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**National Research Center on Membrane**  
**Technologies**  
**(MEM-TEK)**

**05.05.2022**





# About MEM-TEK



- The establishment of the National Research Center on Membrane Technologies (MEM-TEK) was started in 2010 with the support of the Ministry of Development of the Republic of Turkey in order to produce membranes in Turkey,
- To develop modules and processes,
- To offer opportunities to researchers working on membrane technologies, and
- To contribute to global membrane science.
- The construction of the center was completed in 2011 and the installation of the devices was completed in 2012.
- The Center gained the status of Application and Research Center (UYG-AR) in 2014.





# Organizations Supporting MEM-TEK



İTÜ

- Republic of Turkey Ministry of Development
- Republic of Turkey Ministry of Forestry and Water Affairs
- Republic of Turkey Ministry of Science, Industry and Technology
- TUBITAK
- ITU Rectorate
- İSKİ General Directorate
- Istanbul Development Agency





# Vision

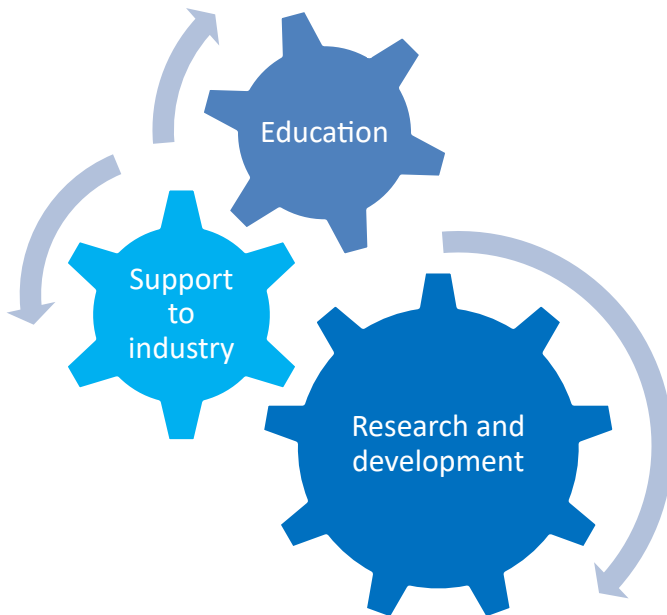


## VISION OF MEM-TEK

To become a world-leading research center for membrane fabrication, module manufacturing and process development in water and wastewater applications.



## MISION of MEM-TEK



- **Research and Development:** MEM-TEK will conduct research to improve existing technologies and produce new technologies.
- **Support to the industry:** MEM-TEK will provide all areas of the industry with the technical knowledge and infrastructure they need on membrane technologies.
- **Educating researchers and scientists:** The latest technologies will be presented to researchers.





## Membrane Characterization Infrastructure Facilities

<u>Equipment</u>	<u>Brand/Model</u>
Scanning Electron Microscopy	FEI Quanta FEG 200
Contact Angle Measurement	KSV Nima Attention
Optical Profilor	Zygo NewView 7100
Nano Sizer	Malvern Nano-S
Porometer	Quantachrome Porometer 3G
Gas Chromotography	Agilent 7890A
UV Spektrophotometry	Hach-Lange DR5000
Master sizer	Malvern Mastersizer 2000
Zeta Sizer	Malvern Nano-Z
GPC-HPLC	Schimadzu
Laktose Measurement	Funke Gerber -LactoStar
Osmometer	Advanced Instruments Model 3250
FTIR -ATR	Perkin Elmer Spectrum 100
Elektro Kinetik Analyser	Anton Paar SurPaas
Total Organic Carbon	Schimadzu TOC-Vcph
Viskozimeter	AND SV-10
Confokal Laser Microscopy	Nikon C2
Dynamic Mekanik Analyser	SII DMS6100



## Membrane Processes Equipment Infrastructure

### Membran Processes Systems in MEM-TEK

Pilot Scale MF/UF Treatment System

Pilot Scale NF/RO Treatment System

2 Pilot Scale MBR System

4 Lab Scale MBR Treatment System

Lab Scale Membrane Distillation System

Lab Scale Cross Flow System

7 Lab Scale Membran Treatment System (Sterlitech)

Lab Scale Cross Flow Hollow Fiber System

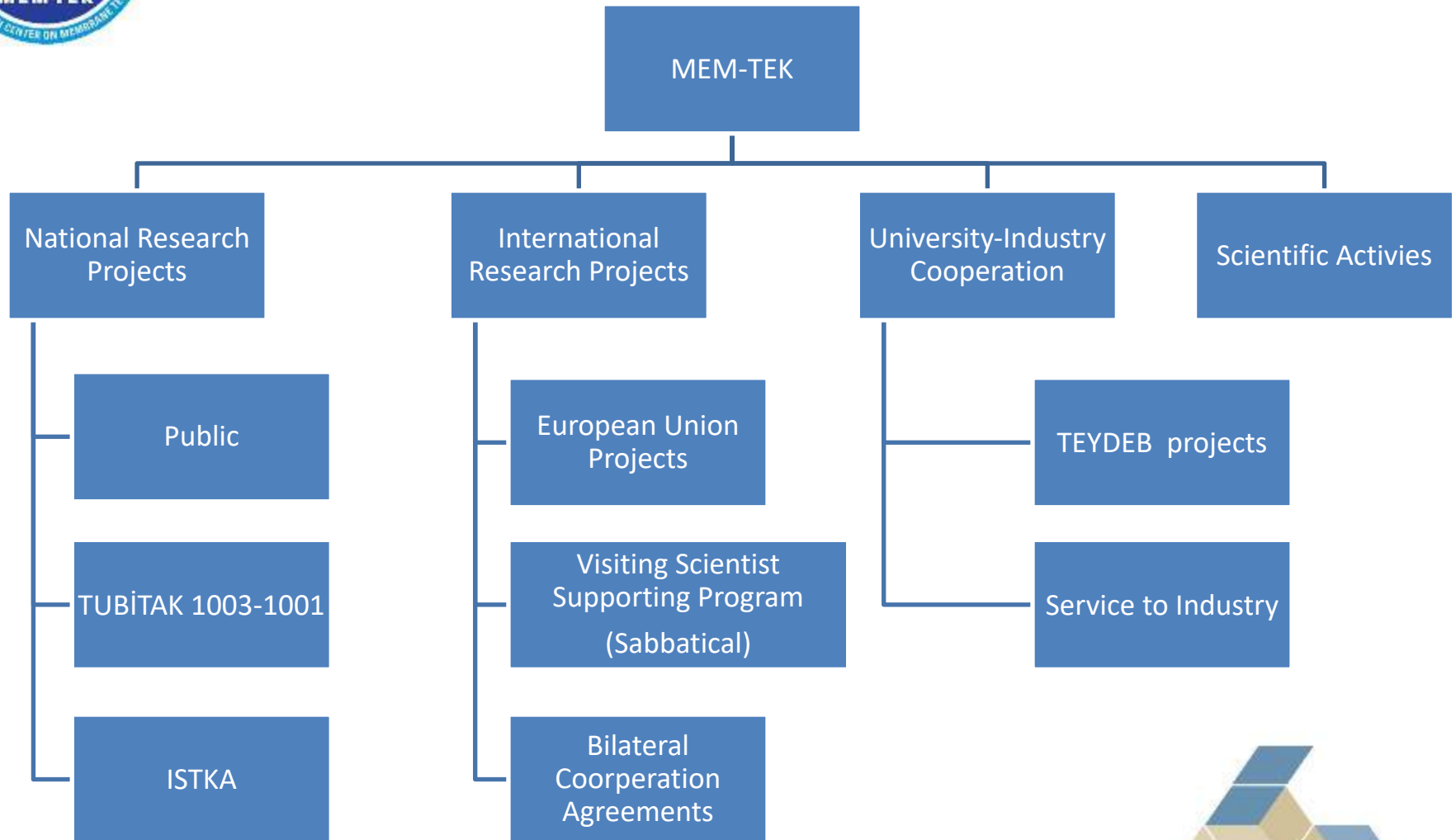
Pilot Scale Cross Flow Hollow Fiber System



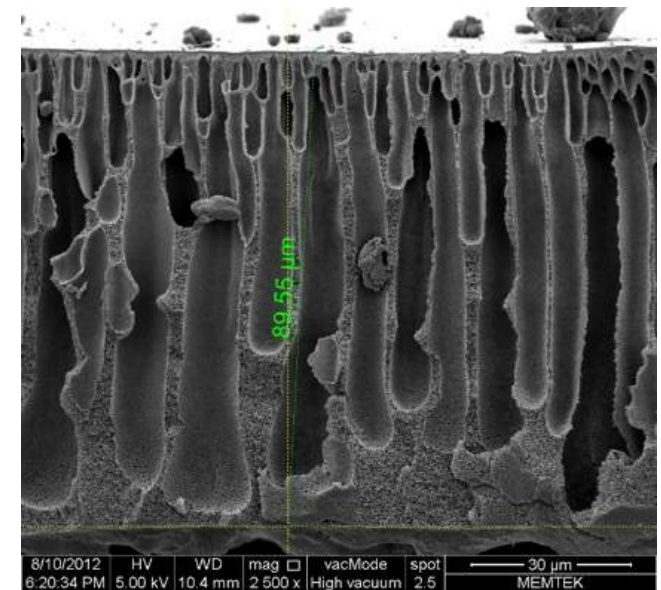




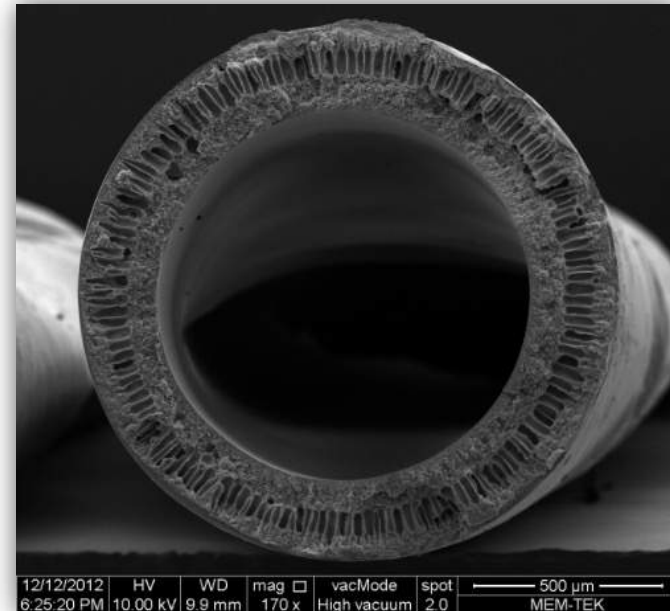
# Conducted Research



Turkey's first pilot scale flat sheet membrane fabrication



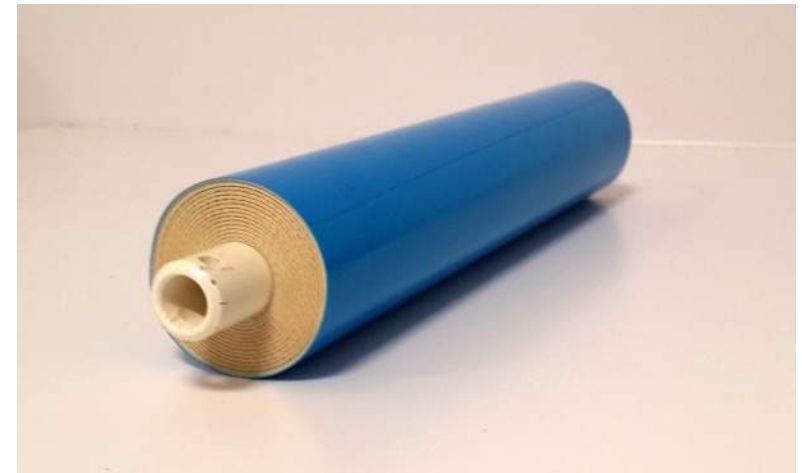
Turkey's first pilot scale hollow fiber membran fabrication



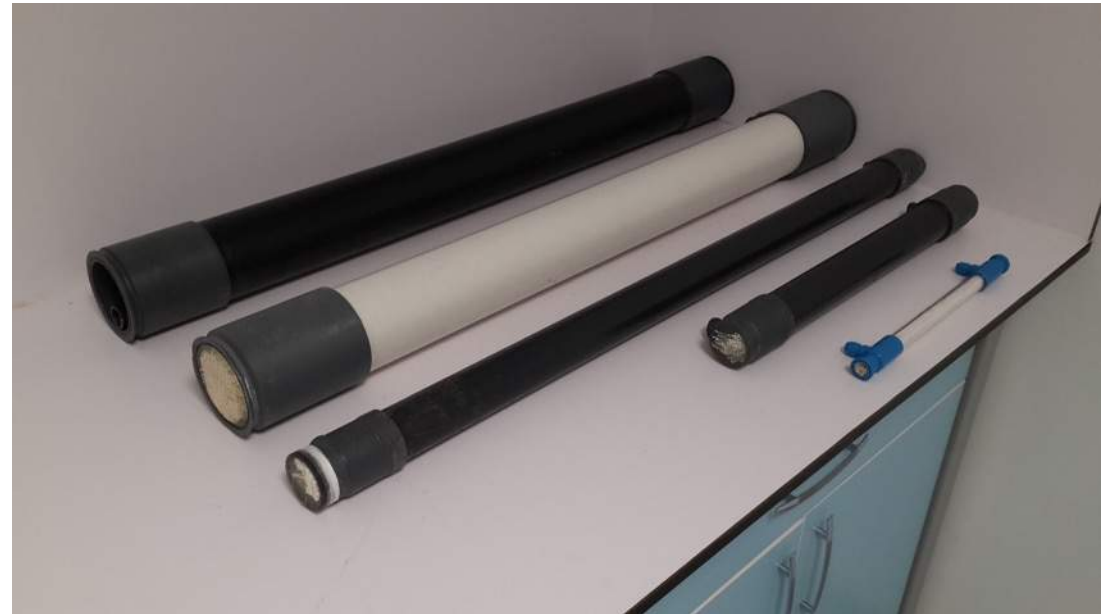
Turkey's first reinforced fiber membrane and the first completely domestic MBR module containing these membranes were produced.



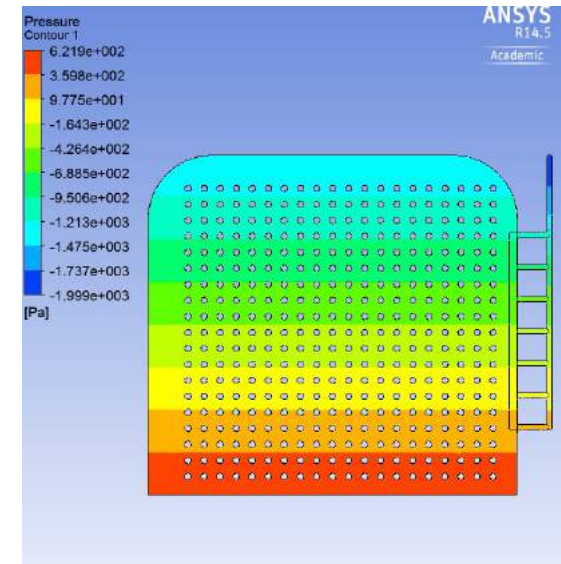
Turkey's first domestically fabricated spiral wound modules



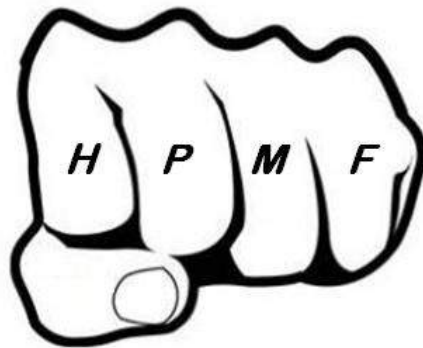
The first fully domestically fabricated hollow fiber membrane modules



## Turkey's first flat sheet membrane modules

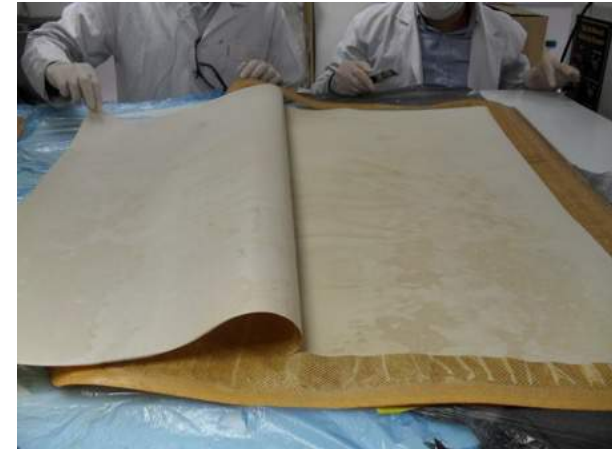


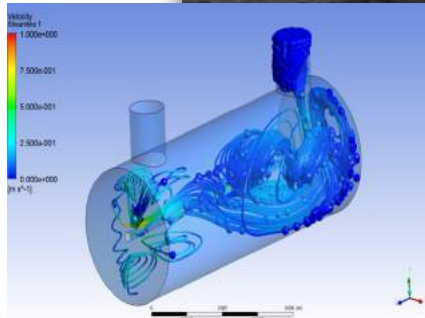
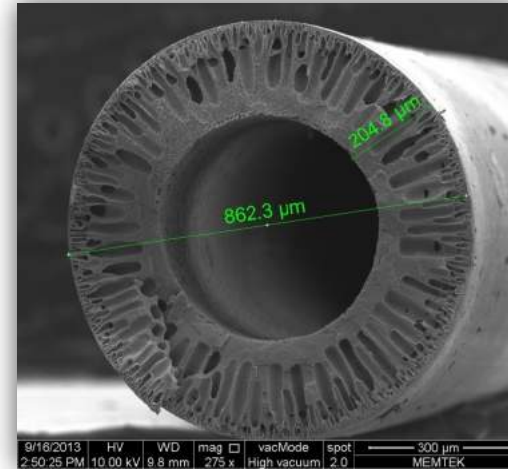
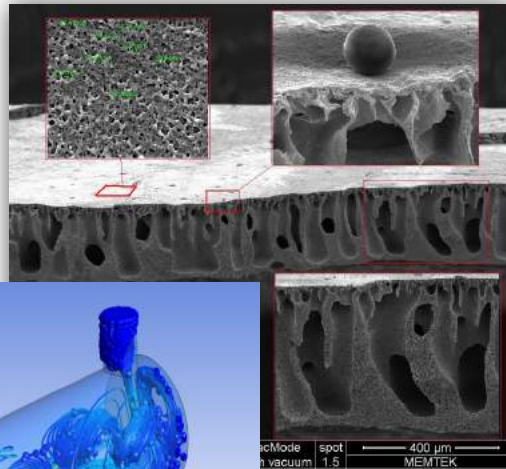
- Water production without the need for electricity and fossil fuels
- It can be used in natural disasters, military activities, in places like Africa with water shortages.
- Ideal for turbidity, pathogen and virus removal.
- Patent application filed





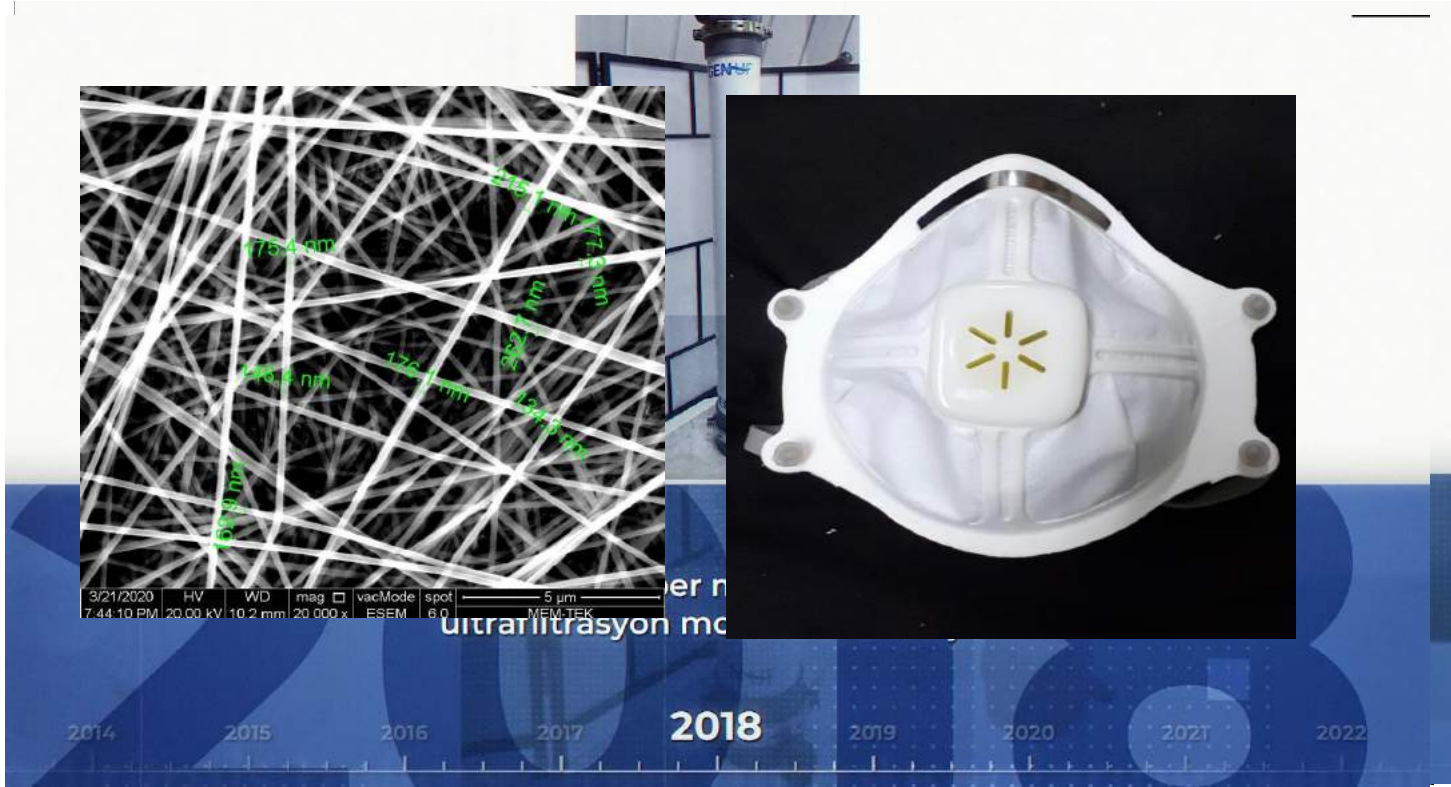
Membrane autopsy service was started to be provided for the first time in Turkey.





