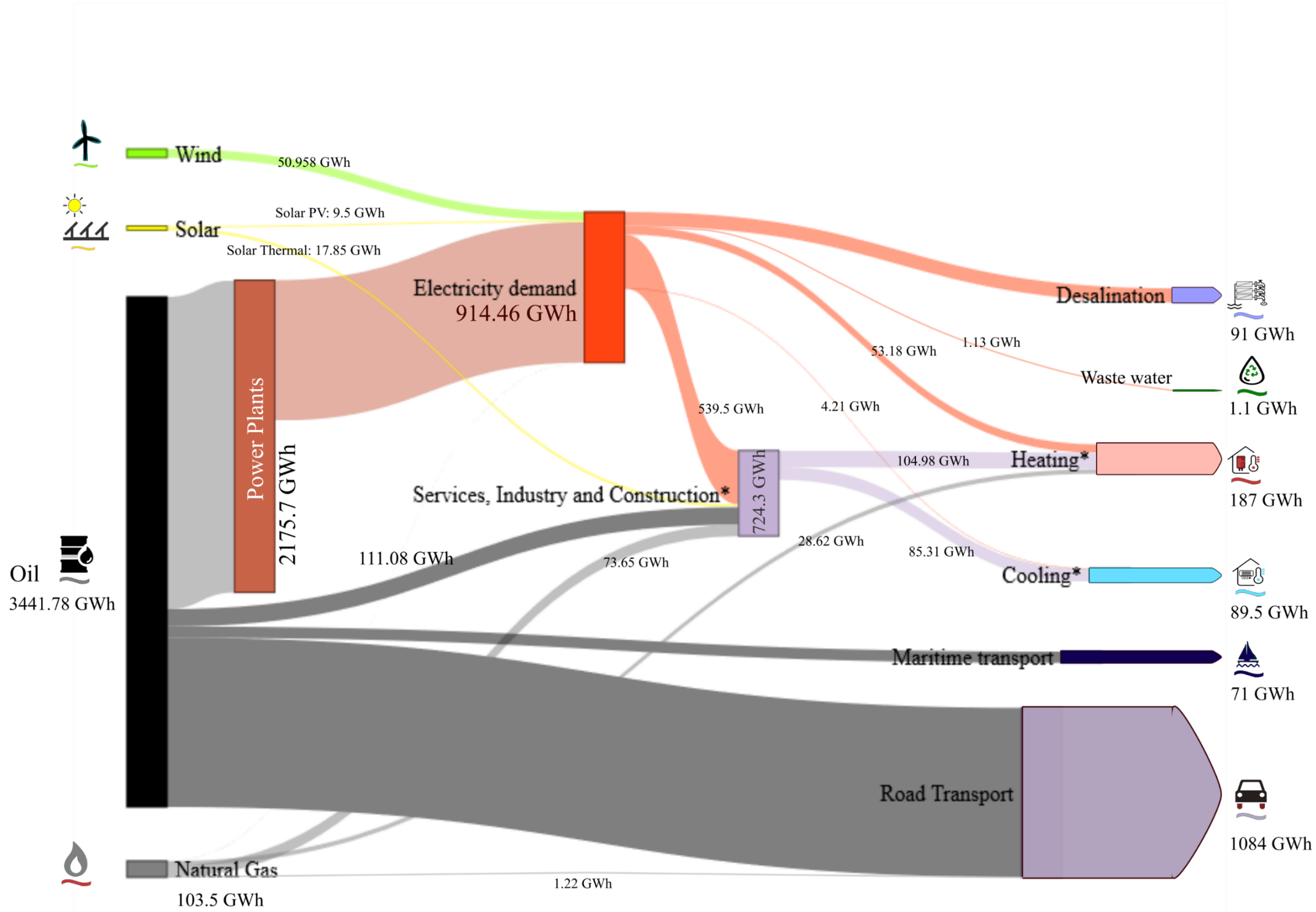
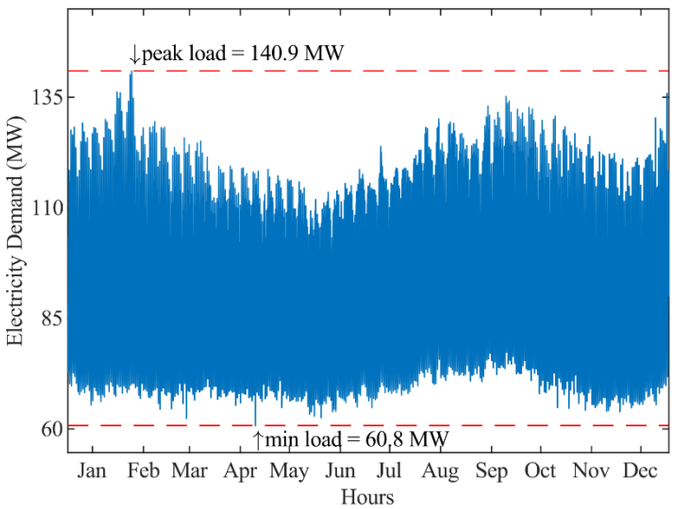
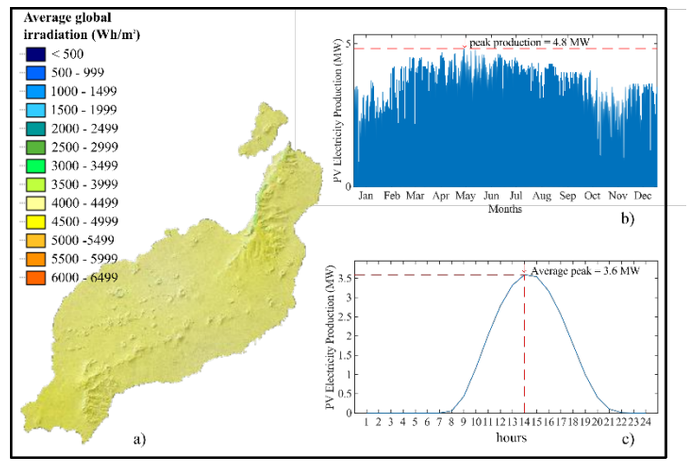
1. Identificación de los recursos disponibles y las demandas



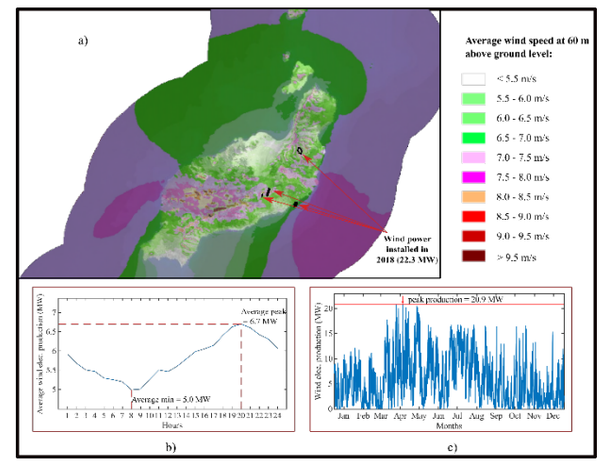
1. Identificación de los recursos disponibles y las demandas



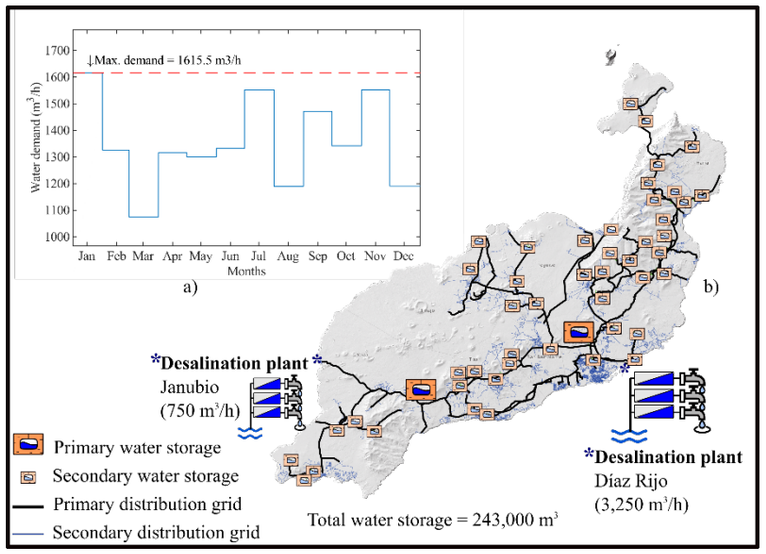
Electricity demand



PV resource

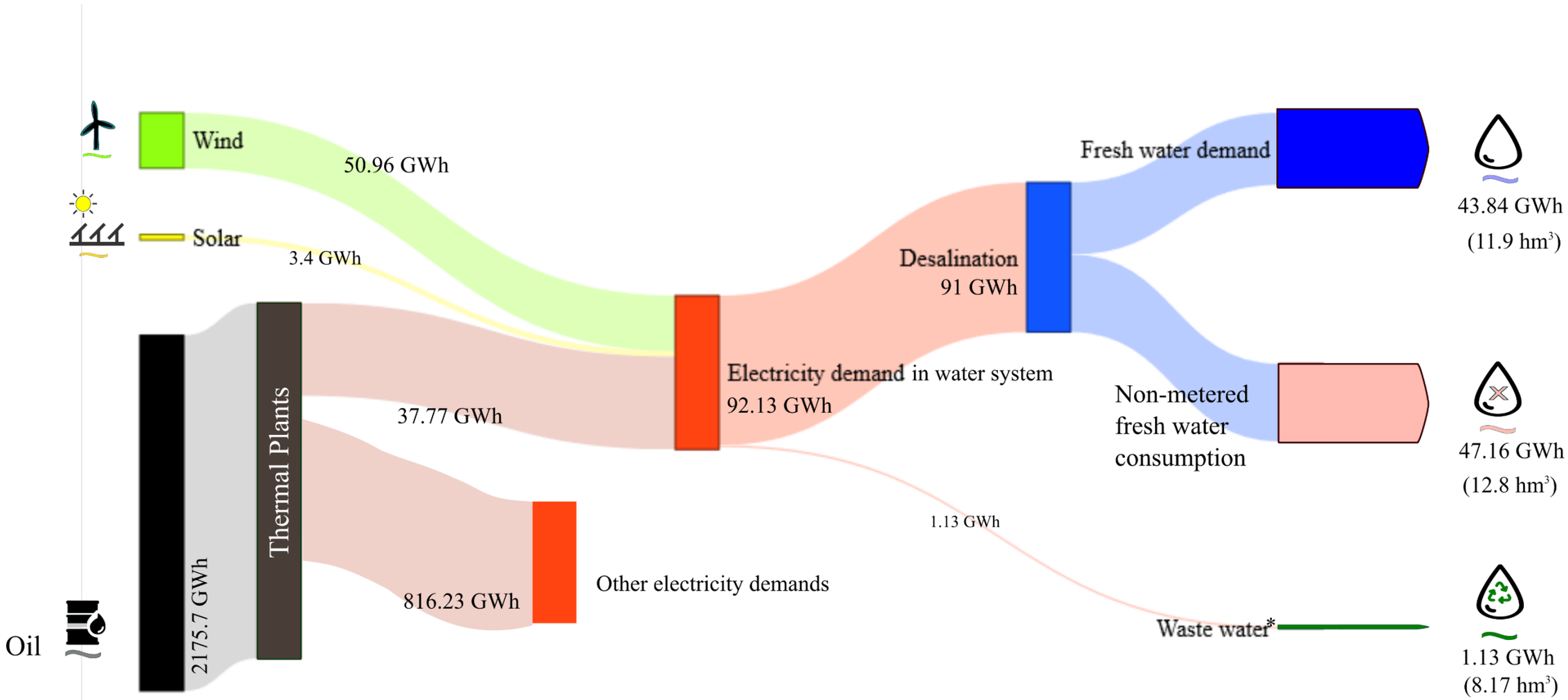


Wind resource

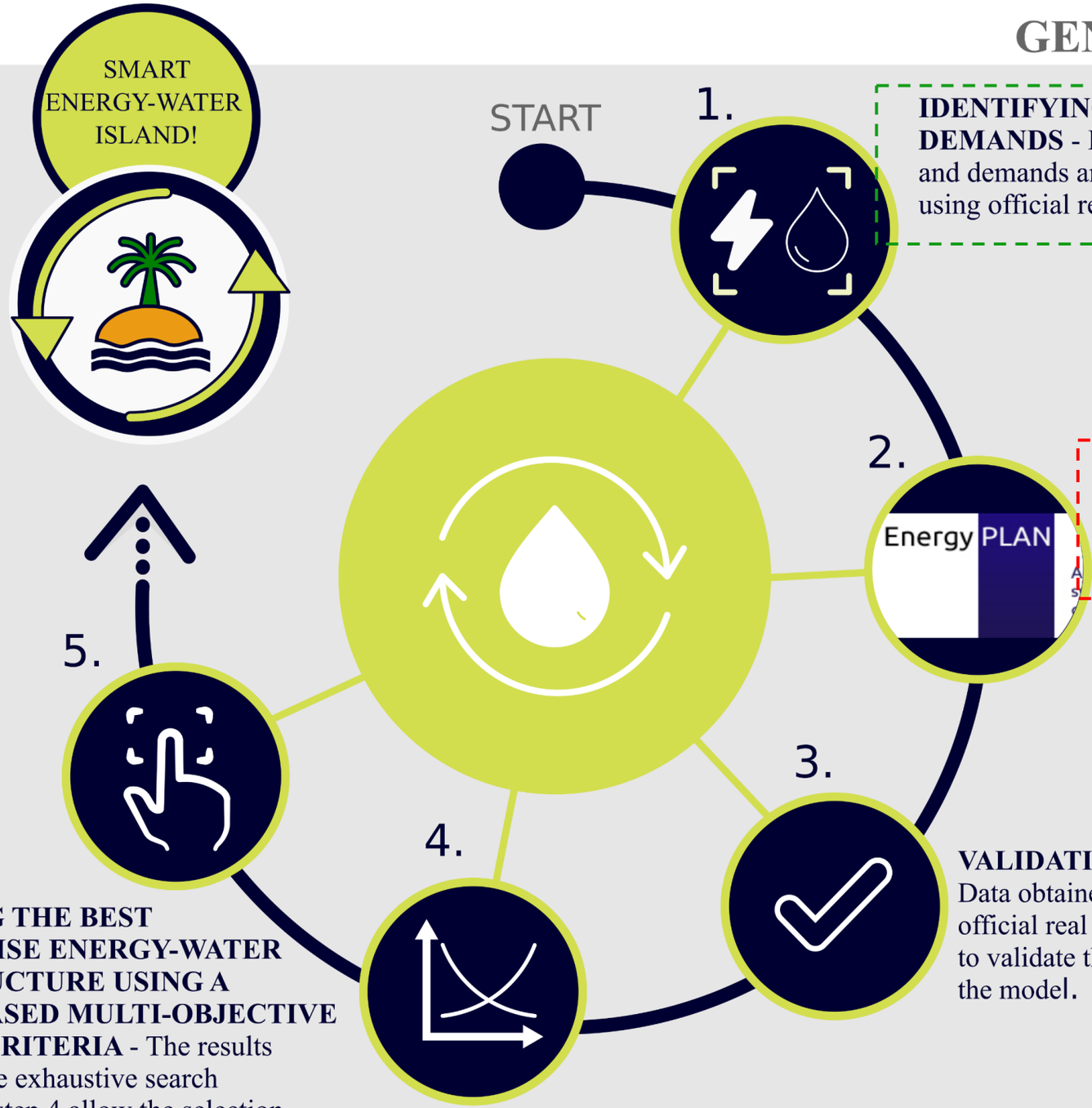


Water supply infrastructure configuration