- **MBR modules**, including membrane fabrication, have been commercialized. (**GENMBR® Modules**)
- **Pressure UF modules** have been commercialized, including membrane fabrication. (**GEN UF® Modules**)
- **Spiral wound reverse osmosis (RO) module**, including membrane production, has been produced and its know-how has been brought to Turkey. It is in the commercialization stage. (**GEN RO® Modules**)
- Nanofiber fabric (N95, N99 mask filter and air filtration) is in the commercialization stage (**GENFIBER**)
- **MBR Package purification systems** have been developed. (**GEN PAKET®**)
- **Gray Water MBR Treatment Systems** have been commercialized as 100% domestic. (**GEN GRİ®**)
- **Forward osmosis membrane technology** has been developed. Patent applications have been made and prototype work continues.
- The first printouts were obtained on the **membrane distillation membrane**. Prototype work continues.
- **Membrane autopsy** service has started to be provided in Turkey.





The image displays two outputs of the research center. On the left is a scanning electron microscope (SEM) image of a dense network of nanofibers. Green lines indicate fiber diameters: 175.4 nm, 175.5 nm, 177.5 nm, 176.8 nm, 176.1 nm, 176.2 nm, 176.3 nm, and 176.4 nm. On the right is a photograph of a white, cup-shaped respirator mask with a central yellow star-shaped filter. Below the images is a timeline from 2014 to 2022, with the year 2018 highlighted in a blue circle. The text 'er n' and 'ultrafiltrasyon m' is partially visible below the SEM image.

3/21/2020	HV	WD	mag	vacMode	spot	5 µm
7:44:10 PM	20.00 kV	10.2 mm	20,000 x	ESEM	6.0	MEM-TEK

er n  
ultrafiltrasyon m

2014 2015 2016 2017 **2018** 2019 2020 2021 2022





# Industrial Wastewater Treatment Projects İTÜ





# Industrial Wastewater Treatment Projects **İTÜ**







# ***THE POTENTIAL OF OSMOTIC POWER FOR TURKEY***







# THE POTENTIAL OF OSMOTIC POWER FOR TURKEY



- In Turkey, Law on The Use of Renewable Energy Resources for Electrical Energy Production was come into operation in 2005.
- To support RE, Promotion on Renewable Energy Sources Law inured in 2010.
- Under the Renewable Energy Sources Act, the law on incentives also entered into force.
- It also envisages the implementation of additional support in the case of the use of domestic production equipment and equipment in the facilities used for energy production.





# THE POTENTIAL OF OSMOTIC POWER FOR TURKEY



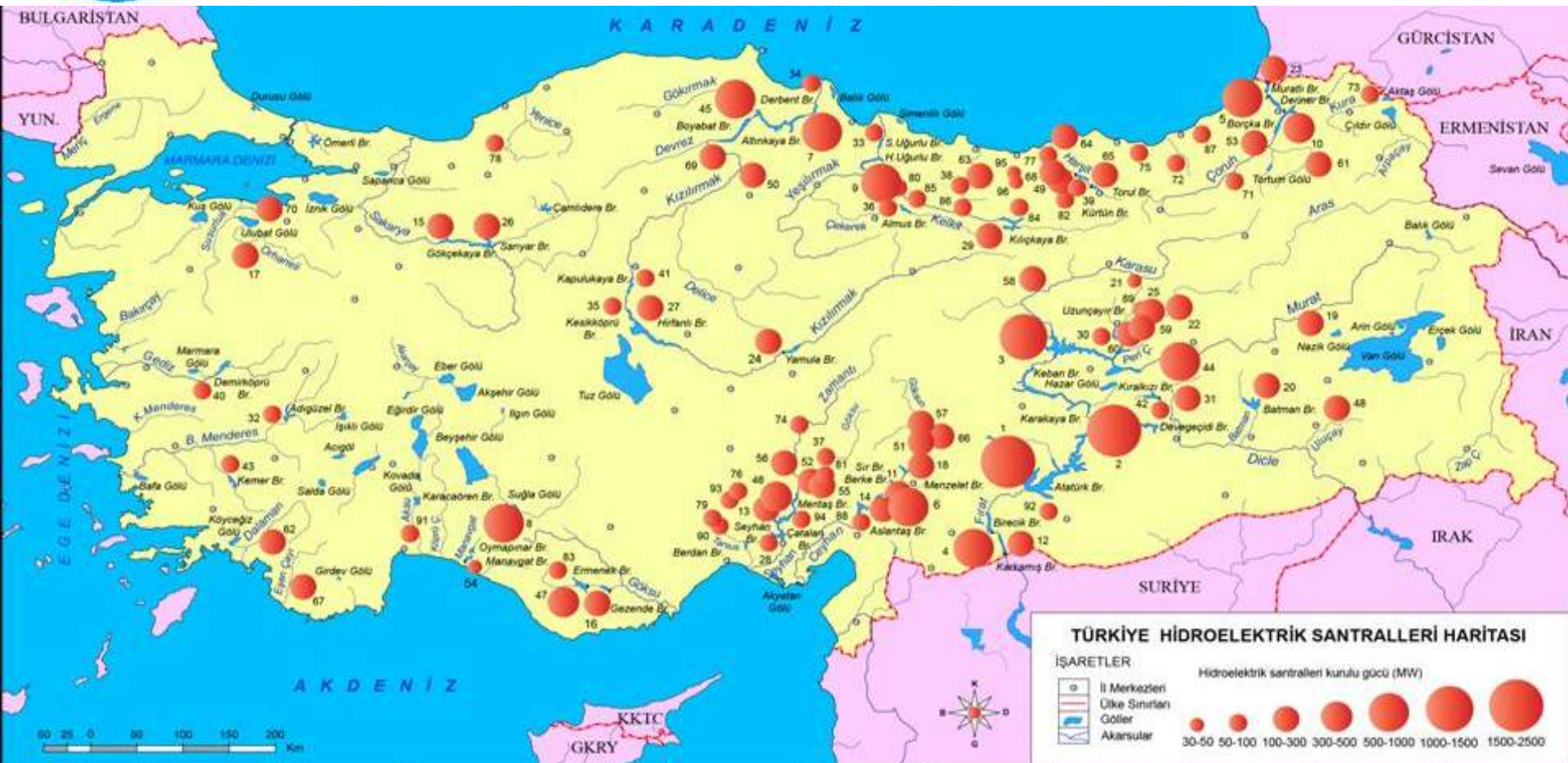
The renewable energy potential of Turkey is assessed by the Renewable Energy General Directorate of the Ministry of Energy and Natural Resources.

Energy Resource	Potential	Unit
Solar Power	1500	KW/year-m <sup>2</sup>
Wind Power	48000	MW
Geothermal (Electricity Production)	2000	MW
Biomass	8.6	Mtoe (oil-eq)
Hydraulic	34000	MW





# THE POTENTIAL OF OSMOTIC POWER FOR TURKEY



1 Ataturk HES	2 Karakaya HES	3 Keban HES	4 Birecik HES	5 Deriner HES	6 Berke HES	7 Altinkaya HES	8 Oymapınar HES	9 H.Üğurlu HES	10 Borçka HES	11 Sir HES	12 Karkamış HES
13 Çatalan HES	14 Aslantaş HES	15 Gökçekaya HES	16 Gezende HES	17 Çınarcık HES	18 Menzelet HES	19 Alpaslan 1 HES	20 Batman HES	21 Bağıştaş 2 HES	22 Kuğu HES	23 Muratlı HES	24 Yamula HES
25 Özlüce HES	26 Sarıyar HES	27 Hırfanlı HES	28 Seyhan HES	29 Kılıçkaya HES	30 Uzunçayır HES	31 Dicle HES	32 Adıgözel HES	33 S.Üğurlu HES	34 Derbent HES	35 Kesikköprü HES	36 Köklüce HES
37 Menge HES	38 Topçam HES	39 Körtün HES	40 Demirköprü HES	41 Kapulukaya HES	42 Karakızı HES	43 Kılıvazlı HES	44 Beyhan HES	45 Boyabat Duragan HES	46 Sarıbey HES	47 Ermenek HES	48 Akıncı HES
49 Akköy 2 HES	50 Obruk HES	51 Kandil HES	52 Kavşakbendi HES	53 Artvin HES	54 Manavgat HES	55 Köprü HES	56 Göktaş HES	57 Hacıminoğlu HES	58 Bağıştaş 1 HES	59 Tatar HES	60 Pembek HES
61 Ayvalı HES	62 Dalaman Akköprü HES	63 Kanca Danca HES	64 Aialanık HES	65 Tonul HES	66 Sarıgözel HES	67 Egen 1-2 HES	68 Akköy 1 HES	69 Karşı Kızıllık HES	70 Ulubat HES	71 Güllübağ HES	72 Çevizlik HES
73 Karabeyli HES	74 Çamlıca 1 HES	75 Akocak HES	76 Karakız HES	77 Doğankent HES	78 Köprübaşı HES	79 Kadıncık 1 HES	80 Tepeköşü HES	81 Fek 2 HES	82 Büyükdüz HES	83 Daran 1-2 HES	84 Burçak HES
85 Resadiye HES	86 Koyulhisar HES	87 Uzundere HES	88 C.Öksan Berkman HES	89 Seyrantepeler HES	90 Kadıncık 2 HES	91 Kovada 2 HES	92 Şanlıurfa HES	93 Toros HES	94 Mentaş HES	95 Dereli HES	96 Çrakkadı HES



# THE POTENTIAL OF OSMOTIC POWER FOR TURKEY



Important Rivers in Turkey

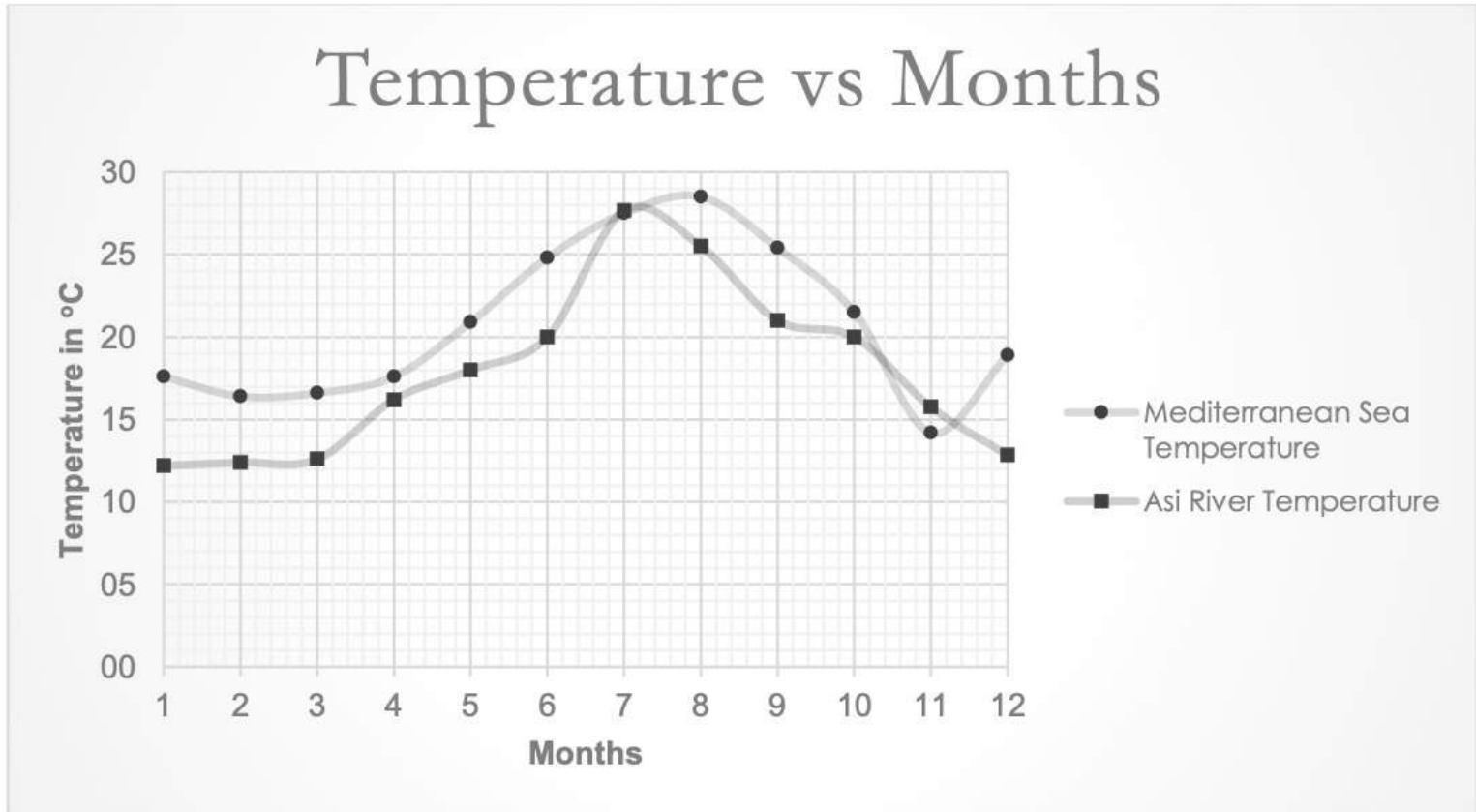
RIVER	AVAILABLE STREAM FLOWRATE (Avg)	SALINITY GRADIENT	INFRASTRUCTURE and GEOLOGY	PROFICIENCY
Asi	65 m <sup>3</sup> /s	0.075-39 g/L	Suitable	☑
Büyük Menderes	NA	NA	Not Suitable	No data, not suitable for construction
Ceyhan	200 m <sup>3</sup> /s	0.03-39 g/L	Suitable	☑
Çoruh	Transboundary			
Dalaman	30 m <sup>3</sup> /s	0.01-37g/L	Suitable	☑
Dicle	Transboundary			
Fırat	Transboundary			
Gediz	30 m <sup>3</sup> /s	0.04-32 g/L	Suitable	☑
Göksu	80 m <sup>3</sup> /s	0.01-39 g/L	Suitable	☑
Kızılırmak	2.5 m <sup>3</sup> /s	0.7-18 g/L	Not Suitable	Insufficient Flowrate (~5 m <sup>3</sup> /s) and Old and Low Salinity, Hard Construction
Küçük Menderes	0.07 m <sup>3</sup> /s	0.2 – 37 g/L	Maybe Suitable (Operations required)	Insufficient Flowrate
Manavgat	115 m <sup>3</sup> /s	0.05-39 g/L	Suitable	☑
Meriç	Boundary between Turkey and Greece			
Sakarya	145 m <sup>3</sup> /s	0.05-18 g/L	Suitable	☑
Seyhan	60 m <sup>3</sup> /s	0.02-39 g/L	Suitable	☑
Yeşilirmak	140 m <sup>3</sup> /s	0.01-18 g/L	Suitable	☑

- Asi river is in southwestern Anatolia, which is draining into the Mediterranean Sea.
- River born in Lebanon and goes into mountains of Syria.
- In Syria, some part of the river has been dammed to form Lake Qaṭṭīnah.
- Lastly it enters to Turkey, where it bends westward and empties into the sea near Samandağı.
- Water is generally used for irrigation but the amount is limited. (Encloypaedia Britannica, 2016).



Figure 8: SHW Çöğürlü Station on Asi River located at 36:4:39N - 36:0:14E (SHW, n.d.-a)





*Figure 11: Temperature change with respect to months in Asi River and Mediterranean Sea*





# Asi River



Table 6: Calculation sheet where all required data written month by month to calculate PRO potential.

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	Δπ <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	17.6	291	12.2	285	39	0.6674	0.0959	0.0016	0.08314	58.44	32.19	16.09	1.6093	12	19.6
FEBRUARY	16.4	290	12.4	286	39	0.6674	0.1071	0.0018	0.08314	58.44	32.04	16.02	1.6022	163	261.5
MARCH	16.6	290	12.6	286	39	0.6674	0.1263	0.0022	0.08314	58.44	32.05	16.03	1.6025	138	221.8
APRIL	17.6	291	16.2	289	39	0.6674	0.1131	0.0019	0.08314	58.44	32.17	16.09	1.6085	87	140.4
MAY	20.9	294	18.0	291	39	0.6674	0.0628	0.0011	0.08314	58.44	32.58	16.29	1.6289	49	80.3
JUNE	24.8	298	20.0	293	39	0.6674	0.0606	0.0010	0.08314	58.44	33.01	16.51	1.6506	22	37.0
JULY	27.5	301	27.7	301	39	0.6674	0.0569	0.0010	0.08314	58.44	33.31	16.66	1.6657	6	10.0
AUGUST	28.5	302	25.5	299	39	0.6674	0.0490	0.0008	0.08314	58.44	33.43	16.72	1.6716	0	0.7
SEPTEMBER	25.4	299	21.0	294	39	0.6674	0.0687	0.0012	0.08314	58.44	33.07	16.54	1.6536	15	24.3
OCTOBER	21.5	295	20.0	293	39	0.6674	0.0632	0.0011	0.08314	58.44	32.64	16.32	1.6322	37	59.8
NOVEMBER	14.2	287	15.8	289	39	0.6674	0.0481	0.0008	0.08314	58.44	31.85	15.92	1.5923	48	76.6
DECEMBER	18.9	292	12.8	286	39	0.6674	0.0477	0.0008	0.08314	58.44	32.37	16.18	1.6185	80	128.7
<b>AVERAGE</b>	20.8	294	17.8	291	39	0.6674	0.0750	0.0013	0.08314	58.44	32.56	16.28	1.6280	55	88.4

- One of the biggest rivers of South Anatolia is Ceyhan.
- The source location of the water is the mountains that cover Elbistan plain.
- The length of the river is 509 km and the precipitation area of the basin is 20000 km<sup>2</sup>. It collects lots of water from the other smaller rivers.
- The place of river mouth is İskenderun Bay. The flow rate of river changes with respect to seasons.
- In the summer, flow rate descends, however, after the February flow rate increases rapidly.
- The downstream of the river height of the water is about 3 meters and the length is around 100 meters. The peak flood of the river is controlled by the dams made on it (“Ceyhan Nehri,” 2009).





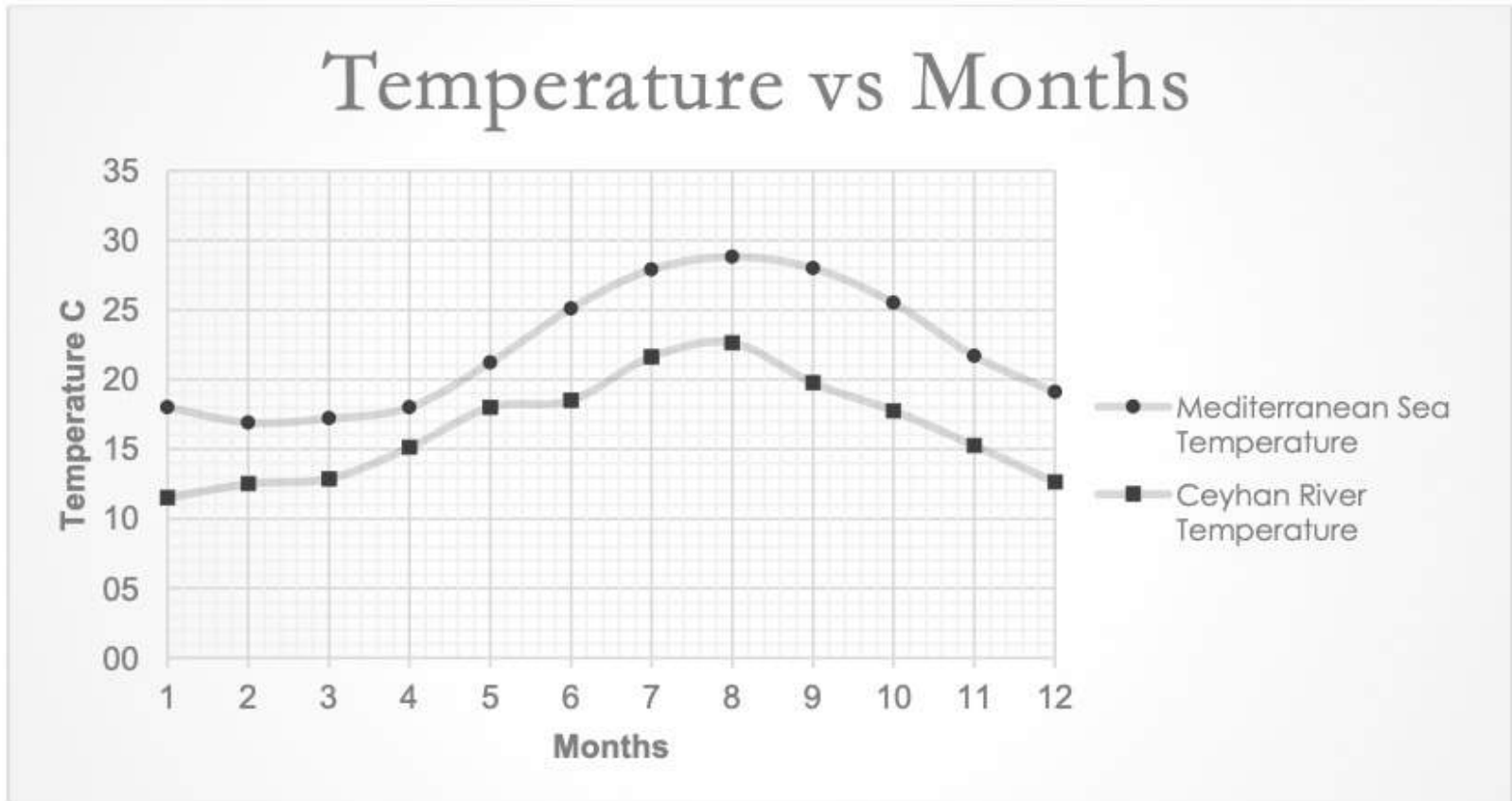


Figure 13: Ceyhan River and Mediterranean Sea temperature changes with respect to months.