1. Identificación de los recursos disponibles y las demandas



GENERAL METHOD



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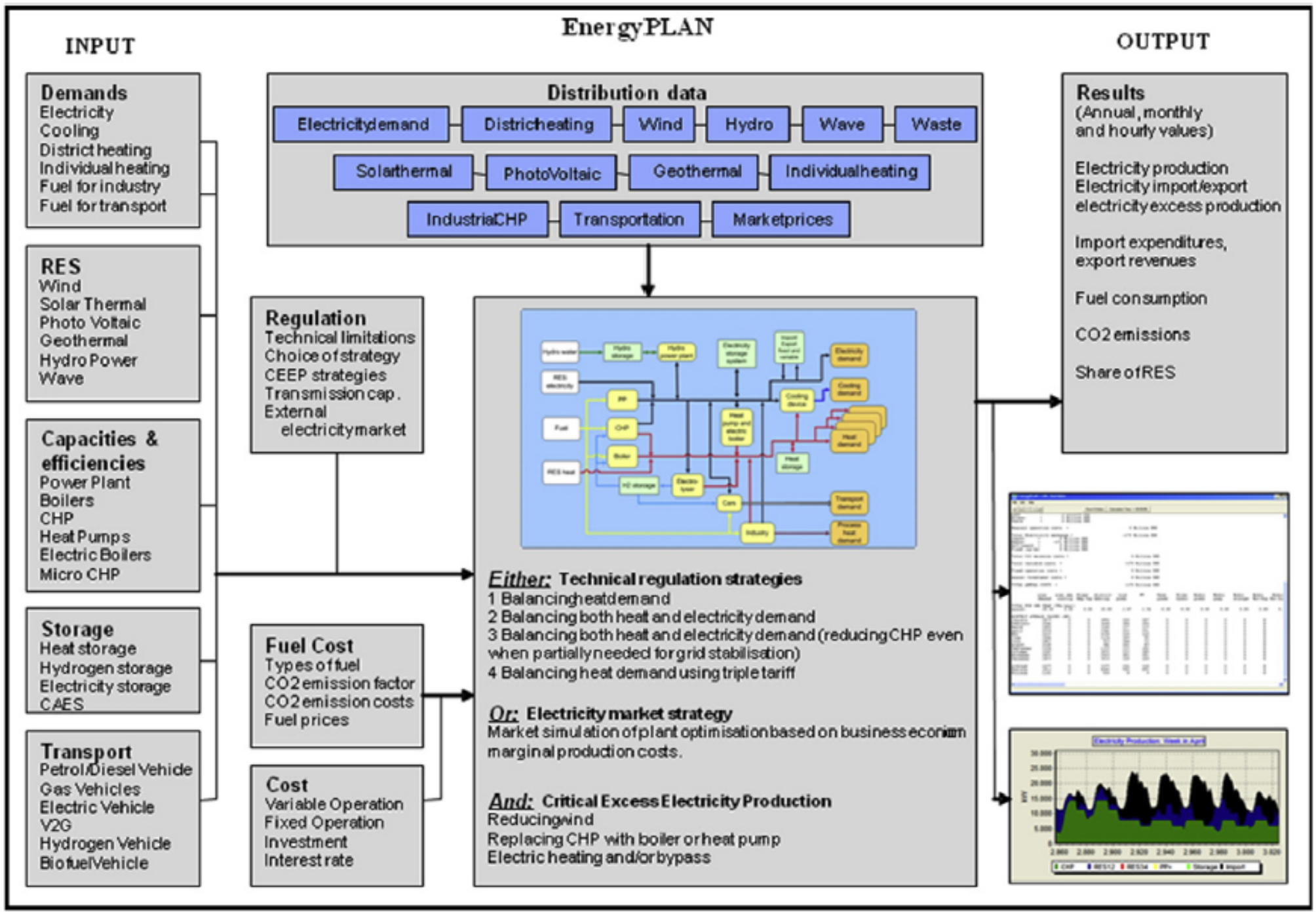
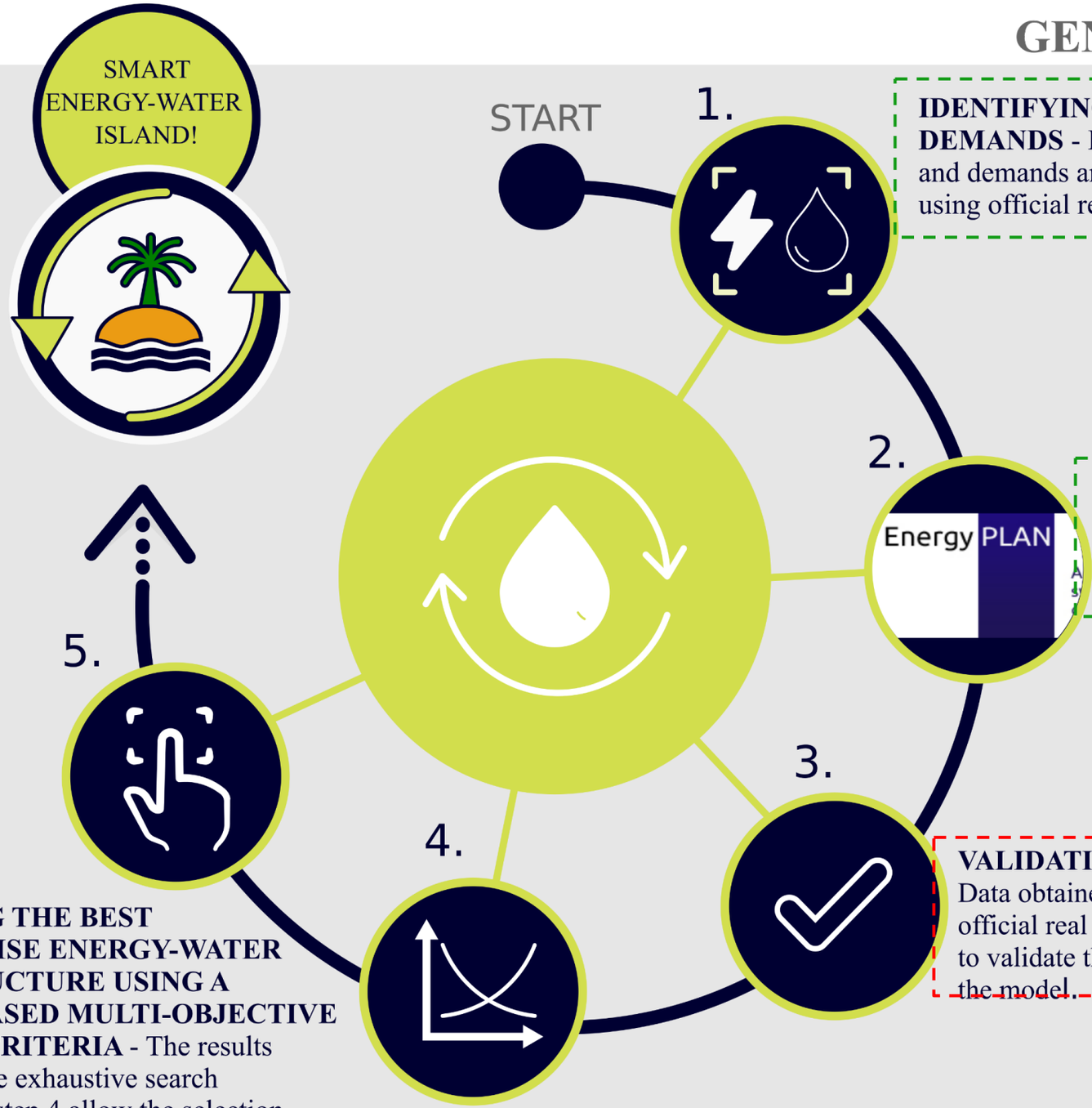
2. Se modela el escenario de referencia



GENERAL METHOD



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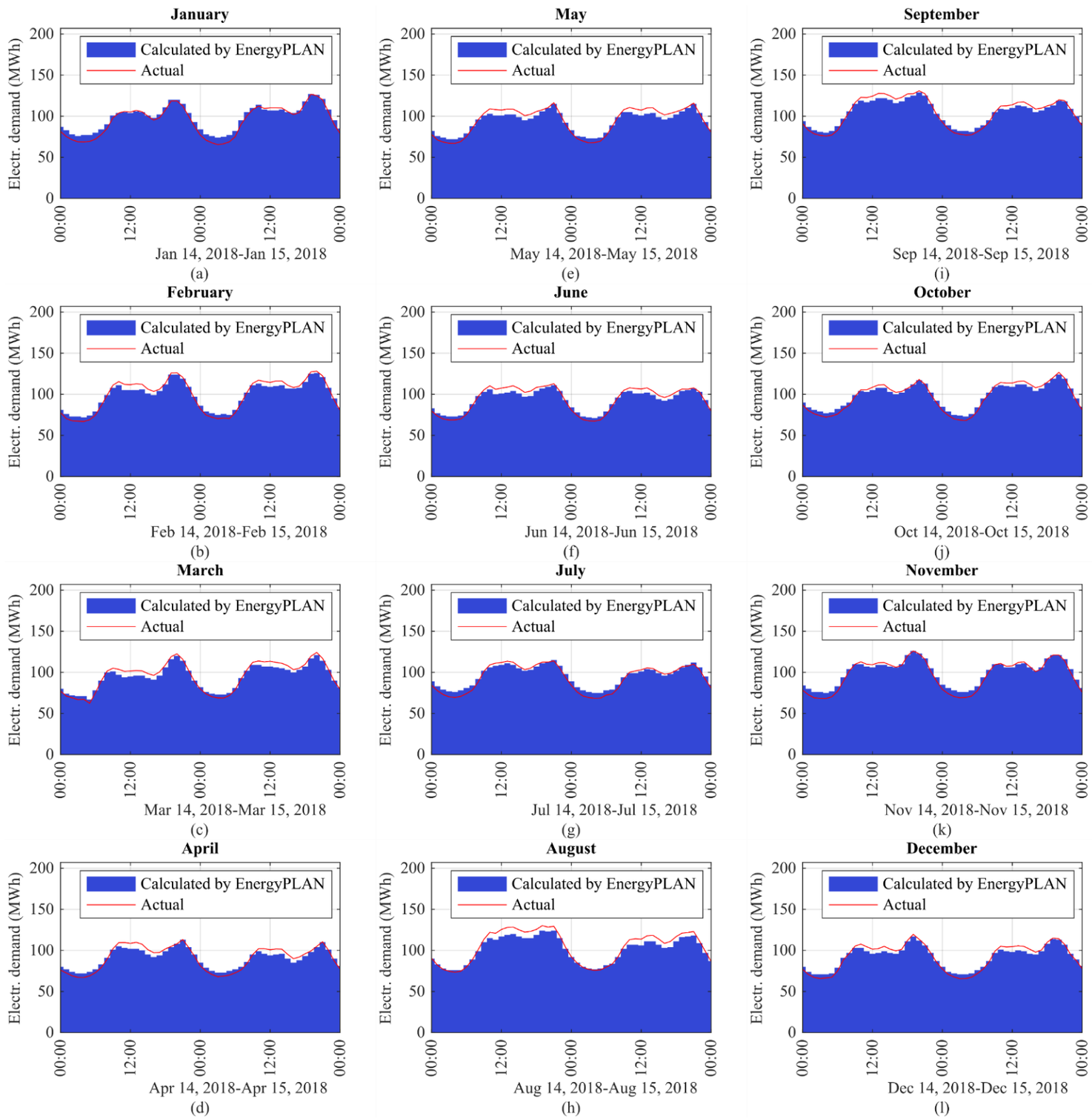
3. Se validan los resultados del modelo con los de la realidad



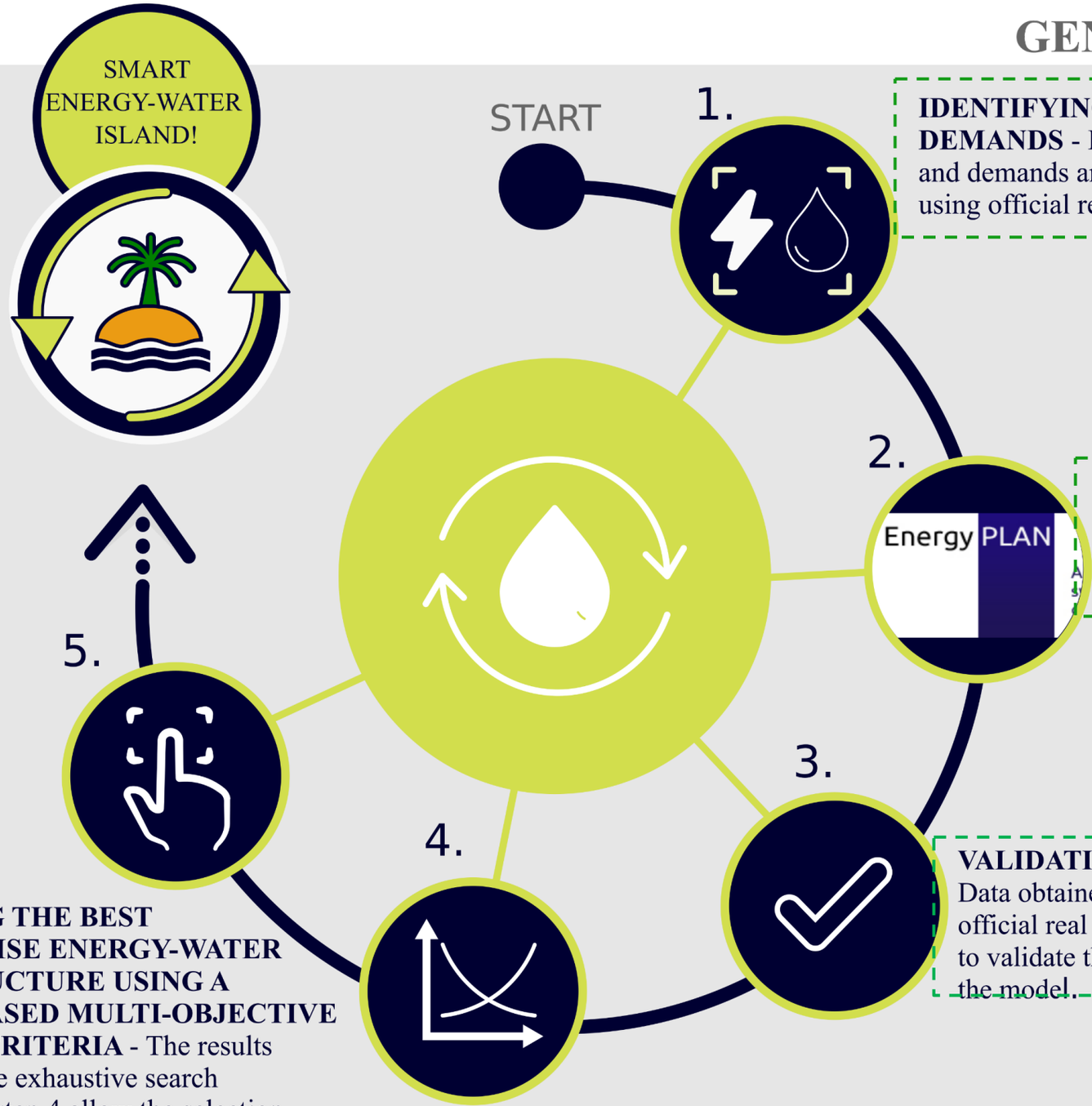
3. Se validan los resultados del modelo con los de la realidad

Table 3
Average monthly electricity demand obtained from the EnergyPLAN model and actual values for the year 2018 in Lanzarote.

Month	Actual 2018 (GWh)	EnergyPLAN 2018 (GWh)	Difference (GWh)	Difference (%)
January	72.98	75.03	2.05	2.81
February	66.70	66.46	−0.24	−0.36
March	71.13	69.83	−1.30	−1.83
April	68.06	67.51	−0.56	−0.82
May	69.03	68.49	−0.55	−0.79
June	67.47	66.74	−0.73	−1.09
July	72.30	73.37	1.07	1.48
August	76.31	73.96	−2.35	−3.08
September	74.62	74.51	−0.10	−0.14
October	75.03	75.37	0.34	0.45
November	68.83	70.50	1.66	2.42
December	72.61	72.28	−0.33	−0.46
Total	855.08	854.05	−1.04	−0.12

Error <5%

GENERAL METHOD



IDENTIFYING RESOURCES AND DEMANDS - Energy-Water resources and demands are identified on the island using official records.