# Ceyhan River



Table 9: Calculation sheet for the Ceyhan River, all required data written month by month and computation done automatically by Microsoft Excel®.

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	ΔT <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	18.0	291	11.5	285	39	0.6674	0.0263	0.0004	0.08314	58.44	32.29	16.14	1.6143	197	317.2
FEBRUARY	16.9	290	12.5	286	39	0.6674	0.0237	0.0004	0.08314	58.44	32.17	16.08	1.6083	297	477.4
MARCH	17.2	290	12.9	286	39	0.6674	0.0267	0.0005	0.08314	58.44	32.20	16.10	1.6099	314	505.0
APRIL	18.0	291	15.1	288	39	0.6674	0.0240	0.0004	0.08314	58.44	32.29	16.14	1.6144	331	534.9
MAY	21.2	294	18.0	291	39	0.6674	0.0261	0.0004	0.08314	58.44	32.64	16.32	1.6321	306	498.9
JUNE	25.1	298	18.5	292	39	0.6674	0.0244	0.0004	0.08314	58.44	33.08	16.54	1.6538	161	265.7
JULY	27.9	301	21.6	295	39	0.6674	0.0309	0.0005	0.08314	58.44	33.38	16.69	1.6690	156	259.8
AUGUST	28.8	302	22.6	296	39	0.6674	0.0328	0.0006	0.08314	58.44	33.48	16.74	1.6739	152	255.0
SEPTEMBER	28.0	301	19.8	293	39	0.6674	0.0272	0.0005	0.08314	58.44	33.40	16.70	1.6698	147	245.5
OCTOBER	25.5	299	17.8	291	39	0.6674	0.0280	0.0005	0.08314	58.44	33.12	16.56	1.6559	78	128.4
NOVEMBER	21.7	295	15.3	288	39	0.6674	0.0240	0.0004	0.08314	58.44	32.70	16.35	1.6349	100	163.2
DECEMBER	19.1	292	12.6	286	39	0.6674	0.0221	0.0004	0.08314	58.44	32.41	16.21	1.6206	149	241.7
<b>AVERAGE</b>	22.3	295	16.5	290	39	0.6674	0.0264	0.0005	0.08314	58.44	32.76	16.38	1.6381	199	324.4

- The Dalaman Brook antique name was Indos, born from Kocaş mountain close to Dirmil.
- It is located between Fethiye and Marmaris, where attracts lots of tourists in all seasons.
- Brook has length of 229 km, water colour is turquoise throughout the year.
- There are small waterfalls and suitable for rafting (Ministry of Culture and Tourism, 2015).



Figure 14: Dalaman brook is a very favoured place for rafting enthusiast ("Dalaman Çayı," n.d.)



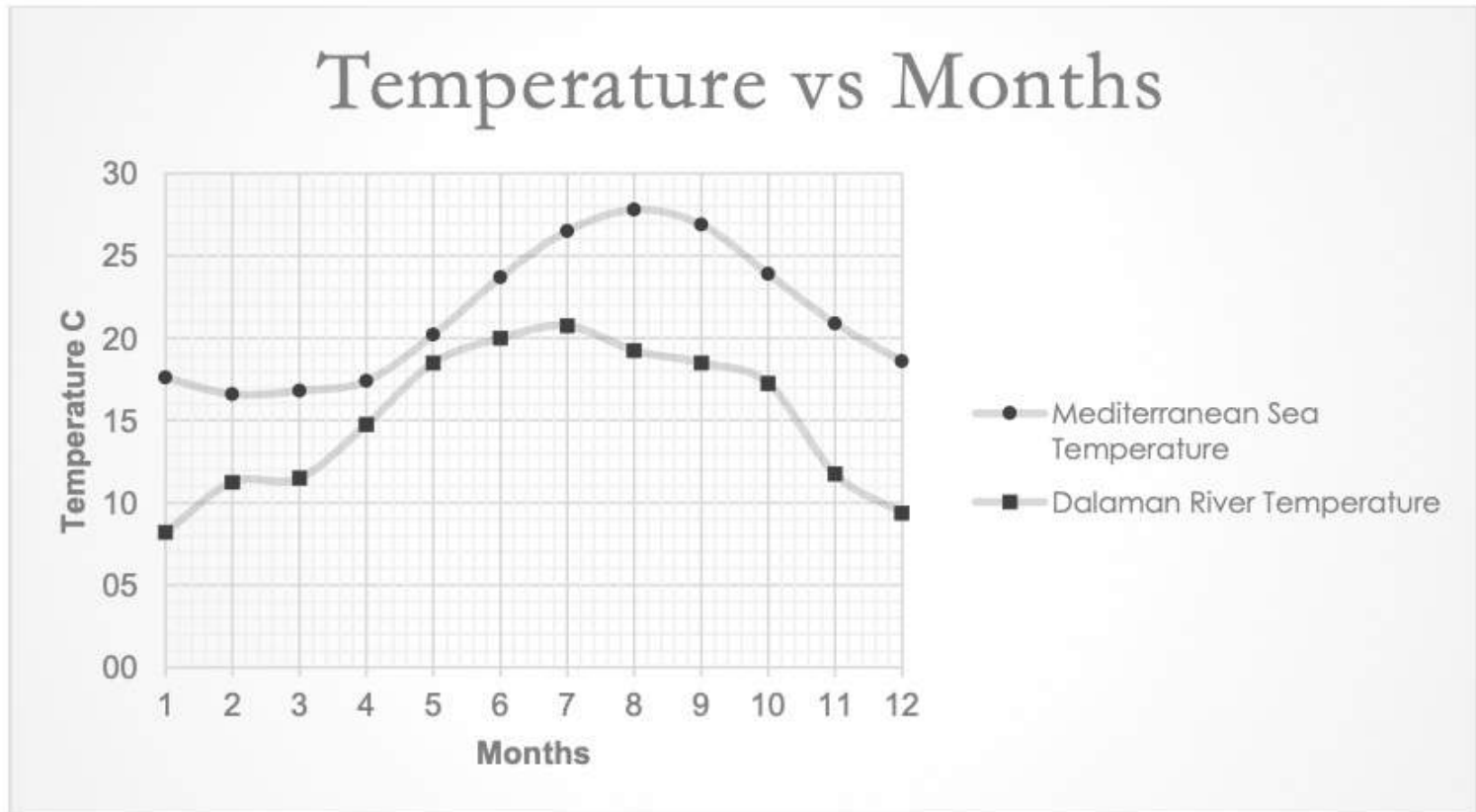


Figure 16: Annual temperature change graph of Dalaman Creek and Mediterranean Sea





# The Dalaman Brook



Table 11: Calculation sheet for Dalaman Creek., all required data written month by month and computation done automatically by Microsoft Excel ®.

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	ΔT <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	17.6	291	8.2	281	39	0.6674	0.0097	0.0002	0.08314	58.44	32.26	16.13	1.6128	15	23.5
FEBRUARY	16.6	290	11.3	284	39	0.6674	0.0098	0.0002	0.08314	58.44	32.14	16.07	1.6072	22	35.3
MARCH	16.8	290	11.5	285	39	0.6674	0.0108	0.0002	0.08314	58.44	32.17	16.08	1.6083	42	66.9
APRIL	17.4	291	14.8	288	39	0.6674	0.0098	0.0002	0.08314	58.44	32.23	16.12	1.6117	46	74.7
MAY	20.2	293	18.5	292	39	0.6674	0.0100	0.0002	0.08314	58.44	32.54	16.27	1.6272	53	86.5
JUNE	23.7	297	20.0	293	39	0.6674	0.0096	0.0002	0.08314	58.44	32.93	16.47	1.6466	43	71.5
JULY	26.5	300	20.8	294	39	0.6674	0.0117	0.0002	0.08314	58.44	33.24	16.62	1.6621	40	67.1
AUGUST	27.8	301	19.3	292	39	0.6674	0.0083	0.0001	0.08314	58.44	33.39	16.69	1.6694	27	44.9
SEPTEMBER	26.9	300	18.5	292	39	0.6674	0.0093	0.0002	0.08314	58.44	33.29	16.64	1.6644	17	28.5
OCTOBER	23.9	297	17.3	290	39	0.6674	0.0392	0.0007	0.08314	58.44	32.93	16.47	1.6465	14	22.9
NOVEMBER	20.9	294	11.8	285	39	0.6674	0.0101	0.0002	0.08314	58.44	32.62	16.31	1.6311	12	19.5
DECEMBER	18.6	292	9.4	283	39	0.6674	0.0100	0.0002	0.08314	58.44	32.37	16.18	1.6183	12	18.8
<b>AVERAGE</b>	21.4	295	15.1	288	39	0.6674	0.0124	0.0002	0.08314	58.44	32.68	16.34	1.6338	29	46.7

- Source of the Gediz River is in Kütahya city boundaries from mountains of Murat and Şaphane.
- Mouth of the river disembogue to İzmir Bay between from the Foça and Çamaltı Tuzlası.
- River basin has an area of 17.500 km<sup>2</sup>. Main stream of river has a length of 401 km with an average flowrate of 60.48 m<sup>3</sup>/s (Ministry of Forestry and Water Management, n.d.).

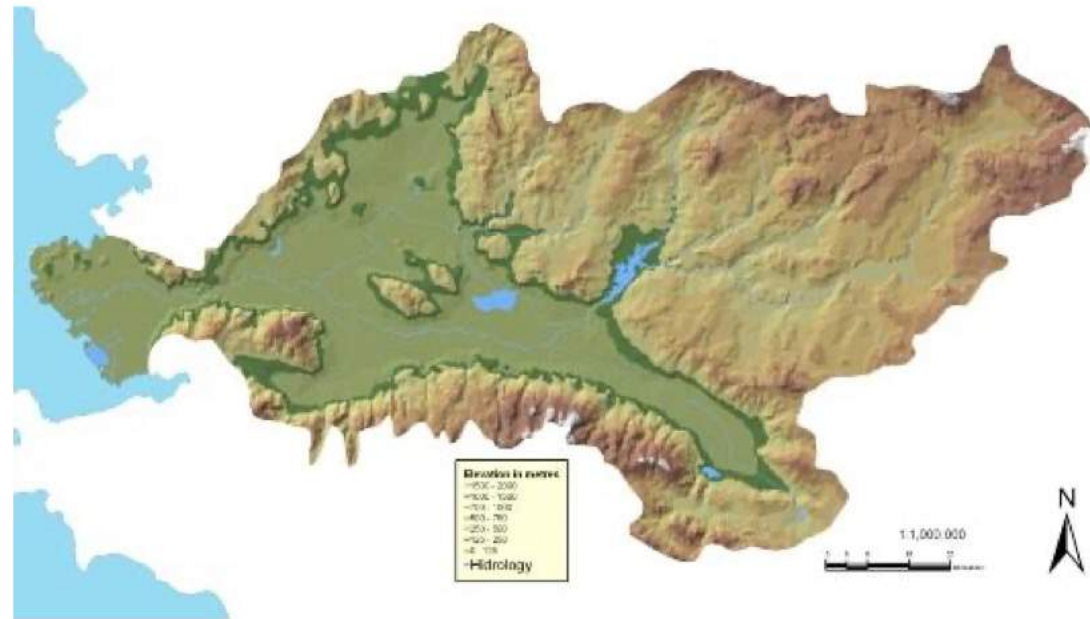


Figure 17: Geographical map of Gediz basin (SHW, n.d.-a).

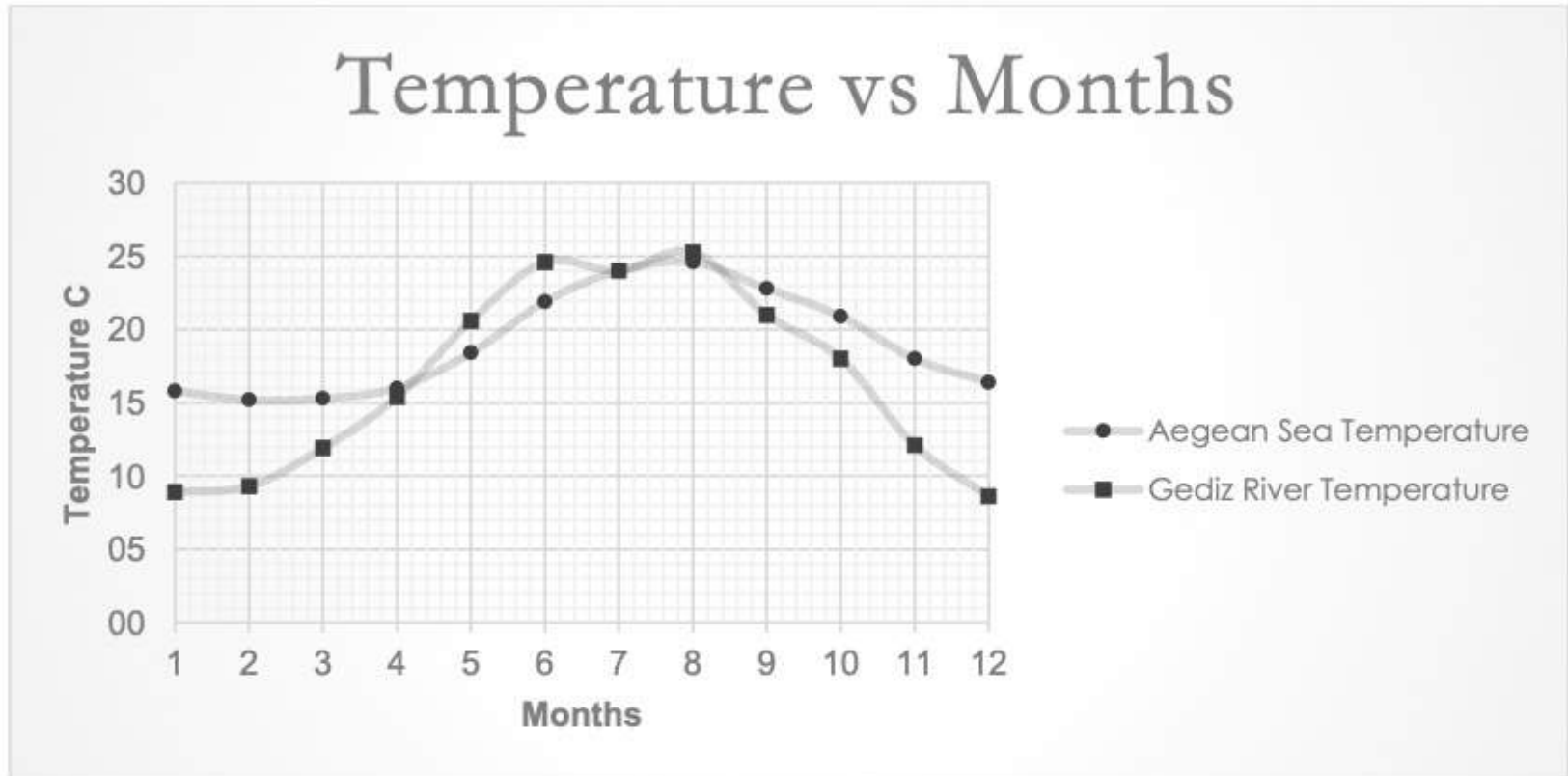


Figure 19: River and sea temperatures with respect to months.





# The Gediz River



Table 13: Calculation sheet for Gediz River, all required data written month by month and computation done automatically by Microsoft Excel®.

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	Δπ <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	15.8	289	8.9	282	37	0.6331	0.0408	0.0007	0.08314	58.44	30.39	15.19	1.5193	28	41.8
FEBRUARY	15.2	288	9.3	282	37	0.6331	0.0387	0.0007	0.08314	58.44	30.33	15.16	1.5163	78	117.9
MARCH	15.3	288	11.9	285	37	0.6331	0.0341	0.0006	0.08314	58.44	30.34	15.17	1.5170	61	92.6
APRIL	16.0	289	15.4	289	37	0.6331	0.0334	0.0006	0.08314	58.44	30.41	15.21	1.5207	31	46.6
MAY	18.4	292	20.6	294	37	0.6331	0.0437	0.0007	0.08314	58.44	30.66	15.33	1.5328	16	24.3
JUNE	21.9	295	24.6	298	37	0.6331	0.0568	0.0010	0.08314	58.44	31.01	15.51	1.5507	18	27.8
JULY	24.0	297	24.0	297	37	0.6331	0.0316	0.0005	0.08314	58.44	31.26	15.63	1.5628	29	45.5
AUGUST	24.6	298	25.3	298	37	0.6331	0.0234	0.0004	0.08314	58.44	31.33	15.66	1.5663	24	37.2
SEPTEMBER	22.8	296	21.0	294	37	0.6331	0.0344	0.0006	0.08314	58.44	31.13	15.56	1.5564	11	17.3
OCTOBER	20.9	294	18.0	291	37	0.6331	0.0589	0.0010	0.08314	58.44	30.91	15.45	1.5454	5	7.7
NOVEMBER	18.0	291	12.1	285	37	0.6331	0.0596	0.0010	0.08314	58.44	30.60	15.30	1.5301	7	11.0
DECEMBER	16.4	290	8.6	282	37	0.6331	0.0504	0.0009	0.08314	58.44	30.44	15.22	1.5221	13	19.5
AVERAGE	19.1	292	16.6	290	37	0.6331	0.0422	0.0007	0.08314	58.44	30.73	15.37	1.5367	27	40.8



- The Göksu River Basin located in Mediterranean region, on the West of Adana.
- It is administratively found in the boundary of Konya, Karaman and İçel cities.
- Starting point of upper conduits of river reaches to the summit of Middle Toros Mountains.
- Stream discharges to sea near Silifke through the delta which exist by its own flow (Buldur, Pinar, and Başaran, 2015).

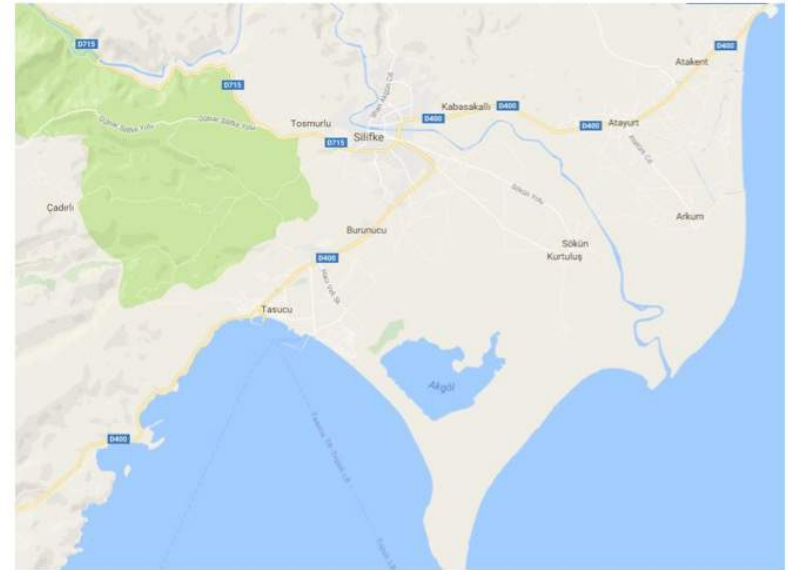
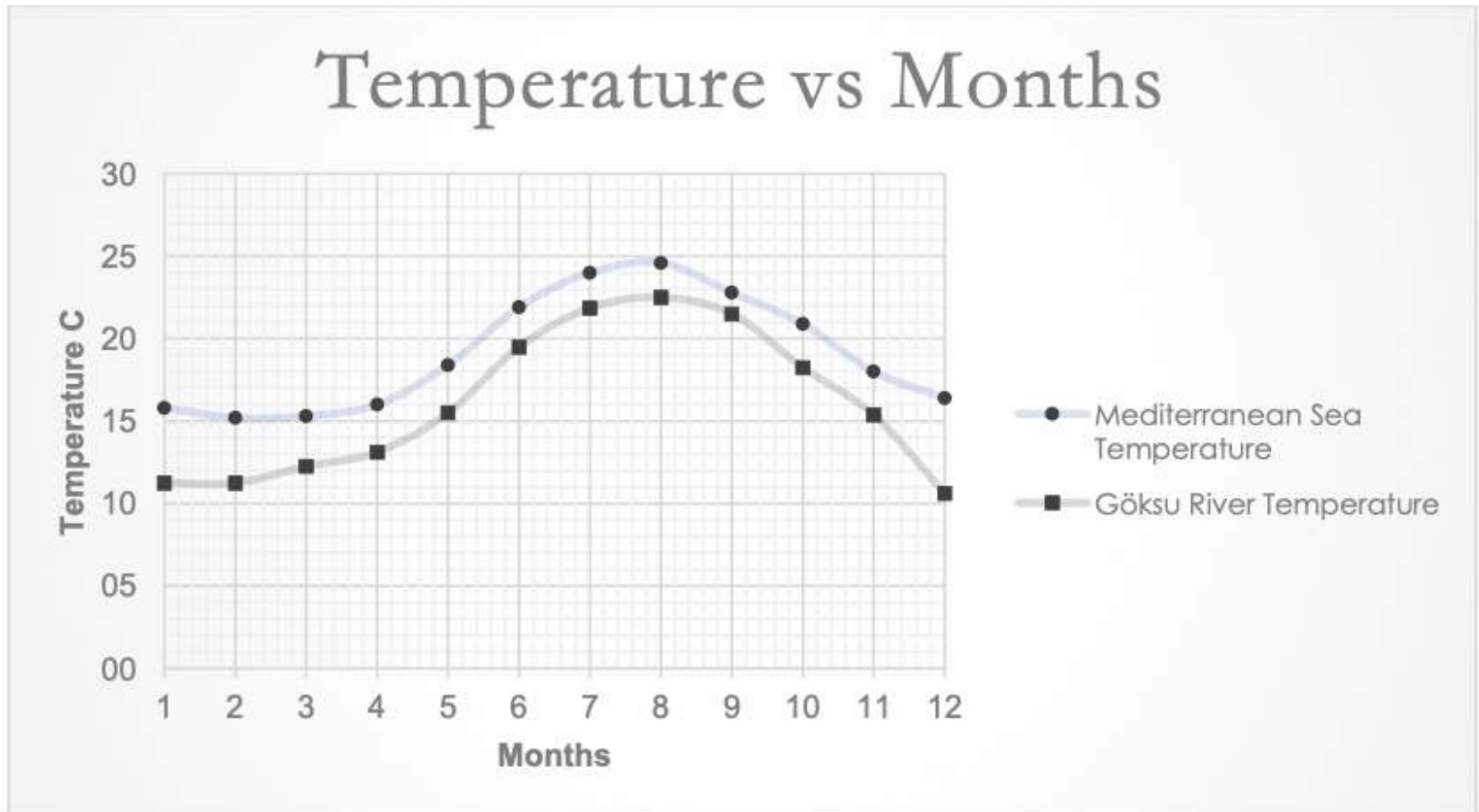


Figure 20: Silifke region and downstream of the Göksu River where it meets Mediterranean Sea





*Figure 22: Temperature of Göksu and Mediterranean Sea with respect to months*



# The Göksu River



Table 15: Calculation sheet for Göksu River, all required data written month by month

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	Δπ <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	18.9	292	11.3	284	39	0.6674	0.0124	0.0002	0.08314	58.44	32.40	16.20	1.6199	99	159.9
FEBRUARY	16.9	290	11.3	284	39	0.6674	0.0122	0.0002	0.08314	58.44	32.18	16.09	1.6088	132	212.0
MARCH	17.2	290	12.3	285	39	0.6674	0.0106	0.0002	0.08314	58.44	32.21	16.11	1.6105	154	247.5
APRIL	18.0	291	13.1	286	39	0.6674	0.0100	0.0002	0.08314	58.44	32.30	16.15	1.6150	165	266.1
MAY	21.2	294	15.5	289	39	0.6674	0.0105	0.0002	0.08314	58.44	32.65	16.33	1.6327	116	189.5
JUNE	25.1	298	19.5	293	39	0.6674	0.0129	0.0002	0.08314	58.44	33.09	16.54	1.6543	46	75.7
JULY	27.9	301	21.9	295	39	0.6674	0.0132	0.0002	0.08314	58.44	33.40	16.70	1.6698	31	51.8
AUGUST	28.8	302	22.5	296	39	0.6674	0.0152	0.0003	0.08314	58.44	33.49	16.75	1.6747	22	36.1
SEPTEMBER	28.0	301	21.5	295	39	0.6674	0.0157	0.0003	0.08314	58.44	33.40	16.70	1.6702	24	39.5
OCTOBER	25.5	299	18.3	291	39	0.6674	0.0144	0.0002	0.08314	58.44	33.13	16.56	1.6564	27	44.0
NOVEMBER	21.7	295	15.4	289	39	0.6674	0.0135	0.0002	0.08314	58.44	32.71	16.35	1.6354	55	89.2
DECEMBER	19.1	292	10.6	284	39	0.6674	0.0120	0.0002	0.08314	58.44	32.42	16.21	1.6210	83	133.8
<b>AVERAGE</b>	22.4	296	16.1	289	39	0.6674	0.0127	0.0002	0.08314	58.44	32.78	16.39	1.6391	79	128.8

- The first waters of the Manavgat River consist of spring waters originating from the mountains south of Akdağ and Beyşehir Lake in the northwest of the Cevizli Township bounded by the Antalya-Akseki county and the waters south of the Gemboş closed basin.
- The beginning of the Manavgat River, which is 1000-2000 meters above the sea level, is a small stream that dries in summer.
- Manavgat River formed by the merging of small rivers in this region.
- River disembogues to the Mediterranean Sea in Dalyan after a 90 km of journey between Manavgat district.
- Manavgat waterfall is well-known place attracting lots of tourists.
- There are lots of boats, social domain and small number of fish farms at the stream mouth (Lerzan and Ertan, 2012).



Figure 23: Manavgat waterfall on the river attracts lots of tourist every year (Kumbara Haber, 2016)



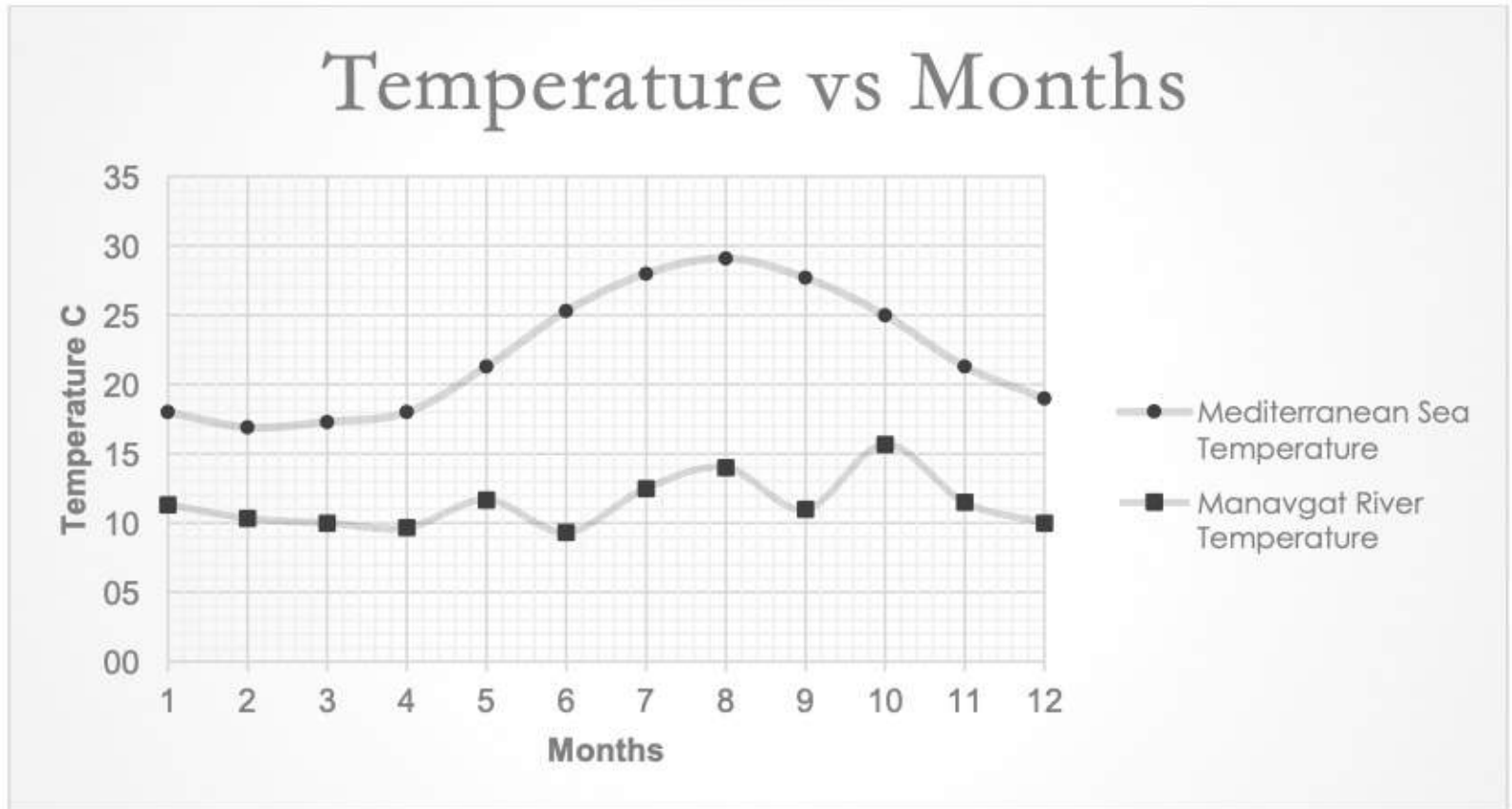


Figure 25: Monthly temperature change of Mediterranean Sea and Manavgat river .



# Manavgat River



Table 17: Detailed Excel sheet of Manavgat river including calculation of monthly power output.

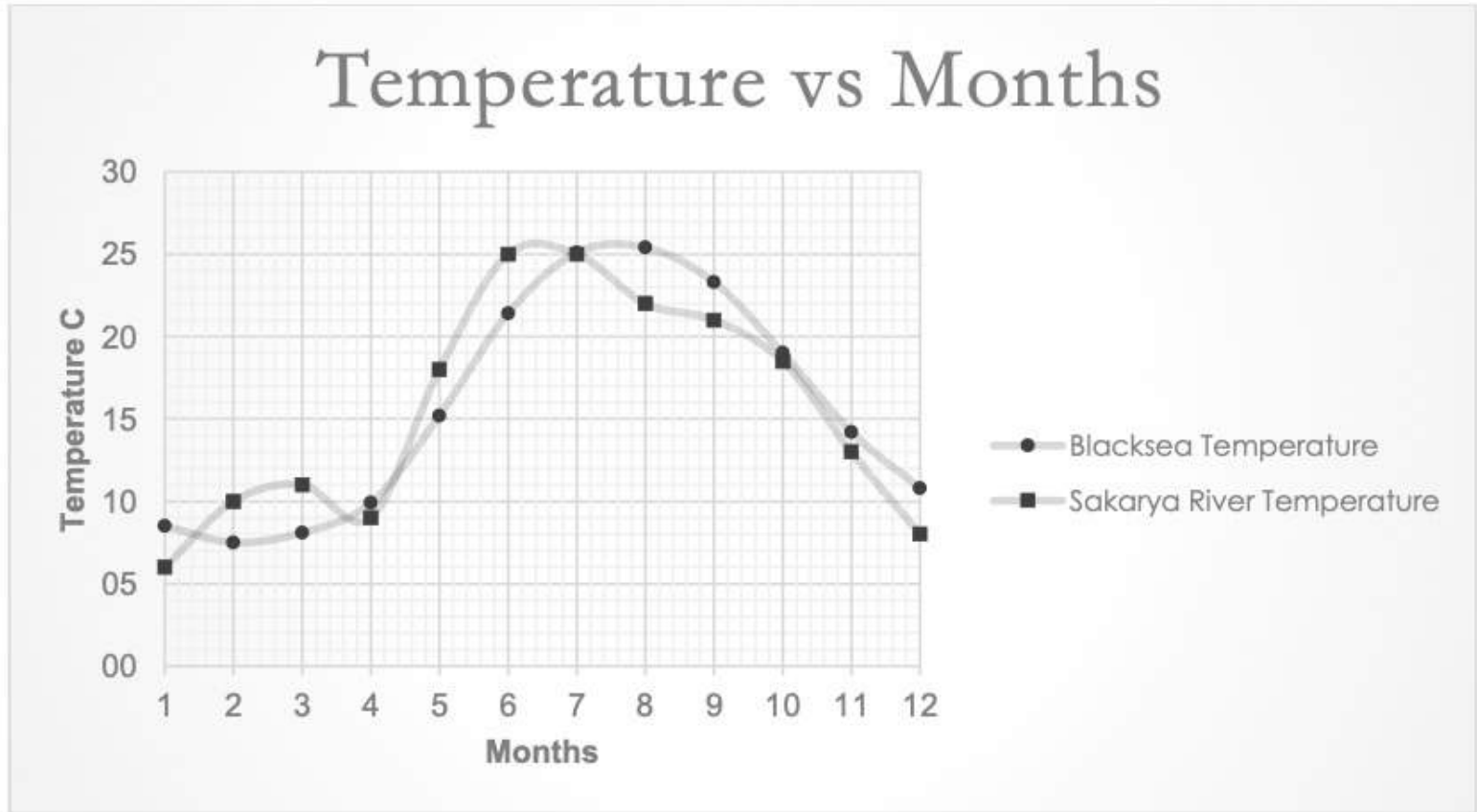
MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	ΔΠ <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	18.0	291	11.3	284	39	0.6674	0.0072	0.0001	0.08314	58.44	32.30	16.15	1.6151	114	183.7
FEBRUARY	16.9	290	10.3	283	39	0.6674	0.0079	0.0001	0.08314	58.44	32.18	16.09	1.6090	108	174.5
MARCH	17.3	290	10.0	283	39	0.6674	0.0069	0.0001	0.08314	58.44	32.22	16.11	1.6112	110	178.0
APRIL	18.0	291	9.7	283	39	0.6674	0.0065	0.0001	0.08314	58.44	32.30	16.15	1.6151	117	189.7
MAY	21.3	294	11.7	285	39	0.6674	0.0072	0.0001	0.08314	58.44	32.67	16.33	1.6334	95	155.9
JUNE	25.3	298	9.3	282	39	0.6674	0.0065	0.0001	0.08314	58.44	33.11	16.56	1.6556	7	11.0
JULY	28.0	301	12.5	286	39	0.6674	0.0062	0.0001	0.08314	58.44	33.41	16.71	1.6706	41	68.0
AUGUST	29.1	302	14.0	287	39	0.6674	0.0089	0.0002	0.08314	58.44	33.53	16.77	1.6766	25	42.3
SEPTEMBER	27.7	301	11.0	284	39	0.6674	0.0098	0.0002	0.08314	58.44	33.38	16.69	1.6688	15	25.4
OCTOBER	25.0	298	15.7	289	39	0.6674	0.0102	0.0002	0.08314	58.44	33.08	16.54	1.6538	14	22.4
NOVEMBER	21.3	294	11.5	285	39	0.6674	0.0093	0.0002	0.08314	58.44	32.67	16.33	1.6333	35	57.8
DECEMBER	19.0	292	10.0	283	39	0.6674	0.0075	0.0001	0.08314	58.44	32.41	16.21	1.6206	99	160.2
<b>AVERAGE</b>	22.2	295	11.4	285	39	0.6674	0.0078	0.0001	0.08314	58.44	32.77	16.39	1.6386	65	105.7

- The Sakarya River has 58200 km<sup>2</sup> of drainage basin that is 7.49% of land of Turkey and total of 824 km length.
- Annual average water volume is above 4 billion meter cube (1995).
- Basin generally has small roughness topography.
- Important branches of river are mainly Porsuk and Ankara brook and smaller ones are Seydisuyu, Çarksuyu, Karasu, Girmir Brook, Göynük Brook, Mudurnu Brook and Göksu.
- Cities which involves the boundary of basin are Ankara, Eskişehir, Kütahya, Bilecik and Sakarya.
- Lots of projects have been developed in the area about irrigation, drinking and tap water and energy production.
- Water pollution problem in the area has been rapidly increasing due to industrialization and population (Şengörür B., 2001).



Figure 26: The point where Sakarya River meets the Black Sea (Öztürk, 2008).





*Figure 28: Monthly surface water temperature for Black Sea and Sakarya River.*





# The Sakarya River



Table 19: Osmotic calculation sheet for the Sakarya River, where power potential is very good.

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	ΔΠ <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	8.5	282	6.0	279	18	0.3080	0.0447	0.0008	0.08314	58.44	14.39	7.19	0.7195	194	139.6
FEBRUARY	7.5	281	10.0	283	18	0.3080	0.0412	0.0007	0.08314	58.44	14.34	7.17	0.7170	238	170.7
MARCH	8.1	281	11.0	284	18	0.3080	0.0369	0.0006	0.08314	58.44	14.37	7.19	0.7187	285	204.8
APRIL	9.9	283	9.0	282	18	0.3080	0.0163	0.0003	0.08314	58.44	14.48	7.24	0.7242	250	181.0
MAY	15.2	288	18.0	291	18	0.3080	0.0490	0.0008	0.08314	58.44	14.73	7.36	0.7364	139	102.4
JUNE	21.4	295	25.0	298	18	0.3080	0.0490	0.0008	0.08314	58.44	15.04	7.52	0.7522	101	76.0
JULY	25.1	298	25.0	298	18	0.3080	0.0508	0.0009	0.08314	58.44	15.23	7.62	0.7616	86	65.5
AUGUST	25.4	299	22.0	295	18	0.3080	0.0604	0.0010	0.08314	58.44	15.24	7.62	0.7620	74	56.4
SEPTEMBER	23.3	296	21.0	294	18	0.3080	0.0566	0.0010	0.08314	58.44	15.14	7.57	0.7568	58	43.9
OCTOBER	19.0	292	18.5	292	18	0.3080	0.0600	0.0010	0.08314	58.44	14.91	7.46	0.7456	60	44.7
NOVEMBER	14.2	287	13.0	286	18	0.3080	0.0525	0.0009	0.08314	58.44	14.67	7.34	0.7337	93	68.2
DECEMBER	10.8	284	8.0	281	18	0.3080	0.0435	0.0007	0.08314	58.44	14.51	7.25	0.7254	143	103.7
<b>AVERAGE</b>	15.7	289	15.5	289	18	0.3080	0.0467	0.0008	0.08314	58.44	14.76	7.38	0.7378	143	104.7

- Seyhan is an important river for Turkey having approximate length of 560 km and born in Kayseri.
- River basin consist of 20,731 km<sup>2</sup> and end with Çukurova plain where population density is high and has effective agricultural land use (Davutluoglu, Seckin, Ersu, Yilmaz, and Sari, 2011).



*Figure 29: Photography of Seyhan River flowing in Adana, one of the biggest city in Turkey (Şimşek, 2015)*



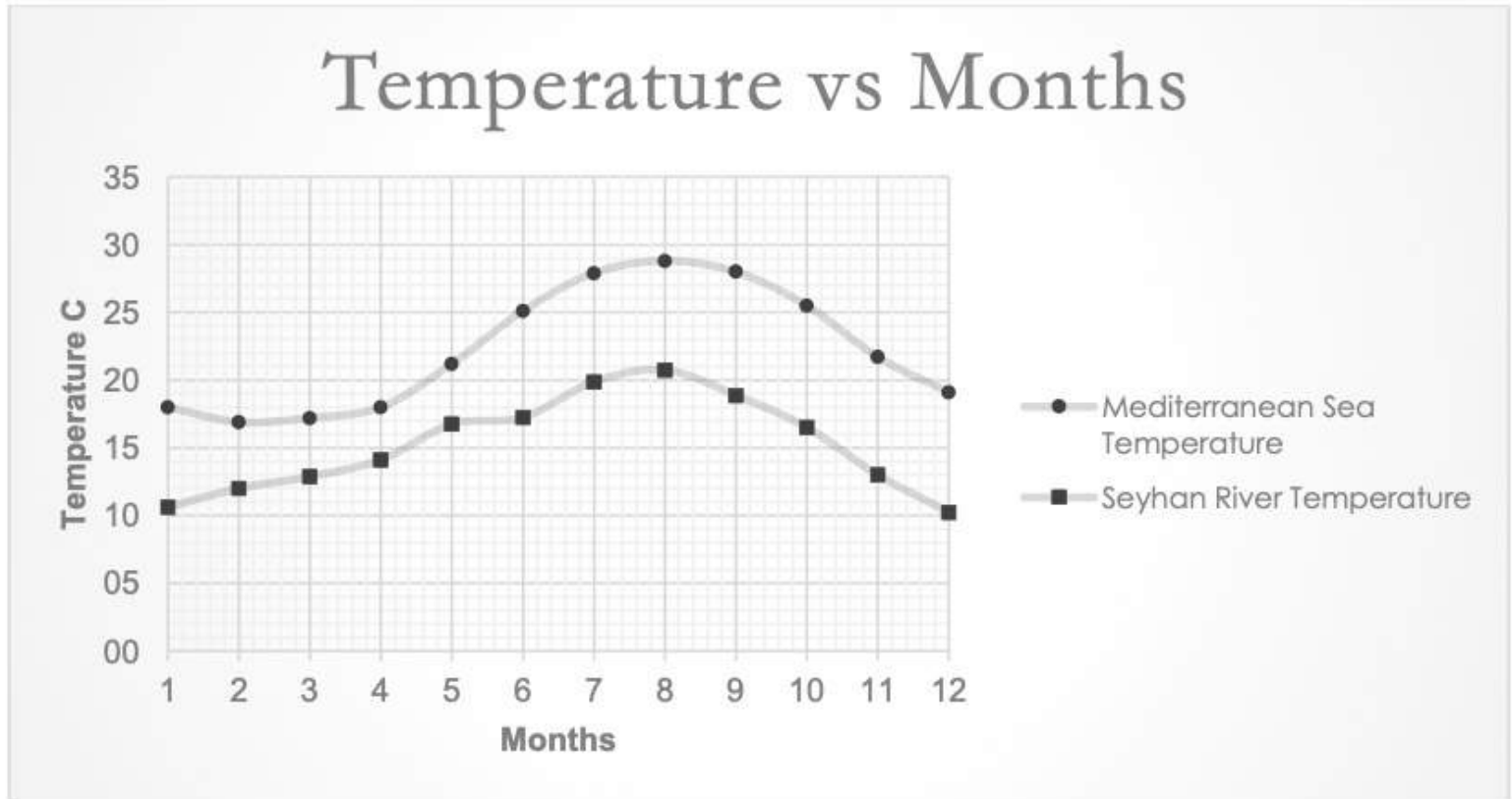


Figure 31: Comparison and monthly temperature change of Mediterranean Sea and Seyhan River.