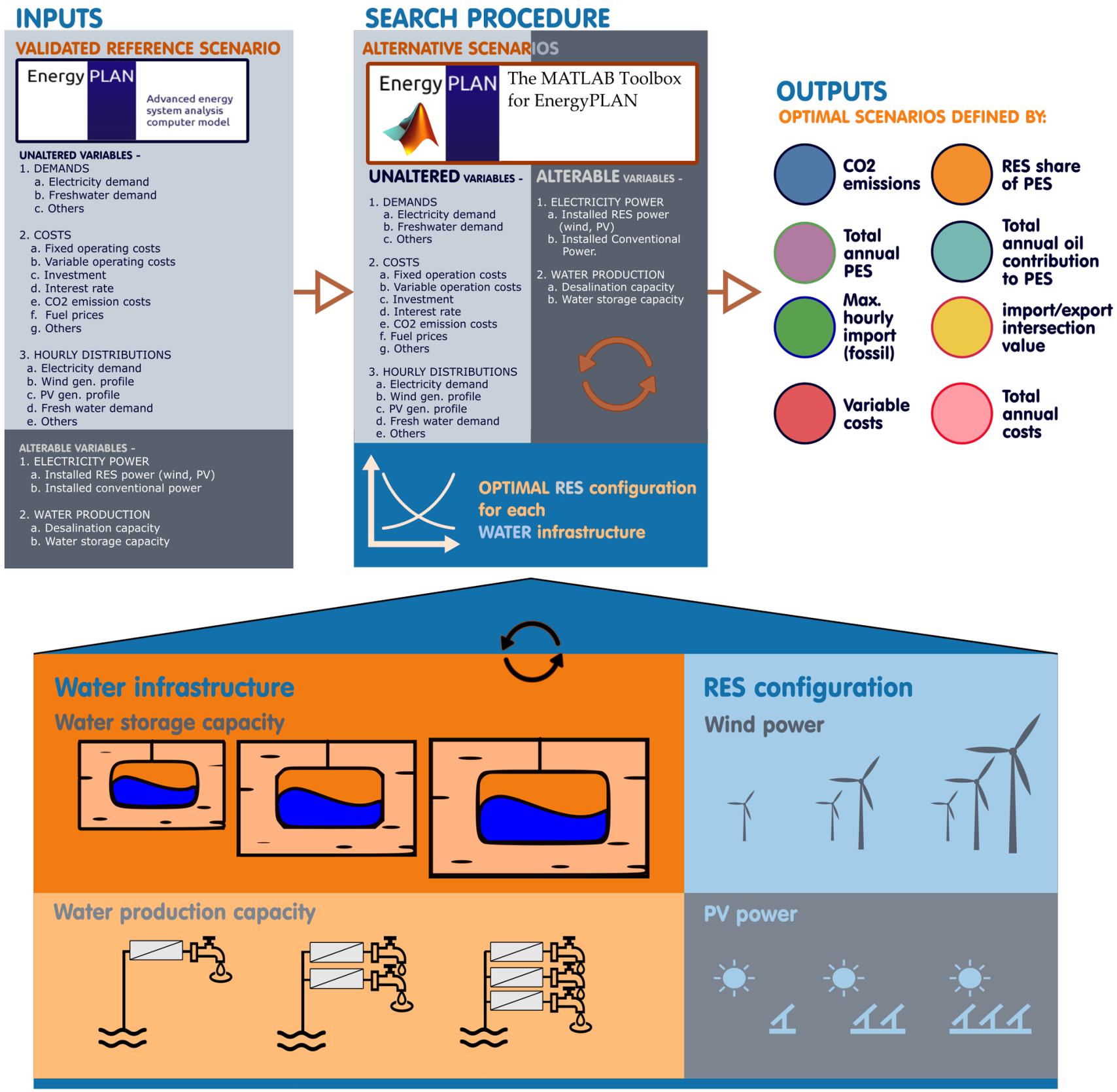
MODELLING REFERENCE SCENARIO - A known reference scenario is modelled using the EnergyPLAN tool.

VALIDATING REFERENCE SCENARIO - Data obtained from EnergyPLAN and official real data are cross-crecked to validate the results obtained from the model.

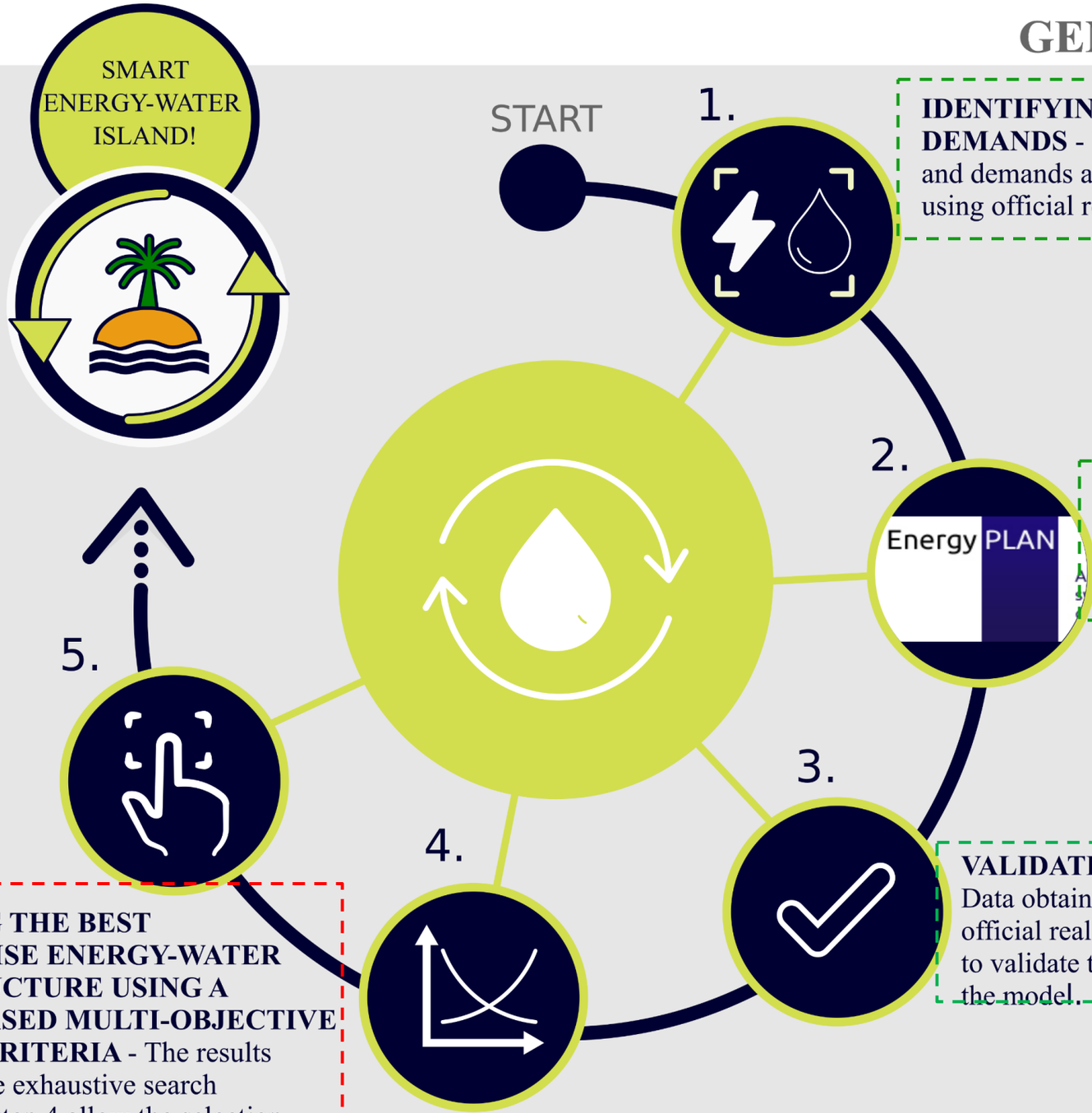
GENERATING THE POPULATION OF FEASIBLE ENERGY-WATER SYSTEMS USING AN *EXHAUSTIVE SEARCH* - An exhaustive search of water infrastructures and optimal renewable configurations is made to generate a set of optimal energy-water feasible solutions to be analysed in the following step..