- The Yeşilirmak River has a total basin area of 2352.8 m<sup>2</sup> 519 km in length, where the large part of it lies in Tokat city.
- Stream has been polluted by industrial wastewater heavily (Tüzen, 2003).
- The River discharges to the Black Sea with an average flowrate of 140 m<sup>3</sup>/s, according to the SHW stream station.



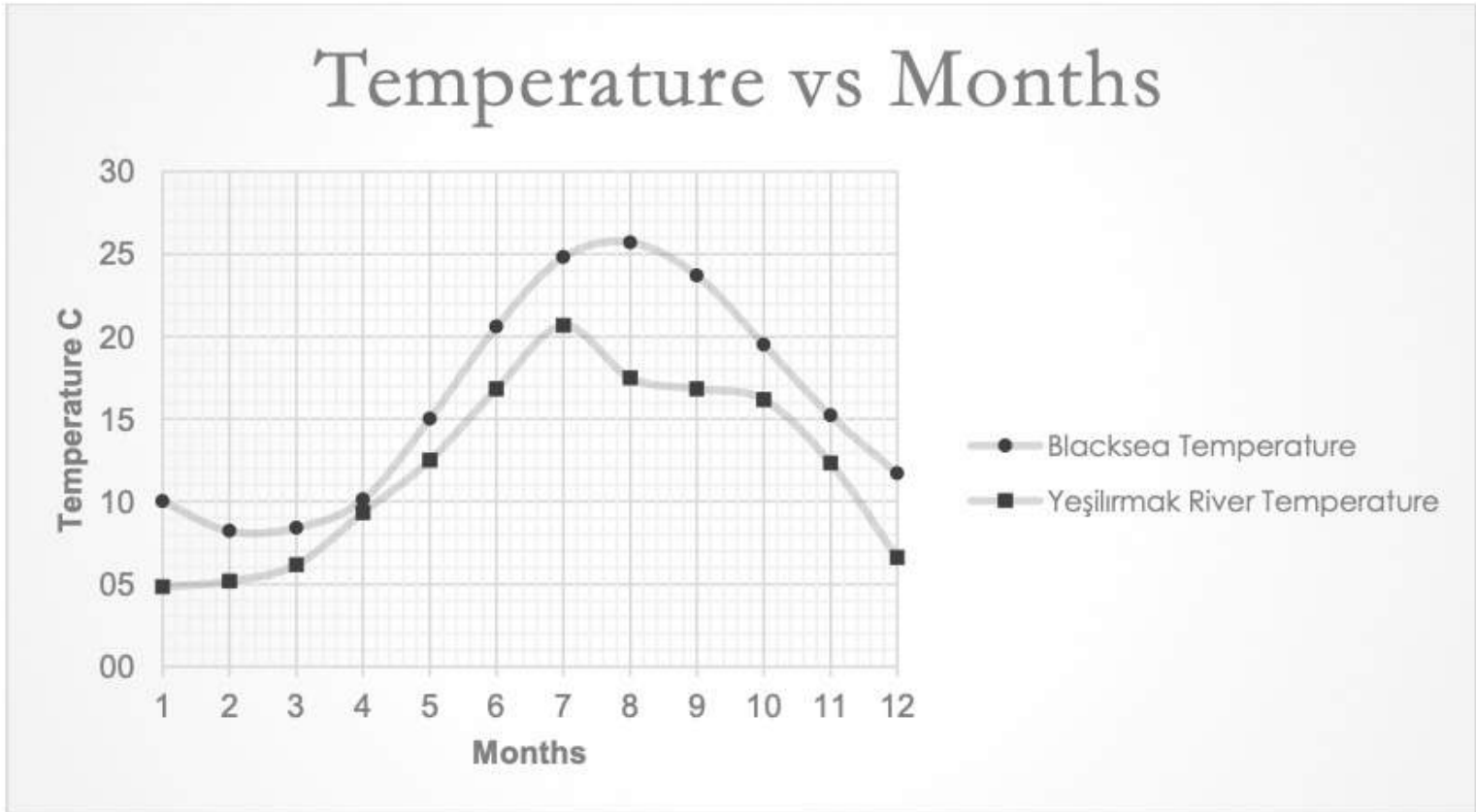


Figure 33: Temperature change of Black Sea and Yeşilırmak River with respect to months





# The Yeşilirmak River



Table 23: Yeşilirmak River calculation and dataset table prepared in Excel ®.

MONTHS	T <sub>sea</sub>	T <sub>sea</sub>	T <sub>river</sub>	T <sub>river</sub>	S <sub>sea</sub>	S <sub>sea</sub>	S <sub>river</sub>	S <sub>river</sub>	R	M <sub>NaCl</sub>	Δπ <sub>osm</sub>	Δp	E <sub>osm</sub>	Q <sub>freshwater</sub>	P <sub>powerplant</sub>
Units	centigrade	Kelvin	centigrade	Kelvin	gram/liter	mol/liter	gram/liter	mol/liter	joule/mol.Kelvin	gram/mol	bar	bar	megajoules/metercube	metercube/second	megawatt
JANUARY	10.0	283	4.8	278	18	0.3080	0.0133	0.0002	0.08314	58.44	14.49	7.25	0.7246	166	120.2
FEBRUARY	8.2	281	5.2	278	18	0.3080	0.0148	0.0003	0.08314	58.44	14.40	7.20	0.7199	185	133.5
MARCH	8.4	282	6.2	279	18	0.3080	0.0147	0.0003	0.08314	58.44	14.41	7.20	0.7204	199	143.3
APRIL	10.1	283	9.3	282	18	0.3080	0.0122	0.0002	0.08314	58.44	14.50	7.25	0.7249	237	171.9
MAY	15.0	288	12.5	286	18	0.3080	0.0134	0.0002	0.08314	58.44	14.75	7.37	0.7373	182	134.4
JUNE	20.6	294	16.8	290	18	0.3080	0.0138	0.0002	0.08314	58.44	15.03	7.52	0.7517	157	118.0
JULY	24.8	298	20.7	294	18	0.3080	0.0169	0.0003	0.08314	58.44	15.25	7.62	0.7623	159	120.9
AUGUST	25.7	299	17.5	291	18	0.3080	0.0195	0.0003	0.08314	58.44	15.29	7.64	0.7645	141	107.5
SEPTEMBER	23.7	297	16.8	290	18	0.3080	0.0181	0.0003	0.08314	58.44	15.19	7.59	0.7594	109	82.4
OCTOBER	19.5	293	16.2	289	18	0.3080	0.0156	0.0003	0.08314	58.44	14.98	7.49	0.7488	97	72.8
NOVEMBER	15.2	288	12.3	285	18	0.3080	0.0136	0.0002	0.08314	58.44	14.76	7.38	0.7378	116	85.7
DECEMBER	11.7	285	6.6	280	18	0.3080	0.0136	0.0002	0.08314	58.44	14.58	7.29	0.7289	153	111.3
<b>AVERAGE</b>	16.1	289	12.1	285	18	0.3080	0.0150	0.0003	0.08314	58.44	14.80	7.40	0.7400	158	116.8



# Osmotic Energy Potential of Turkey



Table: Maximum potential capacity of Turkey when the technology is suitable for variable conditions

River	Capital Capacity (MW)	Annual Energy Production (GWh)
Ceyhan	325	2840
Dalaman	45	415
Gediz	40	355
Göksu	130	1130
Manavgat	105	925
Sakarya	105	915
Seyhan	125	1090
Yeşilirmak	115	1020
<b>TOTAL</b>	<b>990</b>	<b>8690</b>

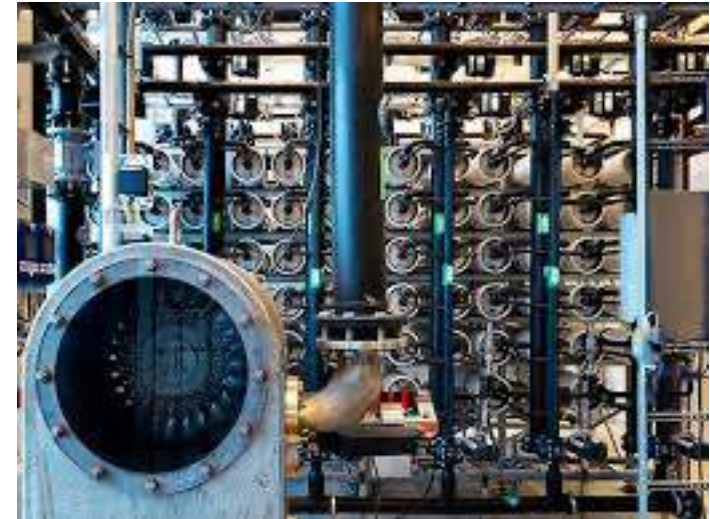




# Osmotic Energy Potential of Turkey



- Turkey is a suitable place to operate osmotic power plants.
- The country is a peninsula and there are lots of rivers discharging into coastal waters.
- These coastal waters have a variety of salinity and temperature characteristics which enables a range of possibilities for osmotic power plants. However, not all the rivers are suitable for producing energy as many of these rivers show strong seasonality such that flow rates can become less than 10 m<sup>3</sup>/s.







# Osmotic Energy Potential of Turkey



- In the final assessment for osmotic energy potential,
- 8 rivers were selected for potential used for PRO.
- It is found that **the total potential of the osmotic capacity of Turkey is nearly 1000 MW and**
- **total annual production is close to 8700 GWh potentially.**



- One of the main problems for site location is unstable soil conditions near areas around the river mouth.
- Moreover, there are protected areas such as Göksu where construction of a power plant may not be permitted.
- Furthermore, it is seen that the most convenient places are usually far away from both river and coastal waters. Therefore, infrastructure and construction costs may be high.



Figure 46: Membrane stack area and possible power plant place for Yeşilirmak.<sup>9</sup>





# Osmotic Energy Potential of Turkey



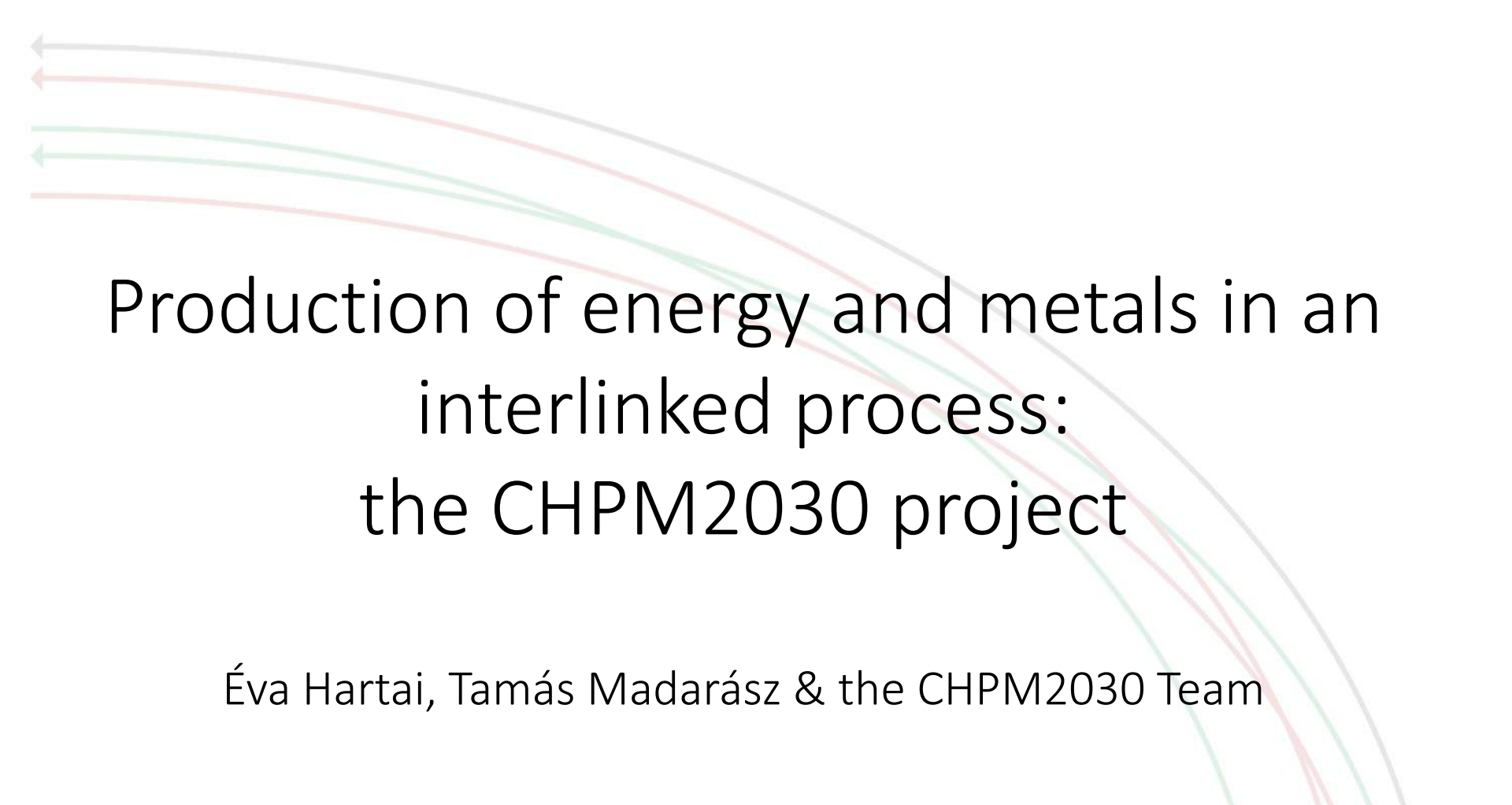
- The last important issue is legal requirements for osmotic power installation.
- Since such regulation does not exist at present, rules and regulations have to be developed for licensing and permission of building an osmotic power plant.





# Thanks for the listening





# Production of energy and metals in an interlinked process: the CHPM2030 project

Éva Hartai, Tamás Madarász & the CHPM2030 Team

<https://www.chpm2030.eu/>

# Content

CHPM2030 - Novel concept of combined heat, power and metal extraction from geothermal brines using ultra deep ore bodies

1. CHPM2030 project facts
2. Research concept
3. Main research results
4. Research roadmap



# Challenge and rationale

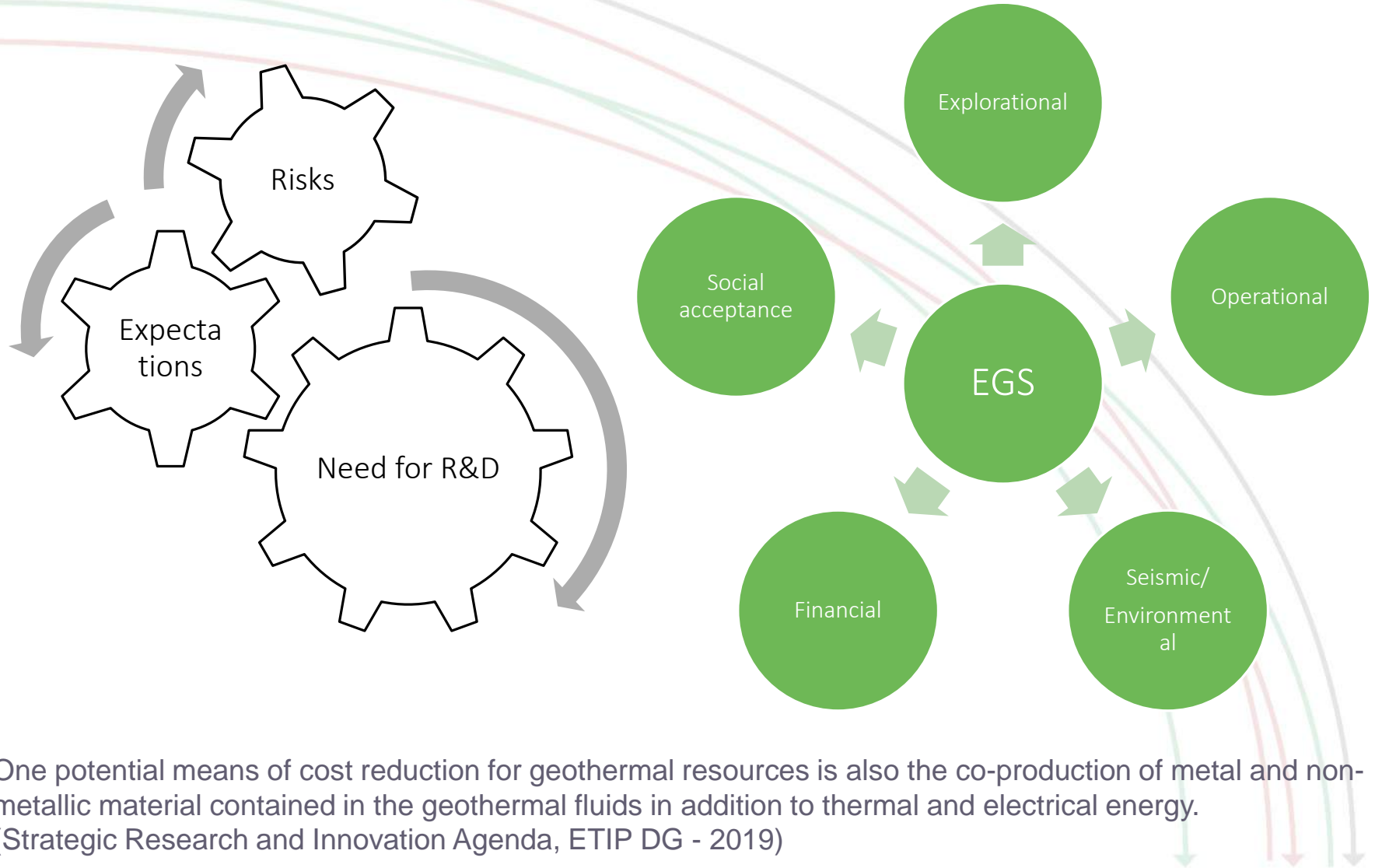
1) Increasing demand for green energy in the EU and worldwide

2) EU needs critical raw materials – limited mining

Developing a new technology for combining geothermal energy production and metal mining

Create a proof of concept of the technical and economic feasibility at laboratory scale

# EGS (Enhanced Geothermal Systems) - a risky business



One potential means of cost reduction for geothermal resources is also the co-production of metal and non-metallic material contained in the geothermal fluids in addition to thermal and electrical energy. (Strategic Research and Innovation Agenda, ETIP DG - 2019)



# The research concept

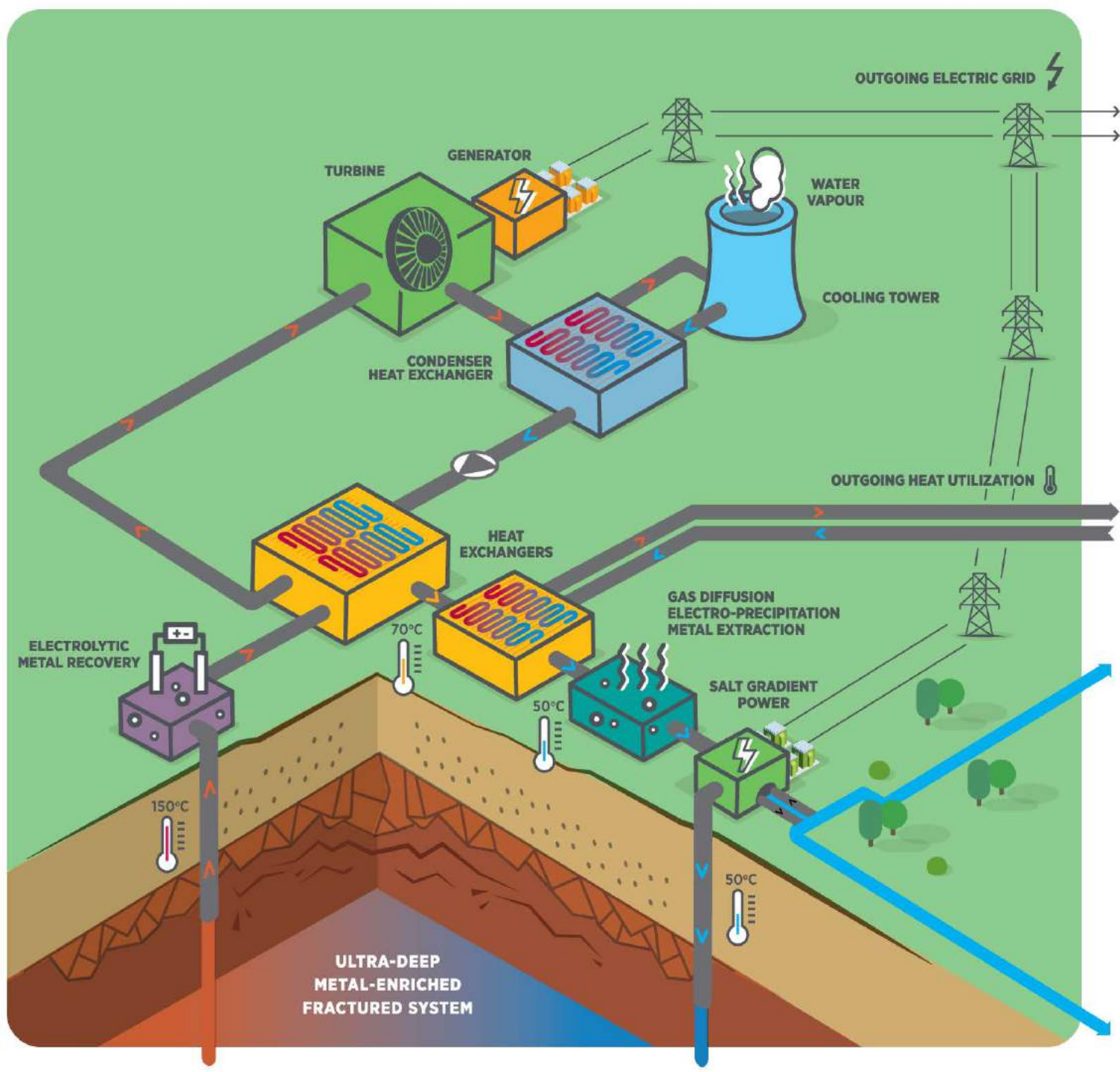
- Identifying ultra deep metalliferous formations
- Establishment of EGS
- Enhancing the interconnected fracture systems within the orebody
- Leaching metals from the orebody
- Extracting metal from the geothermal brine
- Production of heat and electricity
- Financially more feasible operation/earlier return of investment



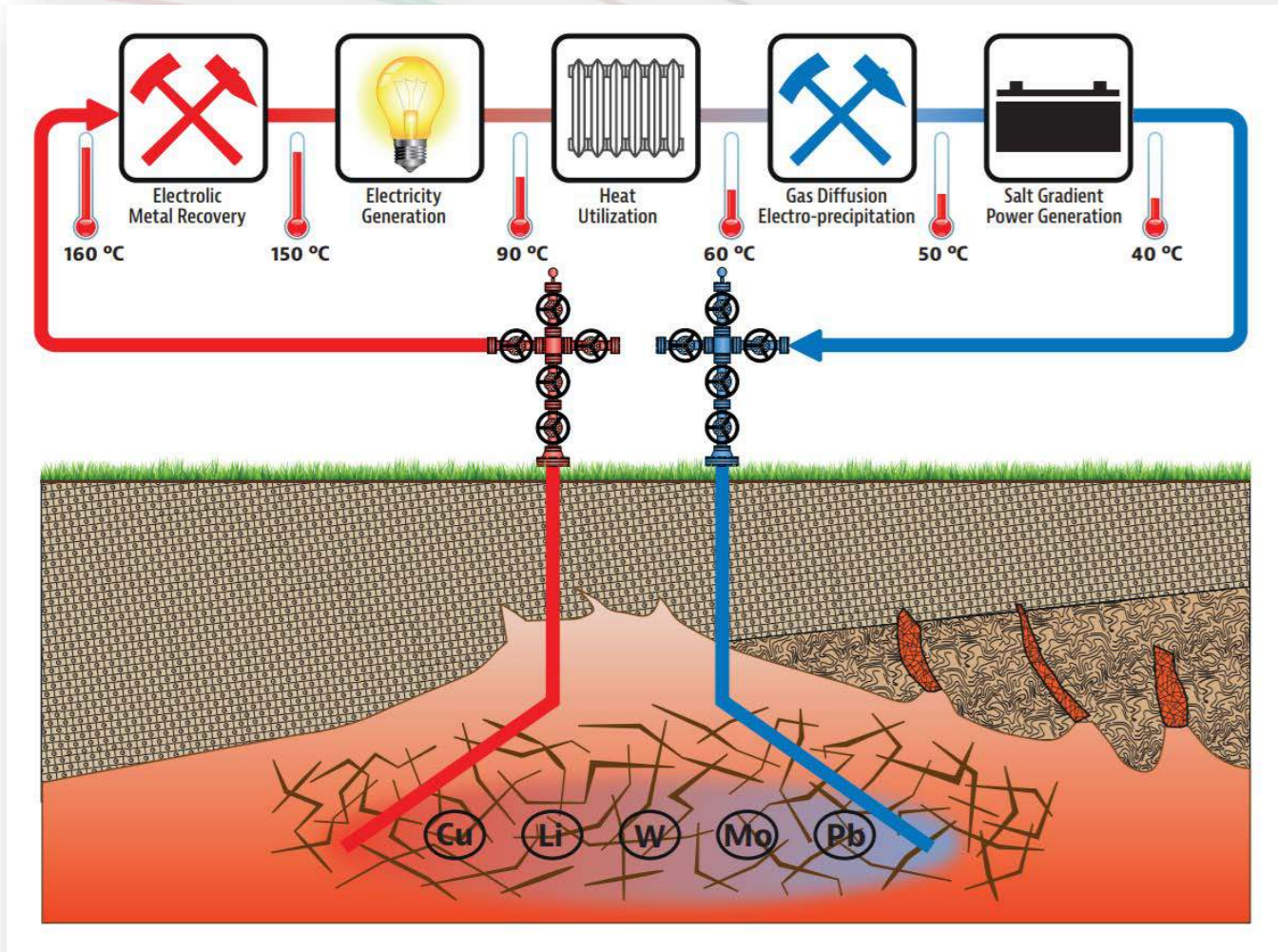
# The research concept

CHPM2030 –  
Combined Heat, Power and Metal extraction from ultra-deep ore bodies

H2020 project  
2016-2019



# Conceptualisation



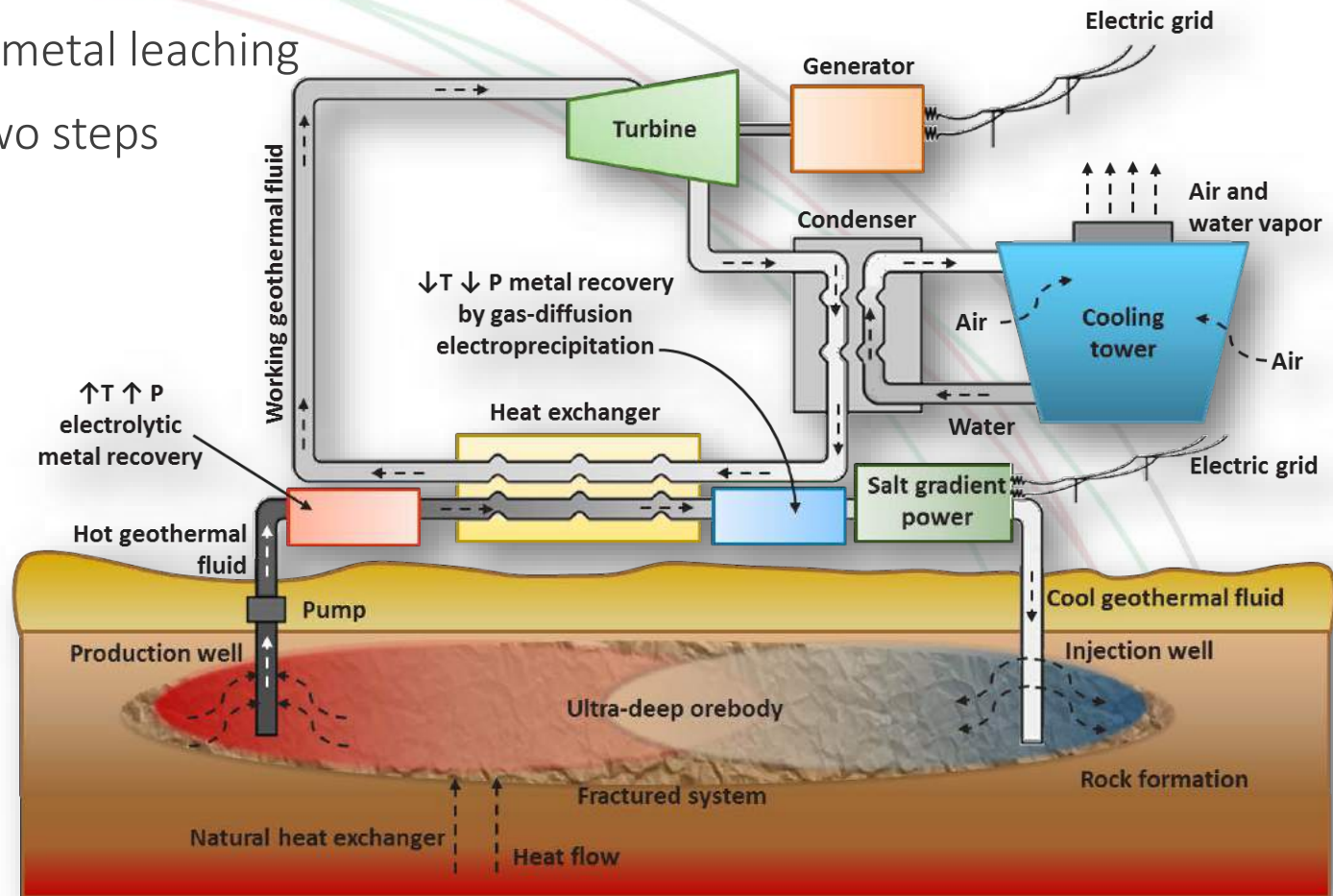
# The CHPM2030 Consortium



Partner organisation	Country
University of Miskolc (UNIM), coordinator	Hungary
University of Szeged (USZ)	Hungary
European Federation of Geologists (EFG)	Belgium
Iceland Geosurvey (ISOR)	Iceland
British Geological Survey (BGS)	UK
Laboratório Nacional de Energia e Geologia (LNEG)	Portugal
Vlaamse Instelling voor Technologisch Onderzoek (VITO)	Belgium
La Palma Research Centre (LPRC)	Spain
Agency for International Minerals Policy (MinPol)	Austria
Geological Survey of Romania (IGR)	Romania
Katholieke Universiteit Leuven (KLeuv)	Belgium
Geological Survey of Sweden (SGU)	Sweden

# Main research results

- EGS relevant review of ore bodies and identification of potential test sites
- Laboratory tests on metal leaching
- Metal recovery in two steps
- System integration
- Research Roadmap



Schematic overview of the envisioned CHPM Installation



# Most appropriate geological settings

- 1) Magmatic-hydrothermal mineralisations associated with intrusive bodies (appropriate mechanical properties of host rocks)
- 2) Basins in rift or subduction zones (relatively thin mineralised horizons, but with large lateral extension)
- 3) Deep-rooted fault zones, with larger extension and elevated heat flow (deep-seated fertile rock body, which can have a potential for further leaching)





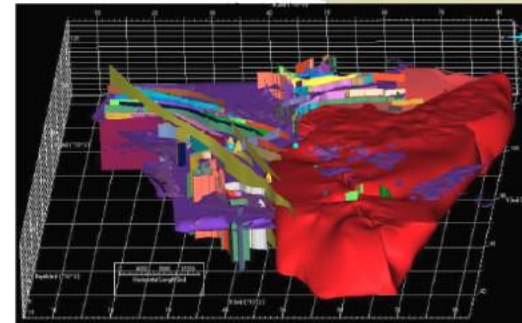
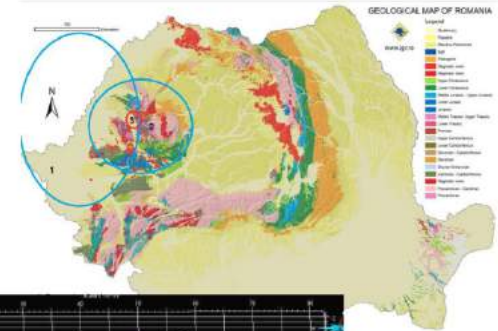


# Potential test sites

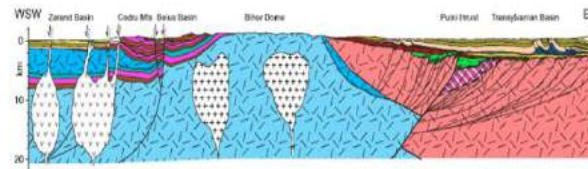
## Beius Basin-Bihor Mountains, Romania, IGR

Diana Persa, persa.diana@yahoo.ro

- Beius basin and Bihor Mountains, favourable geothermal (~Pannonian basin, thin crust, high heat flow/gradient) and mineral (intrusive magmatic bodies, Banatitic Magmatic and Metallogenic Belt) potential.
- Beius Basin geothermal potential (DHS up and running Mg, geothermal potential), Bihor Mountains (granodiorite-granite plutonic body related, skarn (Fe, Boron, Bismuth, Moly), vein (Cu, Zn, lead-Pb, sulphides), brucite deposit, borate deposit, metal skarn (W)).
- 1) Geothermal models (150 Celsius), 2) refraction seismic for the plutonic body and mineral indications, 3) fracture network modeling for understanding reservoir characteristics.



Beius-Bihor report

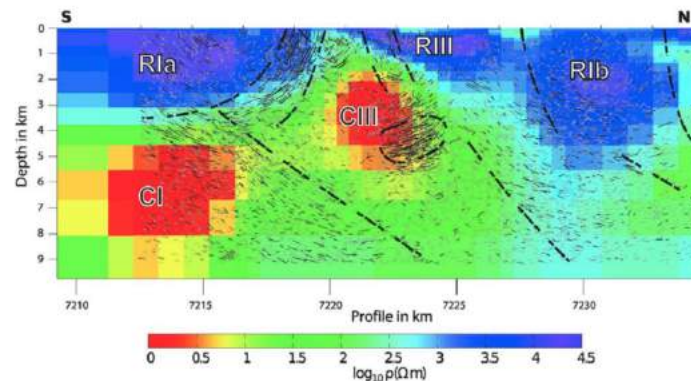


# Potential test sites

## Kristineberg, Nautanen areas, Sweden, SGU

Gerhard Schwarz, Gerhard.Schwarz@sgu.se

- 2 ore provinces: Kristineberg area (Skellefte district, volcanogenic massive sulphide deposits, Zn, Cu, Au), Nautanen area (Northern Norrbotten district, IOCG, Cu, Fe, Au).
- low geothermal gradient, limited info 5-7 km, permeability, deep-seated fluids in the crystalline bedrock is rudimentary, hydraulic conductivity,
- Geophysical studies, deep seismic, magnetotelluric measurements, cooperation with the mining industry?



Sweden report



# Potential sites (European overview)

## European Outlook, EFG

Domenico Marchese, [projects@eurogeologists.eu](mailto:projects@eurogeologists.eu)  
Anita Demény

1. Area selection
2. Basic area evaluation
3. CHPM characteristics

EFG's National Geological Associations

CHPM information platform on prospective locations:

<http://bit.ly/CHPMinfoplatform>

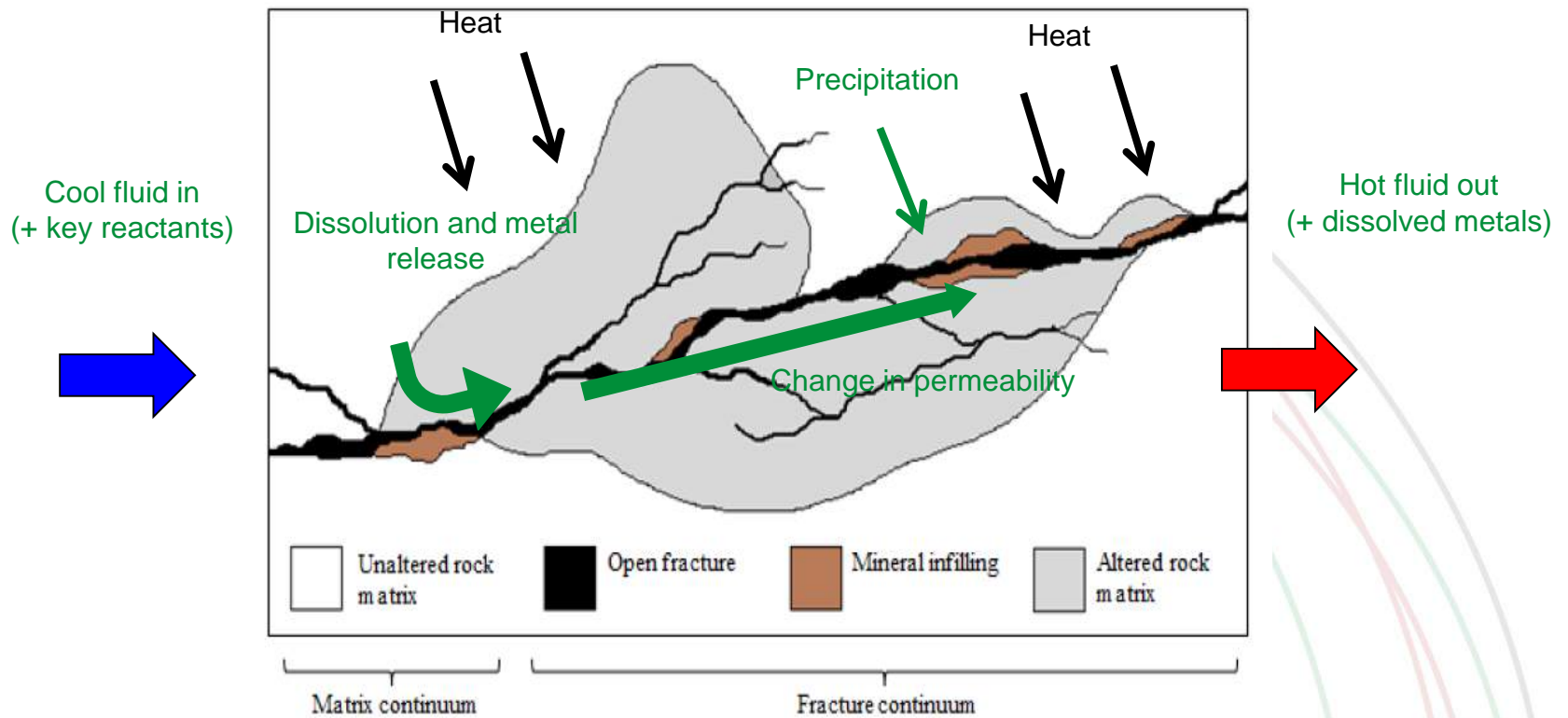


EU outlook report



EFG LTPs involved in CHPM2030 (16+1)			Data collected by RBINS (7)
<ul style="list-style-type: none"><li>• Belgium</li><li>• Czech Republic</li><li>• Finland</li><li>• France (by EFG)</li><li>• Germany</li><li>• Greece</li></ul>	<ul style="list-style-type: none"><li>• Hungary</li><li>• Ireland</li><li>• Italy</li><li>• The Netherlands</li><li>• Poland</li><li>• Portugal</li></ul>	<ul style="list-style-type: none"><li>• Serbia</li><li>• Slovenia</li><li>• Spain</li><li>• Switzerland</li><li>• Ukraine</li></ul>	<ul style="list-style-type: none"><li>• Austria</li><li>• Croatia</li><li>• Cyprus</li><li>• Luxembourg</li><li>• Slovakia</li><li>• Sweden</li><li>• United Kingdom</li></ul>

# Lab experiments on metal leaching



The concept of enhanced metal leaching in geothermal systems

# Selected samples

Sample ID	Sample locality	Geological setting	Summary of bulk mineralogy as determined via X-ray diffraction
HTLMix	Herodsfoot, SW England	Baked sediments with partial quartz vein	87% quartz, 5% muscovite, 2% dolomite, 5% galena, minor albite, chlorite, pyrite and sphalerite
HTL315	South Caradon, SW England	Mainstage mineralisation, associated with granite bodies	70% quartz, 7% schorl, 5% chlorite, 2% calcite, 10% pyrite, 5% arsenopyrite, minor greigite and biotite
HTL319	Cligga Head, SW England	Tin–tungsten mineralisation, associated with granite bodies	88% quartz, 2% muscovite, 3% cassiterite, 3% columbite and 4% ferberite
HTL321	Masca-Cocovaleni, Romania	Mineralised skarn country rock	22% dolomite, 49% pyrite, 27% magnetite, minor quartz, calcite and barite
HTL322	Rudabánya, NE Hungary	Carbonate hosted lead-zinc mineralisation	8% quartz, 2% calcite, 68% magnesite, 6% cerrusite, 1% sphalerite, 1% columbite, 11% barite, 2% magnetite and minor dolomite
HTL324	Recsk, NE Hungary	Porphyry sulphide polymetallic ore	74% quartz, 5% calcite, 9% pyrite, 11% magnetite, minor albite, dolomite and sphalerite

# HPHT batch and flow through experiments

## BGS

- 5 g solid sample
- 40:1 fluid:rock ratio
- 70°C, 100°C, 150°C, 200°C
- 1 bar, 200 bar
- 600-1000 hours
- Leaching agents: deionized water, 0.1 M acetic acid, 0.013 M „aqua regia”

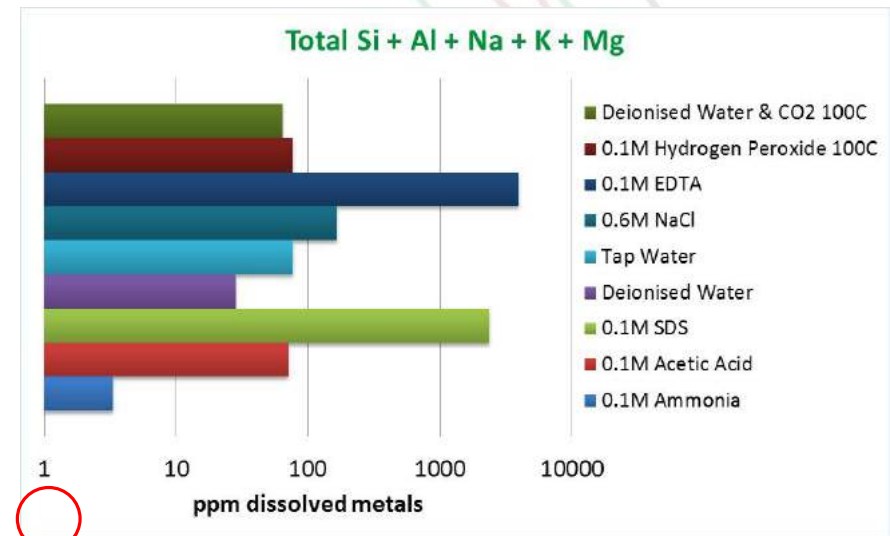
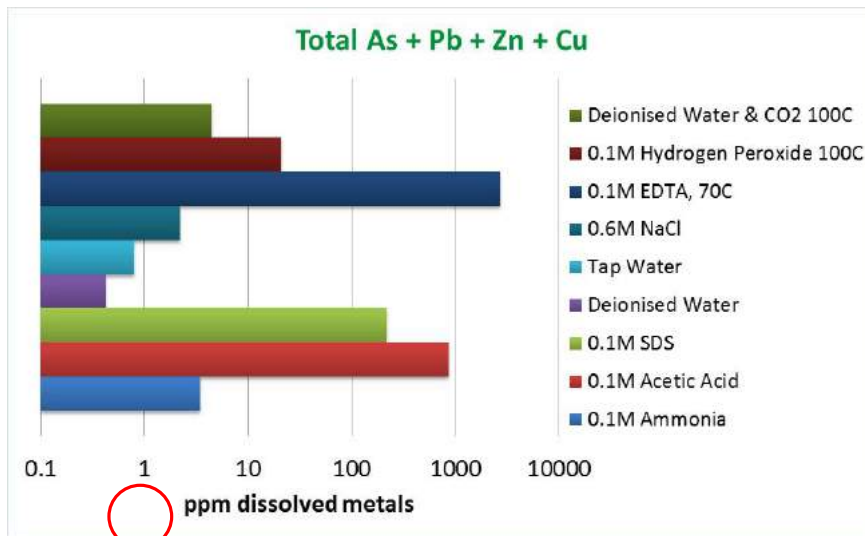
## University of Szeged