SELECTING THE BEST COMPROMISE ENERGY-WATER INFRASTRUCTURE USING A PARETO-BASED MULTI-OBJECTIVE OPTIMAL CRITERIA - The results obtained in the exhaustive search performed in step 4 allow the selection of alternative infrastructures attending to different criteria (minimum CO2 emissions, minimum costs, maximum RES share of PES, etc.). A Pareto-based multi-objective optimal criteria is applied.

4. Se generan diferentes escenarios alternativos óptimos que vinculen el sector de la desalación con las EERR



GENERAL METHOD



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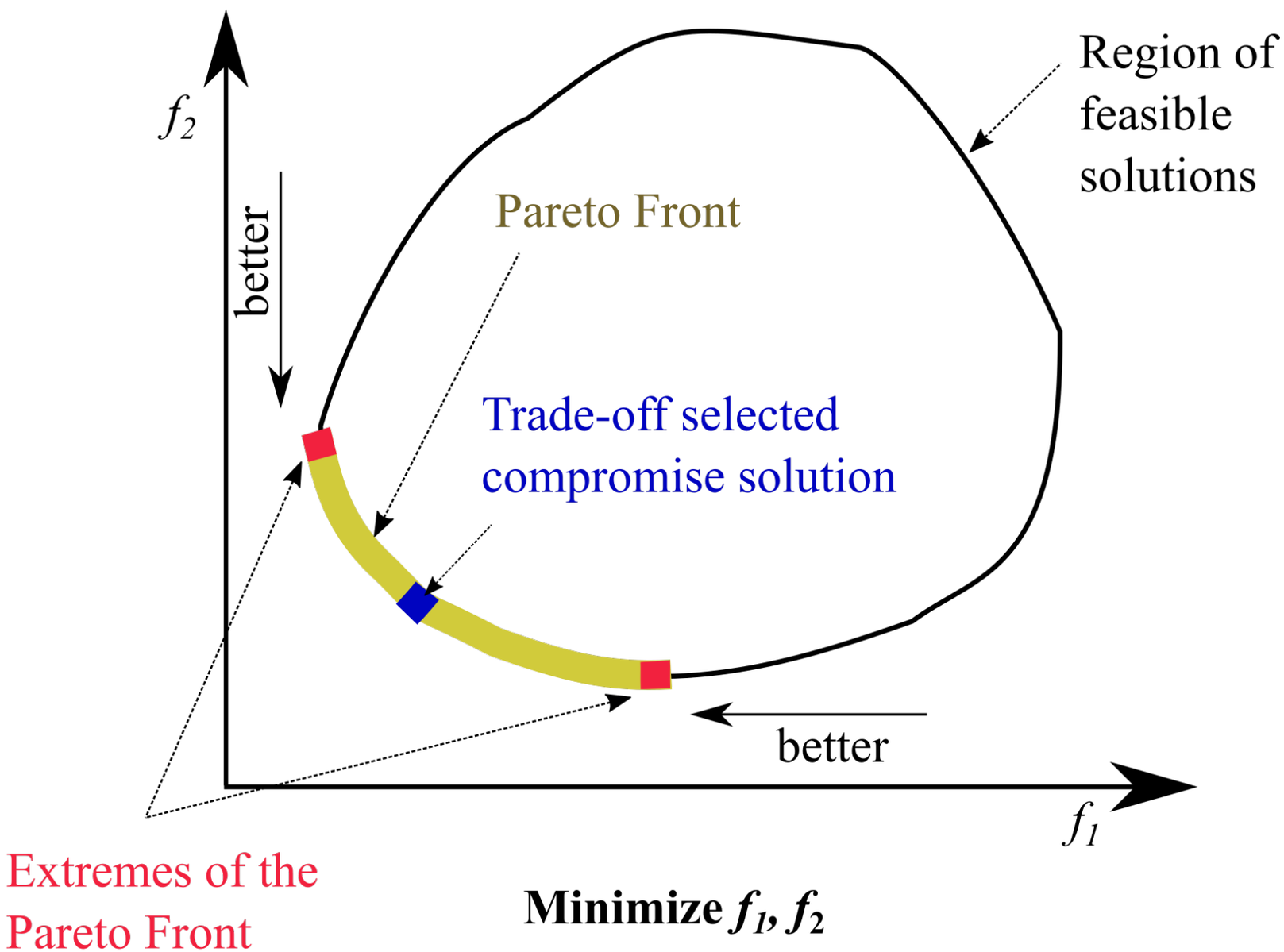
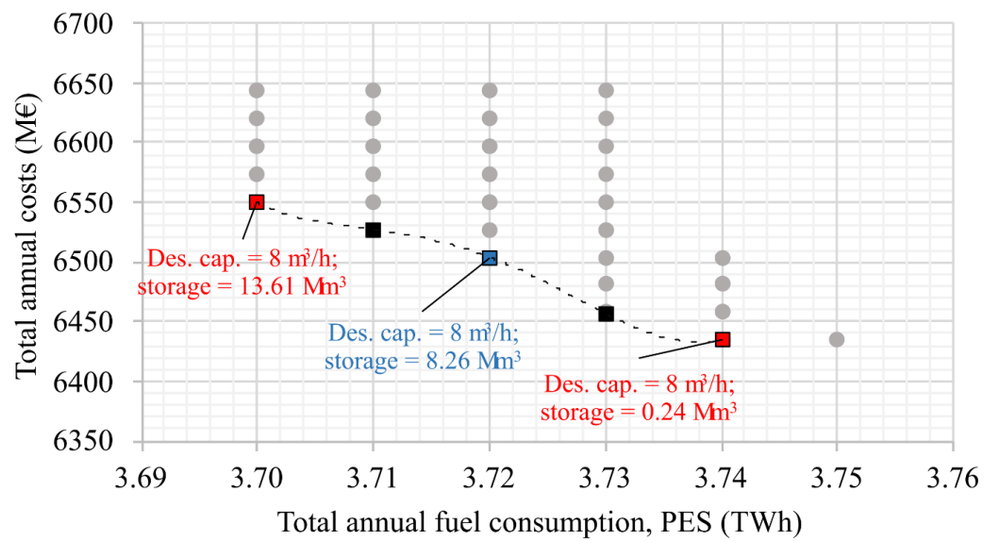
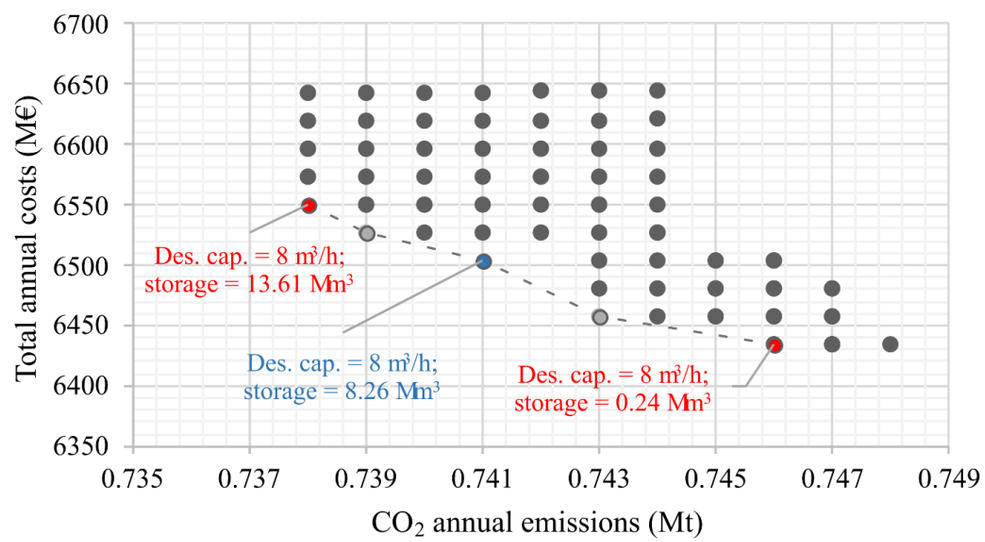
5. Se selecciona el escenario que guarda un mejor compromiso entre las variables objetivo