- HTHP (40 MPa) system: HPLC pump, external heating and insulation;
- Flow through tests on grinded rock (250  $\mu\text{m}$ ) under 300 bar pressure at 300°C temperature
- Pressure, temperature and flow rate can be controlled any time during experiments
- Output analysis: XRF, ICP-MS



# Leachate performance at HTHP batch experiments

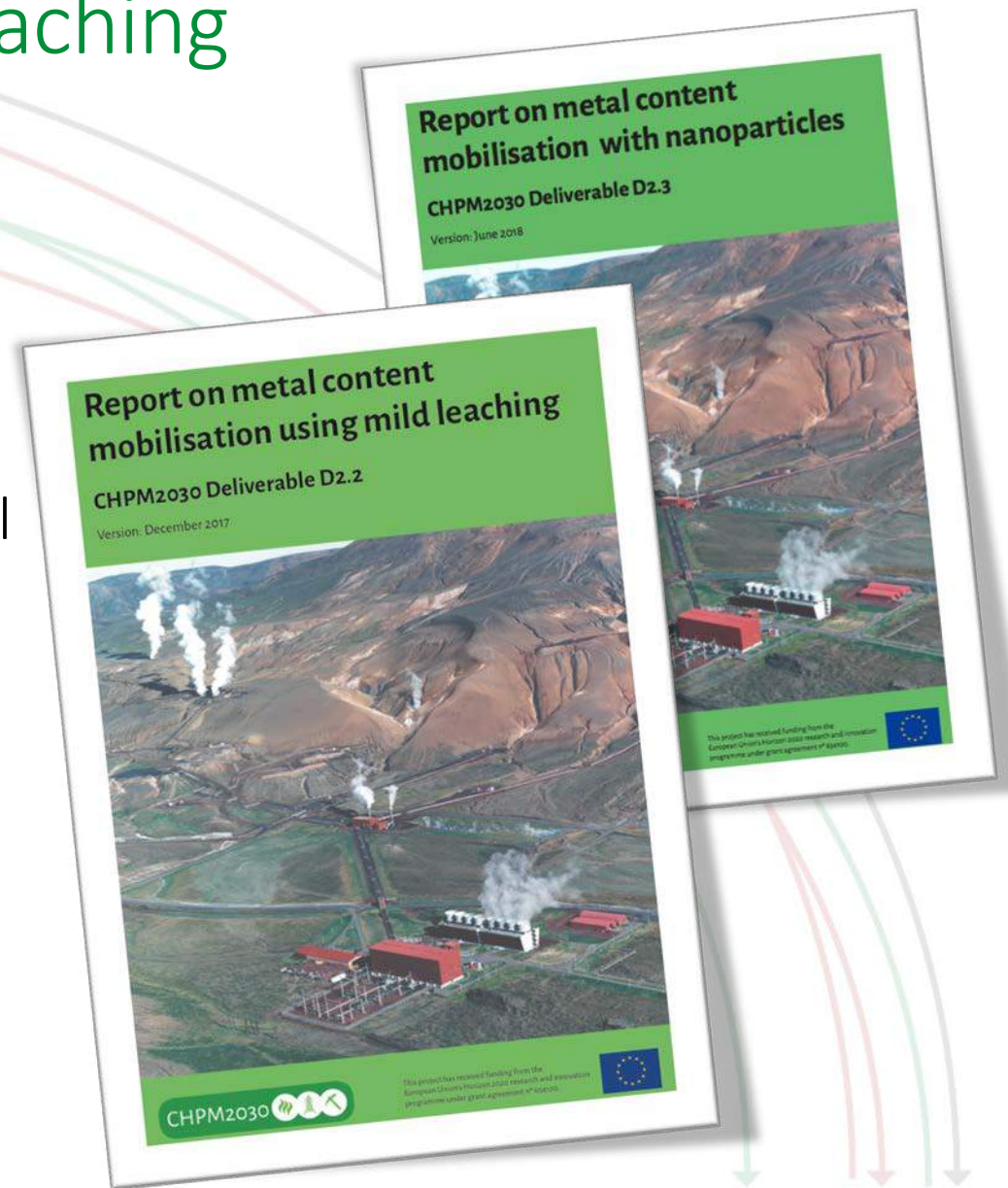
- Tap-water & deionised water: poorest performing fluids (addition of  $\text{CO}_2$  improved leaching, but generally restricted to base metals)
- Best performing fluids: dilute EDTA, SDS and acetic acid (organics): leached 100-1000s ppm base metals & liberate some minor or 'critical' metals
- Most fluids dissolved high loads (10s-1000s ppm) of elements derived from silicate minerals  $\rightarrow$  implications for permeability of the EGS reservoir



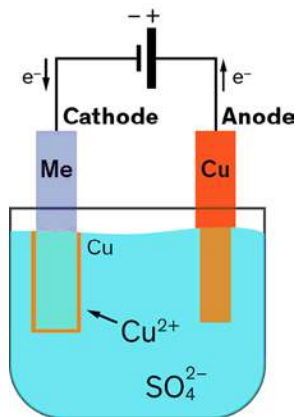
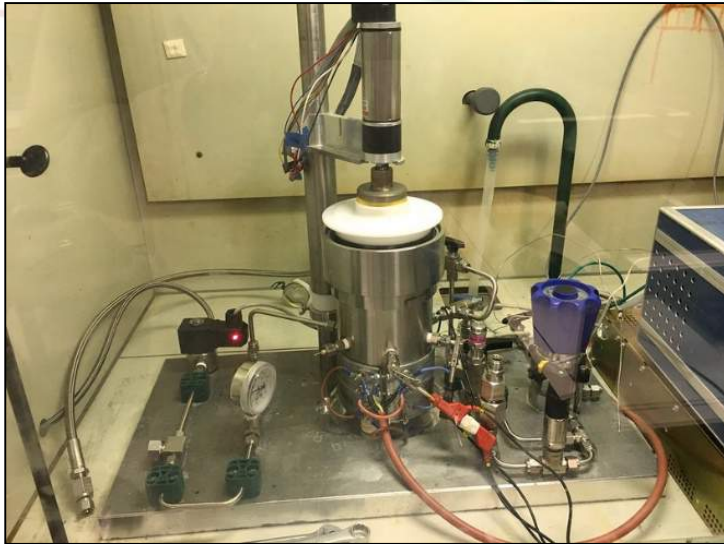


# Report on metal leaching

- 62 pages of main report.
- Plus 305 pages of appendixes.
- Contains details of the experiments, all analytical data, plus conceptual or numerical modelling.



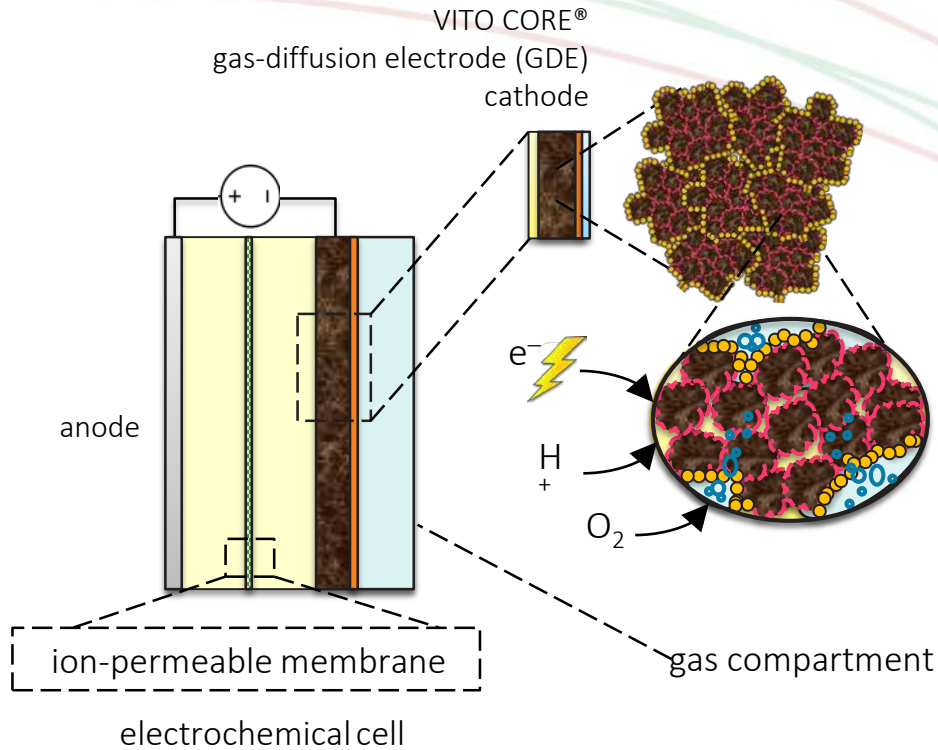
# HThP metal recovery (KU Leuven)








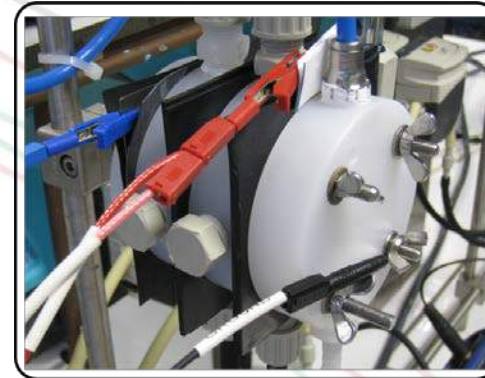
## Electrolytic metal recovery

- Ox/red of metal ions in solution by an electricity-driven conversion, such that they “deposit” onto an electrode:  
**electrodeposition**
- $\uparrow T$   $\uparrow P$  electrodeposition from geothermal brines (100°C, 5MPa):
  - Increases kinetics and mass transport
  - Avoids issues like precipitation of silica
  - More energetically favorable vs. ambient conditions
  - Completely unexplored (no thermodynamic data)
- It only works for a limited number of metals (Cu, Ag, Ni, Pb, Sn, Fe, PGM)

# Metal recovery with GDEx (LTLP)



- liquid electrolyte (water) 
- gas-diffusion layer 
- electrochemically-active porous carbon particles 
- polymeric binder 
- oxidant gas 



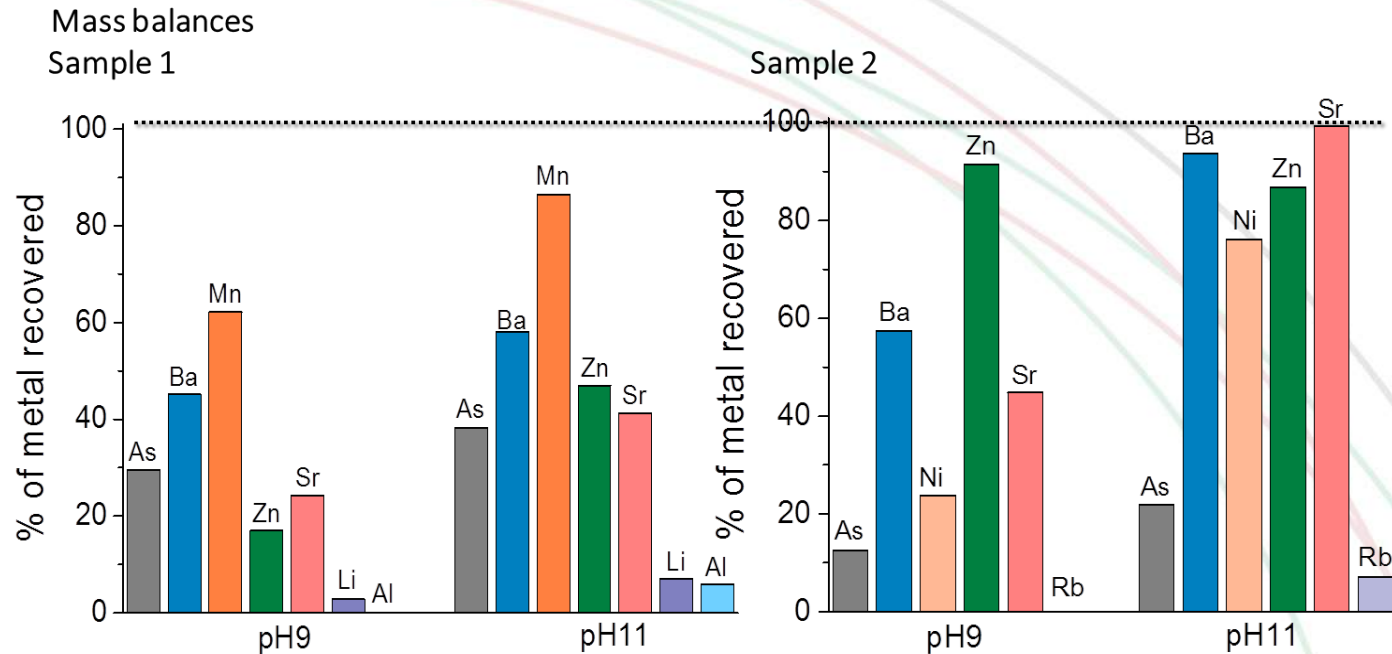
## Test setup

- 250 ml batch vessels
- 10 cm<sup>2</sup> GDE anode



# Metal recovery with GDEx (LTLP)

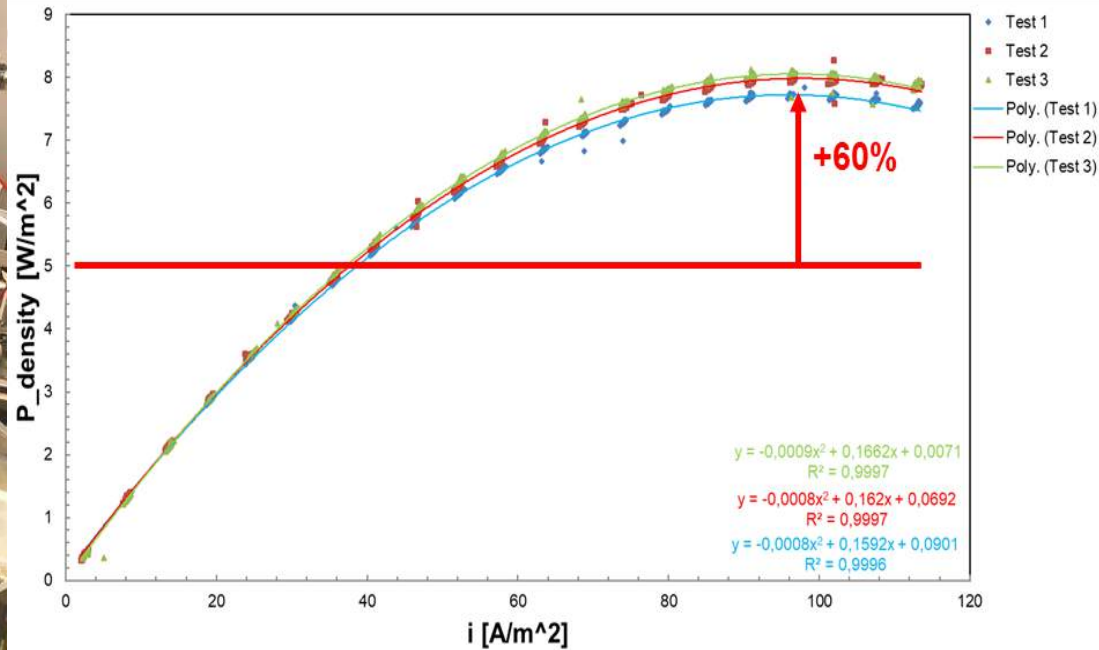
Geothermal brines from Romania



Real brine	Main precipitated products
Sample 1	Magnesium hydroxide Strontium manganese oxide Zinc sulfate hydrate
Sample 2	Strontium manganese oxide Calcium iron oxide



# Additional electricity production by salinity gradient power generation

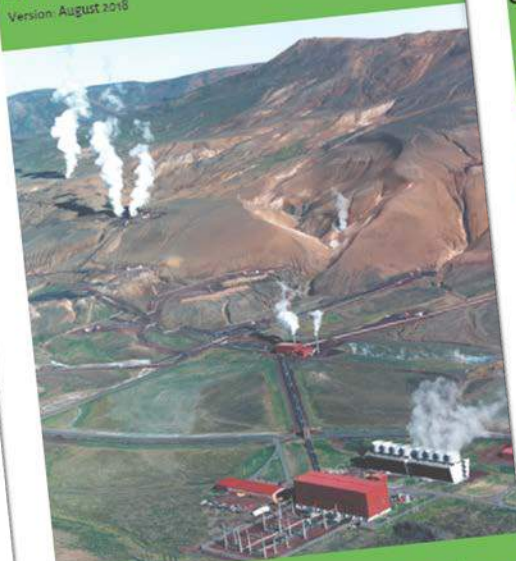


- Reverse electrodialysis
- Effect of T on power generation in the stack: higher T increases power generation

# Report on performance and design criteria for high-temperature, high-pressure electrolysis

CHPM2030 Deliverable D3.1

Version: August 2018



CHPM2030

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement n° 454103

# Report on performance, mass and energy balances and design criteria for gas-diffusion electroprecipitation and electrocrystallization