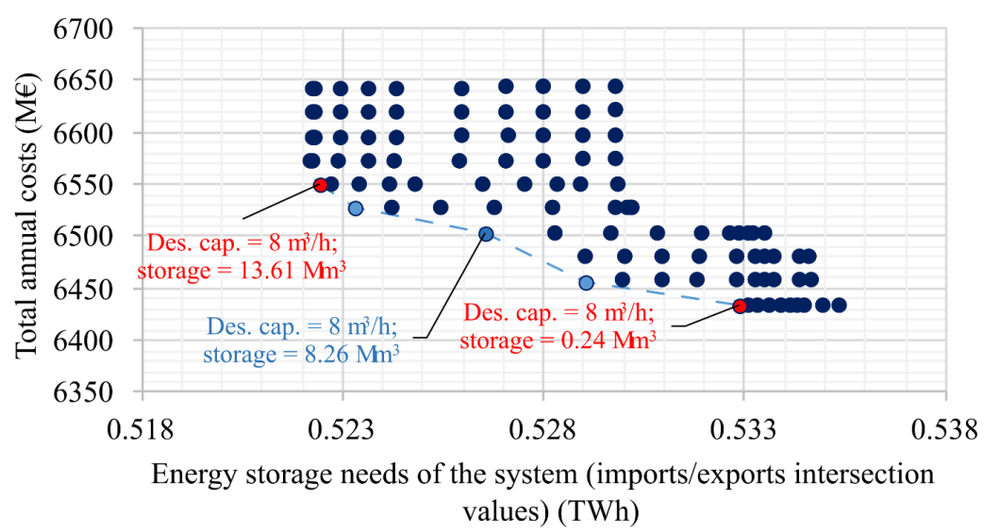



6700
6650
6600
6550
6500
6450
6400
6350
Total annual costs (M€)
3.69
3.70
3.71
3.72
3.73
3.74
3.75
3.76
Total annual fuel consumption, PES (TWh)
Des. cap. = 8 m³/h;
storage = 13.61 Mm³
Des. cap. = 8 m³/h;
storage = 8.26 Mm³
Des. cap. = 8 m³/h;
storage = 0.24 Mm³

(a)

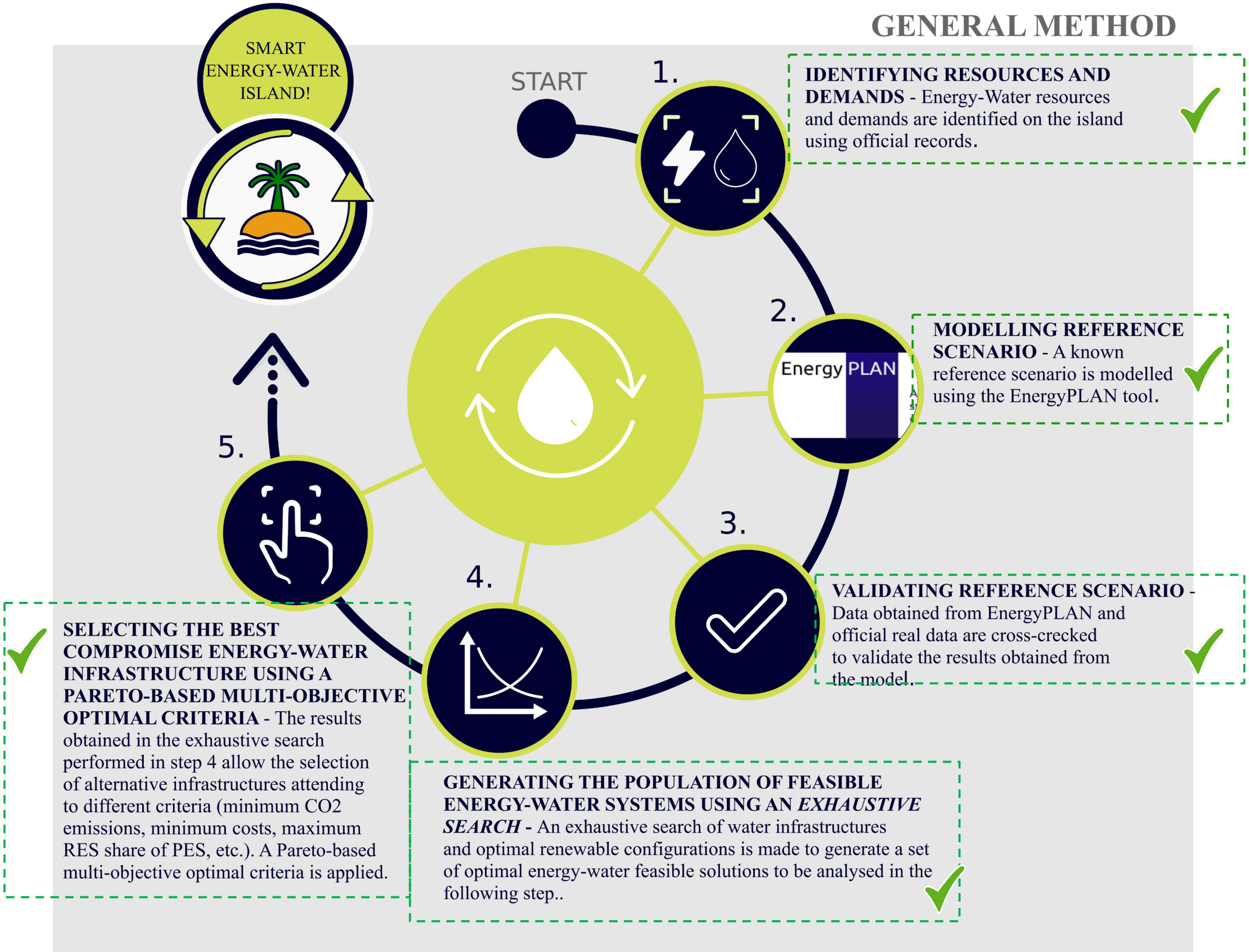

6700
6650
6600
6550
6500
6450
6400
6350
Total annual costs (M€)
0.735
0.737
0.739
0.741
0.743
0.745
0.747
0.749
CO2 annual emissions (Mt)
Des. cap. = 8 m³/h;
storage = 13.61 Mm³
Des. cap. = 8 m³/h;
storage = 8.26 Mm³
Des. cap. = 8 m³/h;
storage = 0.24 Mm³

(b)

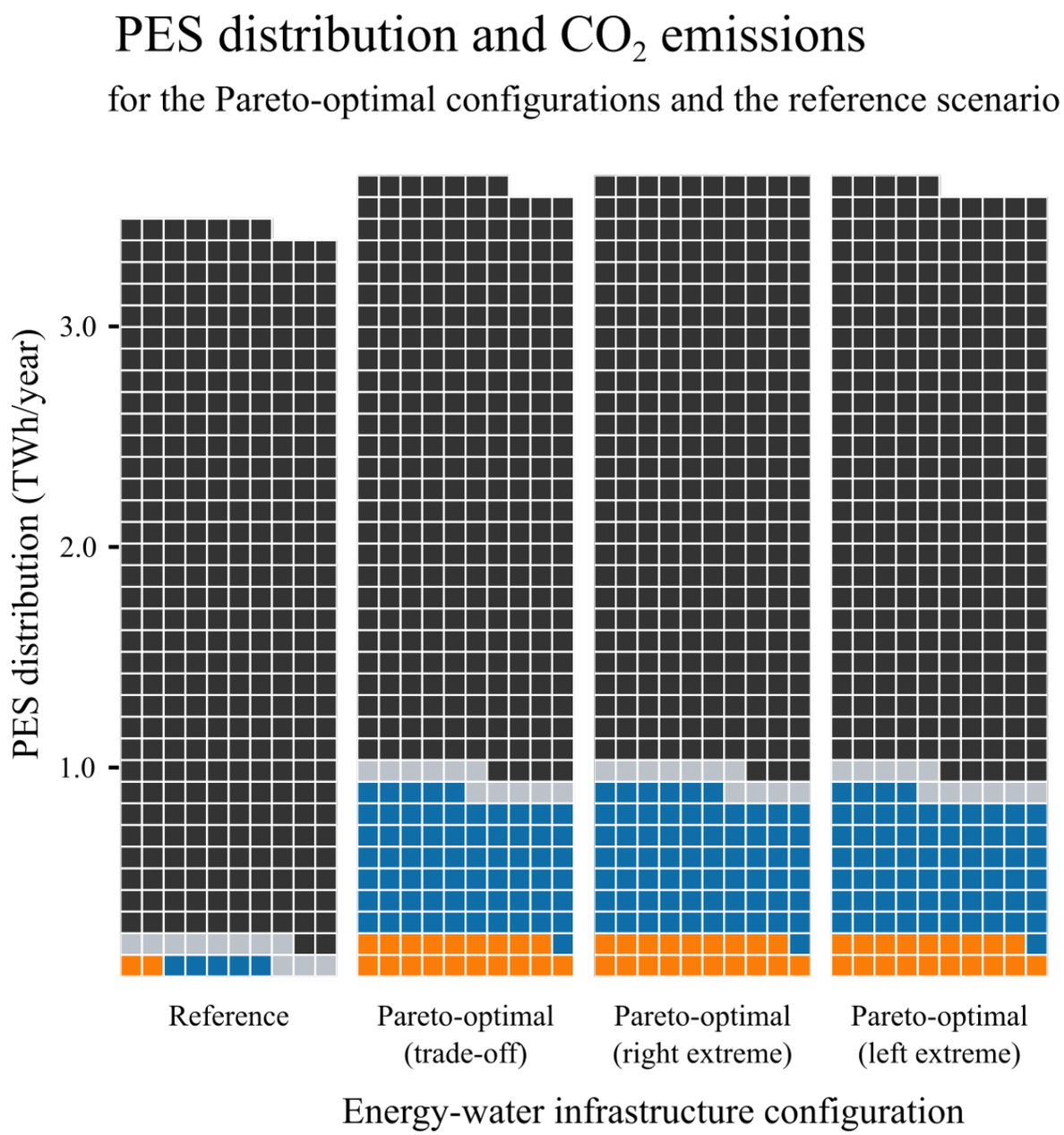

6700
6650
6600
6550
6500
6450
6400
6350
Total annual costs (M€)
0.518
0.523
0.528
0.533
0.538
Energy storage needs of the system (imports/exports intersection values) (TWh)
Des. cap. = 8 m³/h;
storage = 13.61 Mm³
Des. cap. = 8 m³/h;
storage = 8.26 Mm³
Des. cap. = 8 m³/h;
storage = 0.24 Mm³

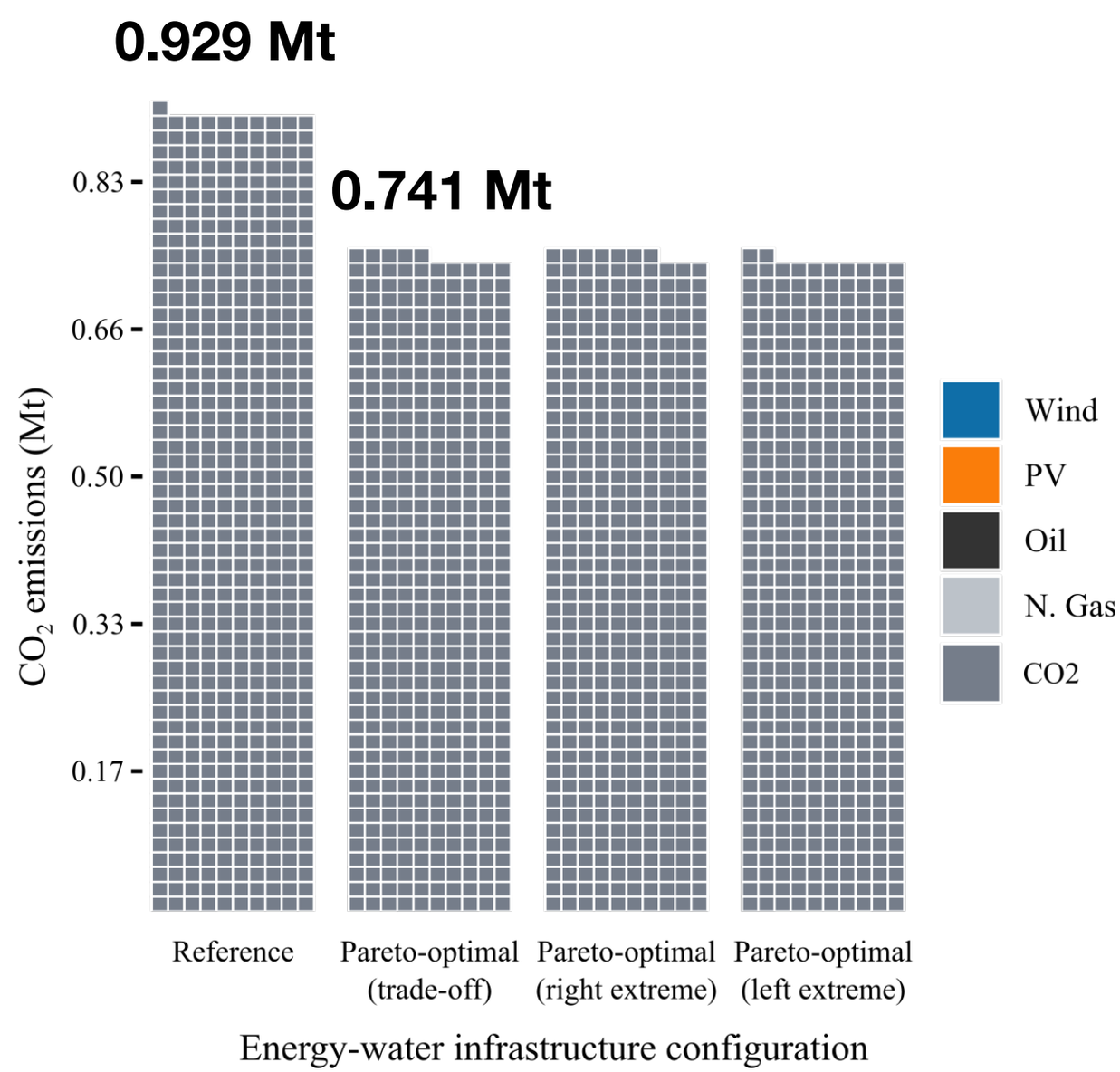
(c)

GENERAL METHOD



Resultados


PES distribution and CO_2 emissions
for the Pareto-optimal configurations and the reference scenario
PES distribution (TWh/year)
3.0
2.0
1.0
Reference
Pareto-optimal (trade-off)
Pareto-optimal (right extreme)
Pareto-optimal (left extreme)
Energy-water infrastructure configuration


0.929 Mt
0.741 Mt
CO_2 emissions (Mt)
0.83
0.66
0.50
0.33
0.17
Reference
Pareto-optimal (trade-off)
Pareto-optimal (right extreme)
Pareto-optimal (left extreme)
Energy-water infrastructure configuration
Wind
PV
Oil
N. Gas
CO2

5.14% RE

24.6% RE

Conclusiones

Conclusiones

Se puede flexibilizar el consumo de la desalación

Las técnicas de Inteligencia Artificial son apropiadas para este objetivo

La flexibilización de la desalación puede contribuir al incremento de renovables en una isla

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Gran Canaria

¡Muchas gracias!

grres ULPGC
group for the research on
renewable energy systems

DESAL+
DESALINATION
LIVING LAB

pedro.cabrerasantana@ulpgc.es

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MAC 2014-2020
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Interreg
Fondo Europeo de Desarrollo Regional

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