CHPM2030 Deliverable D3.2

Version: August 2018



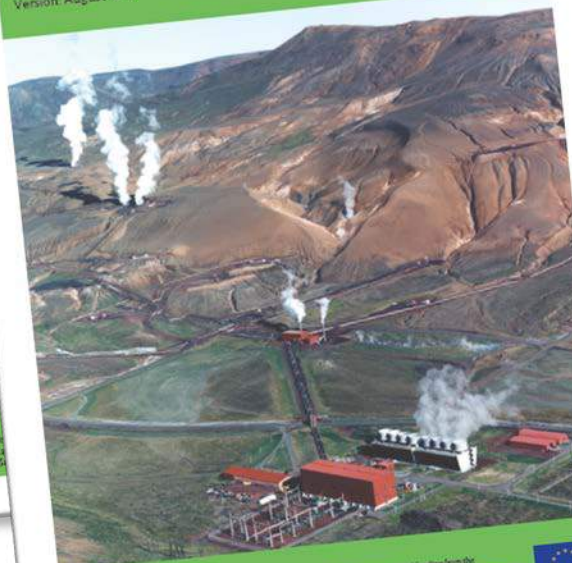
CHPM2030

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement n° 454103

# Report on performance, energy balances and design criteria for salt gradient power reverse electro dialysis

CHPM2030 Deliverable D3.3

Version: August 2018



CHPM2030

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement n° 454103

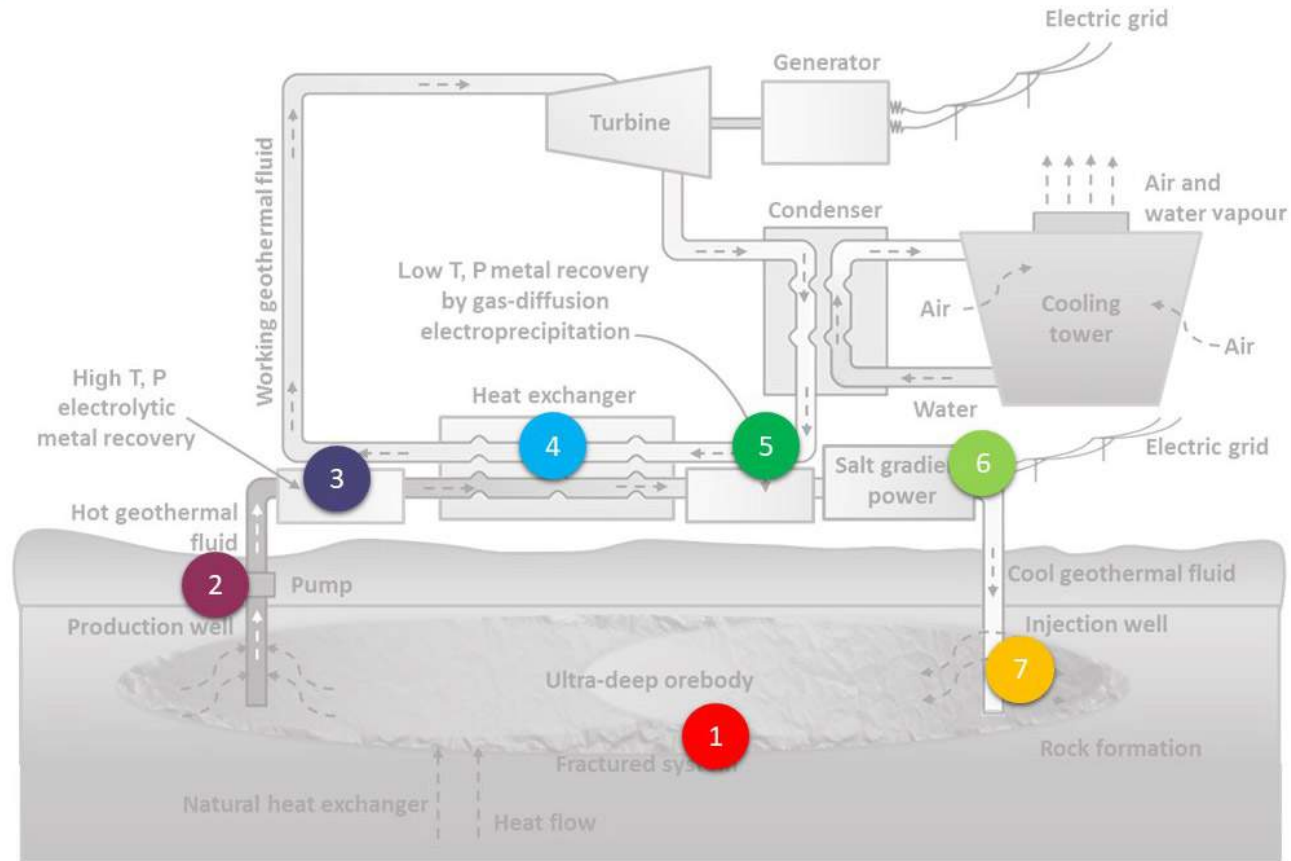


# System integration: technological components – design parameters

## Main technological components

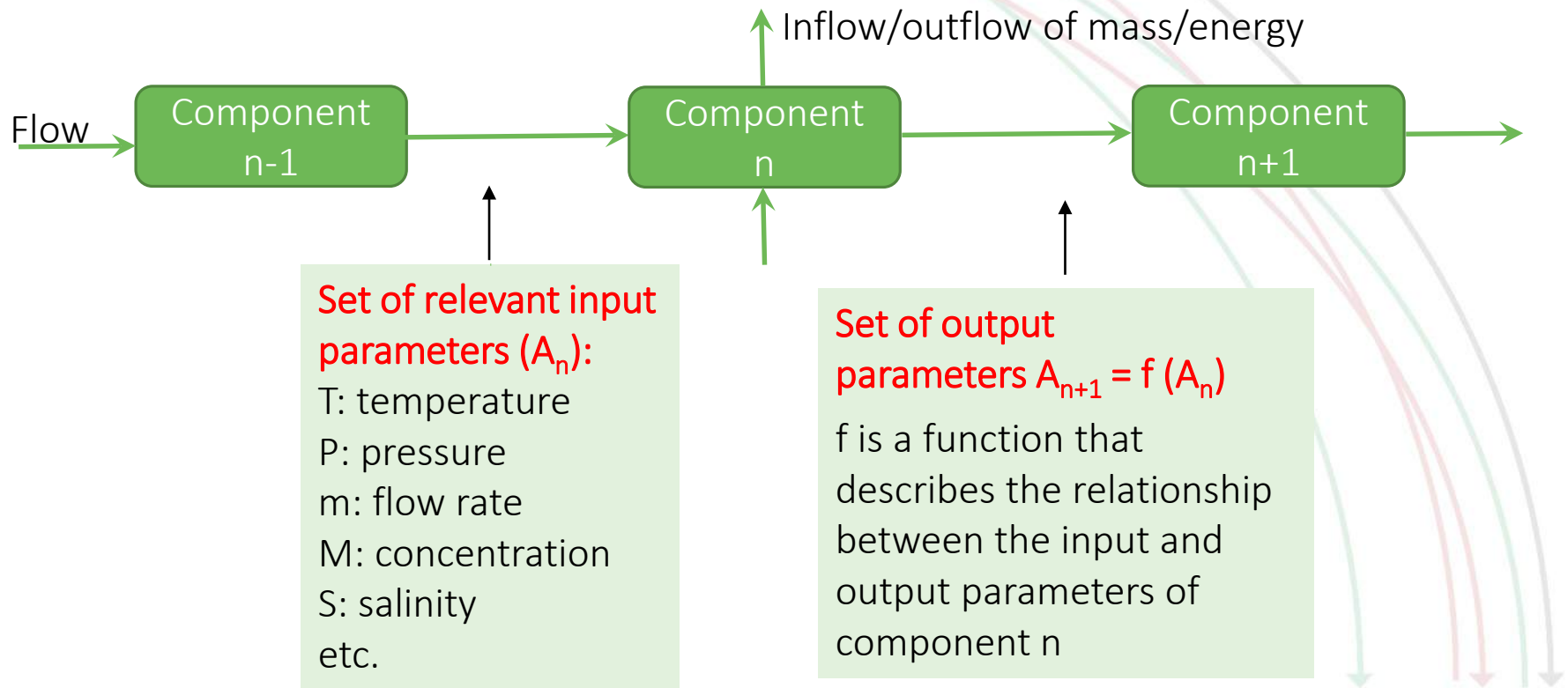
### Design parameters:

- Temperature
- Pressure
- Acidity/basicity
- Redox condition
- Oxygen fugacity
- Carbon dioxide
- Conductivity
- Flow rate
- Salinity
- Oxidizing compounds
- Concentrated suspended solids



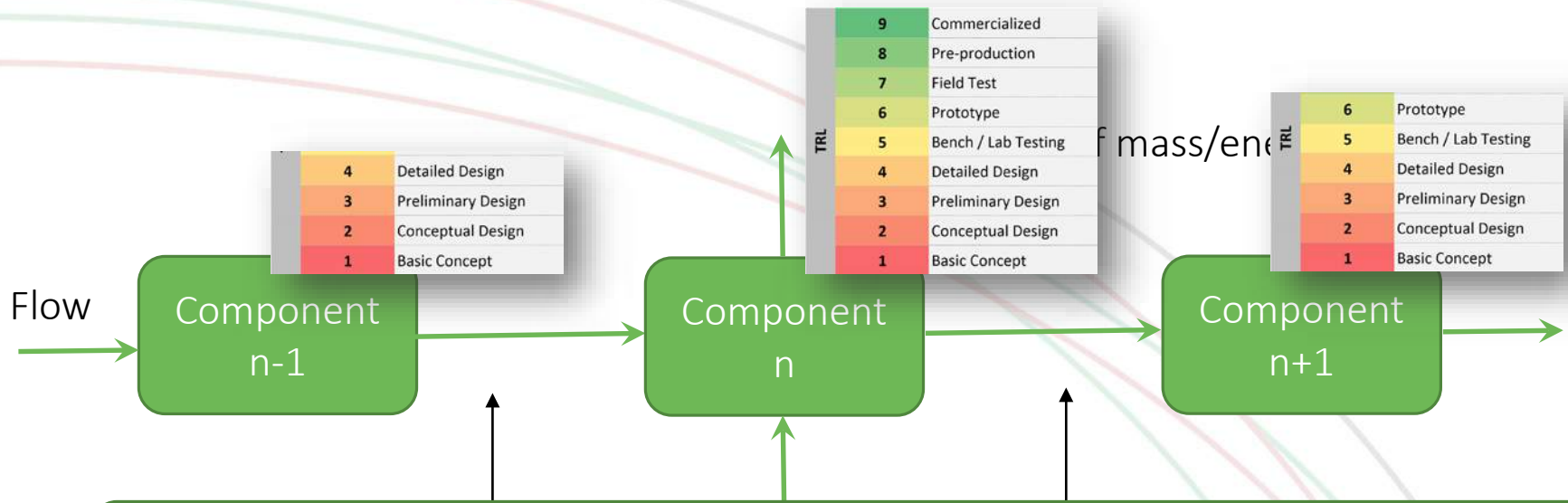
# Model framework based on component level models

The different system components were integrated into a single system by a mathematical model. This model is used to develop optimisation strategies for heat, energy and metal production.





# From component model to systems dynamic



Technology harmonisation issues within the CHPM loop:

- Technology components are at different TRL
- Component models represent different levels of complexity
- The system dynamics model must handle various levels of data reliability
- Agreement on the minimum dataset of design parameters
- Move from very simple to complex
- Move from site specific scenarios toward a general CHPM plant

# Conceptual framework for CHPM power plant

CHPM2030 Deliverable D4.1

Version: September 2018



CHPM2030

This project has received European Union Horizon programme under grant

# Report on CHPM process optimisation

CHPM2030 Deliverable D4.2

Version: August 2019



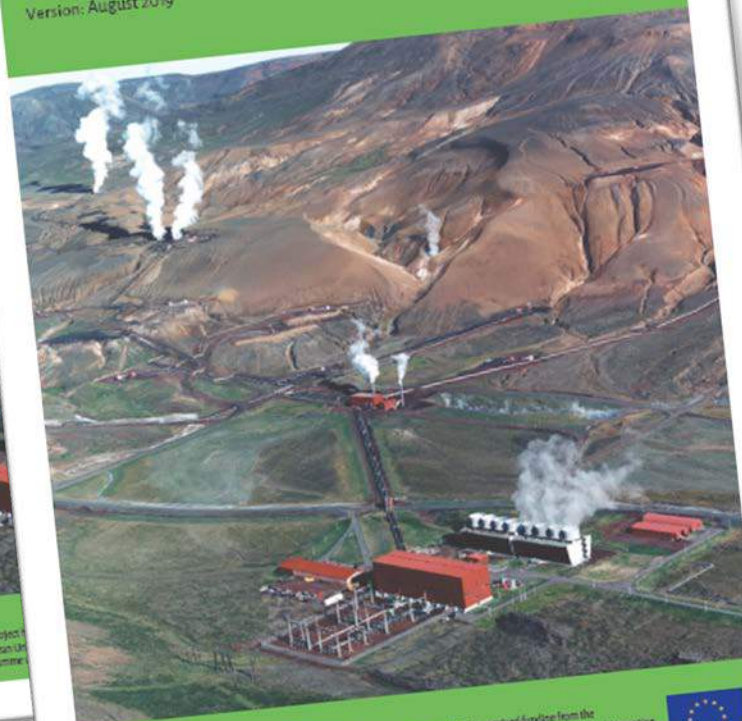
CHPM2030

This project has received European Union programme

# CHPM schematics and blueprints

CHPM2030 Deliverable D4.3

Version: August 2019



CHPM2030

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement n° 454103



# Integrated sustainability assessment

## Economic feasibility assessment methodology

CHPM2030 Deliverable D5.2

Version: August 2019



CHPM2030

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 101019719.

## Self-Assessment Tool

CHPM2030 Deliverable D5.3

Version: April 2019



CHPM2030

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 101019719.

## Report on Policy Implications

CHPM2030 Deliverable D5.4

Version: June 2019



CHPM2030

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 101019719.

## Environmental impact assessment framework

CHPM2030 Deliverable D5.5

Version: March 2019



CHPM2030

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 101019719.

## Ethics Assessment Report

CHPM2030 Deliverable D5.6

Version: June 2019

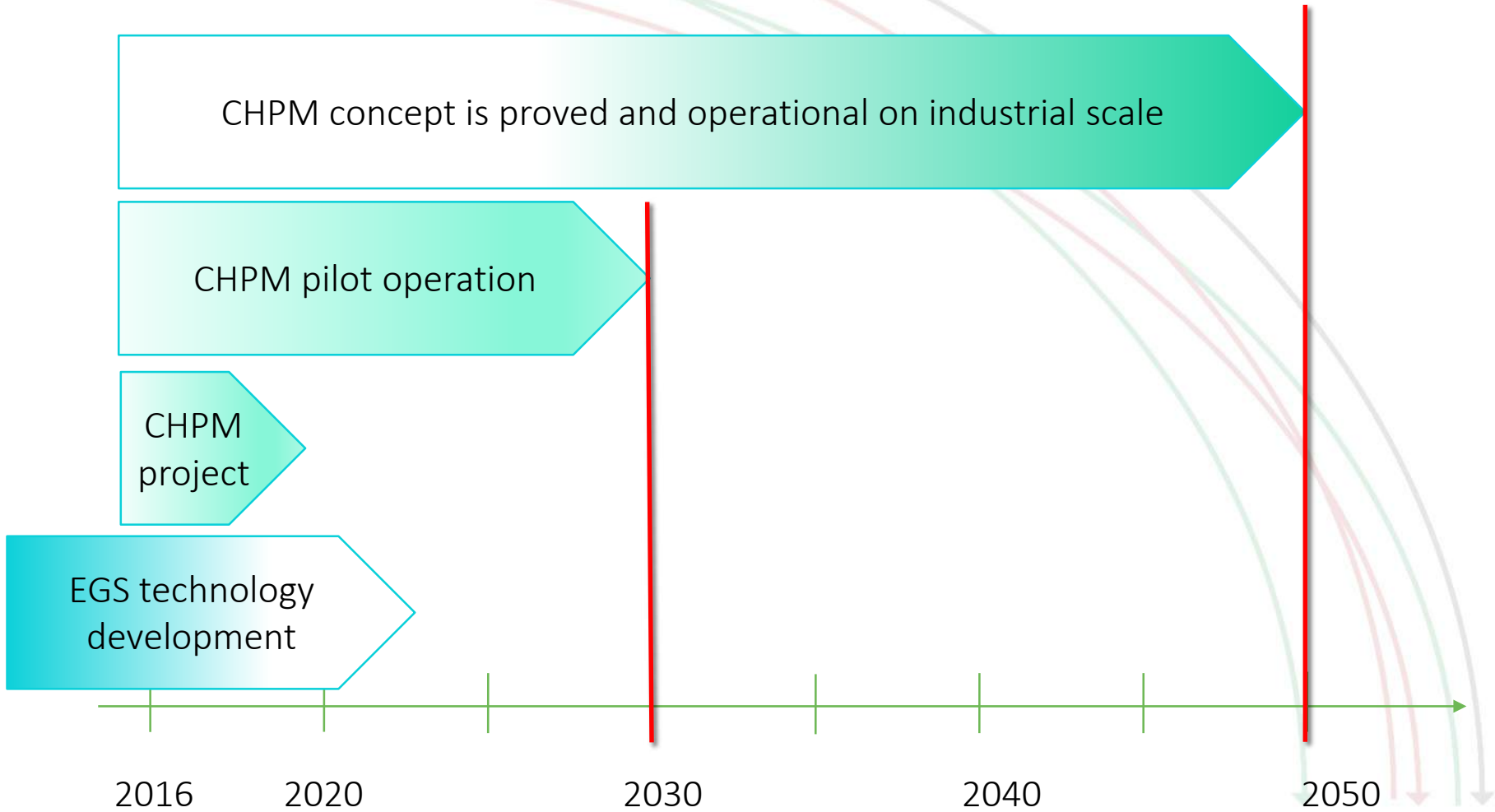


CHPM2030

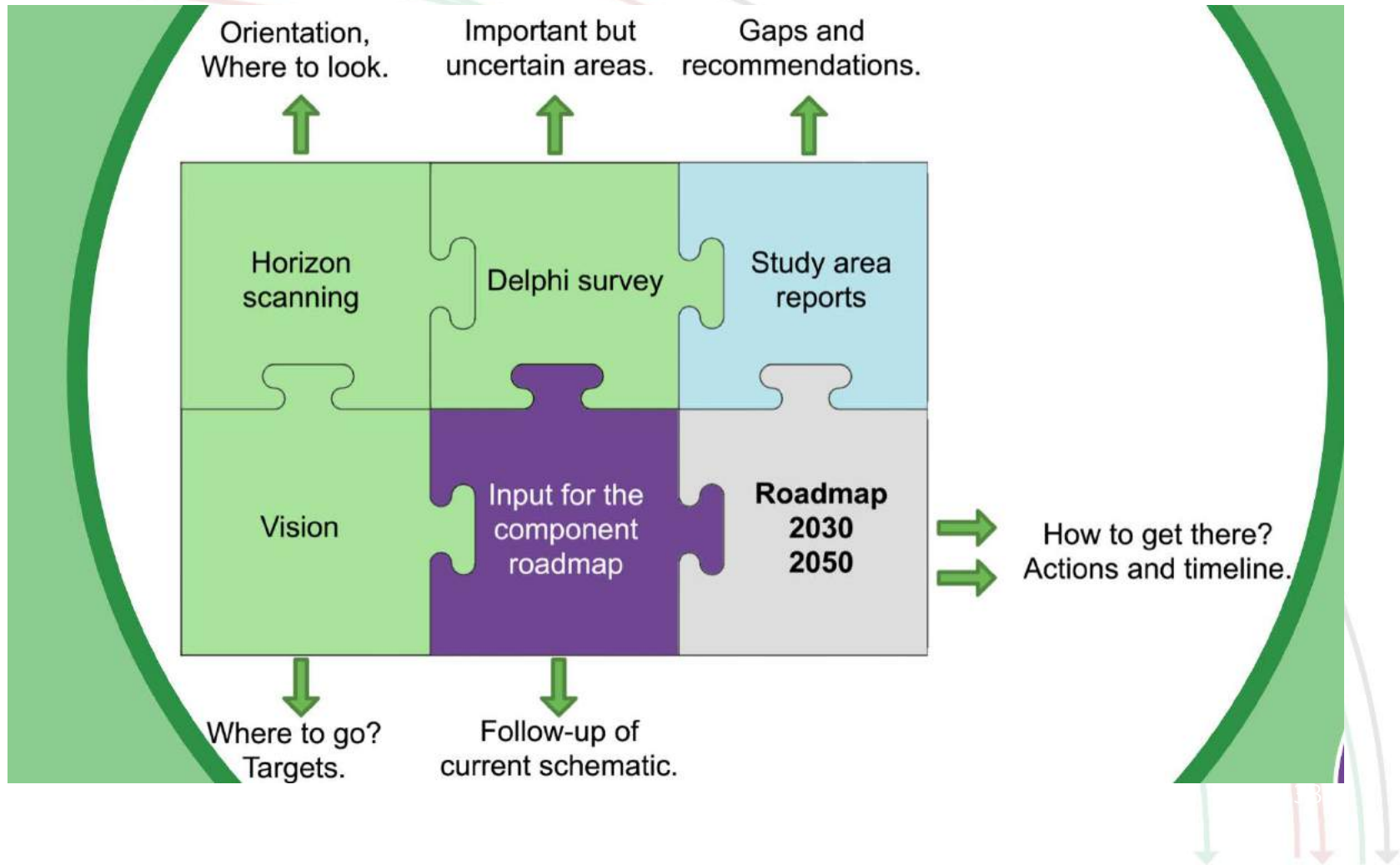
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 101019719.



# The time horizon

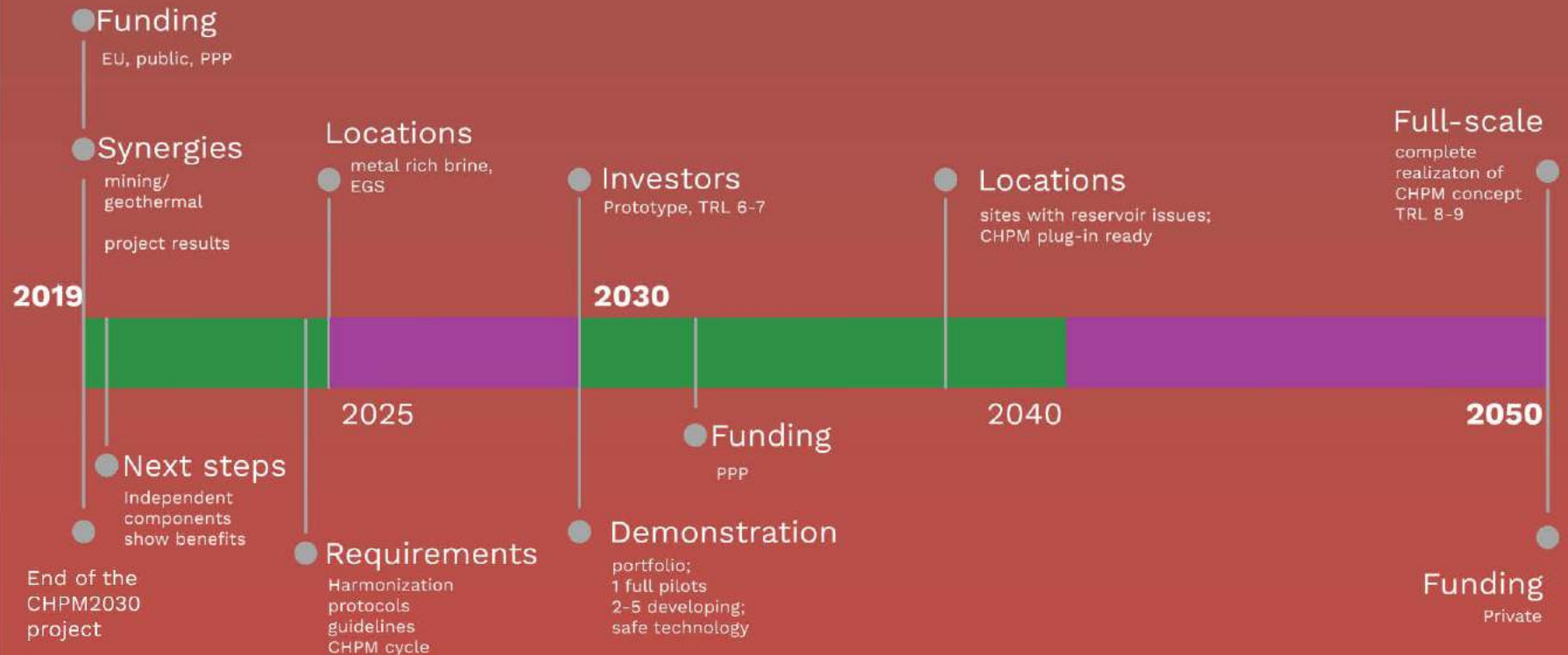


# Research roadmap



# Research roadmap - timeline

## Milestones



# Report on Emerging and Converging Technologies

CHPM2030 Deliverable D6.1

Version: April 2019

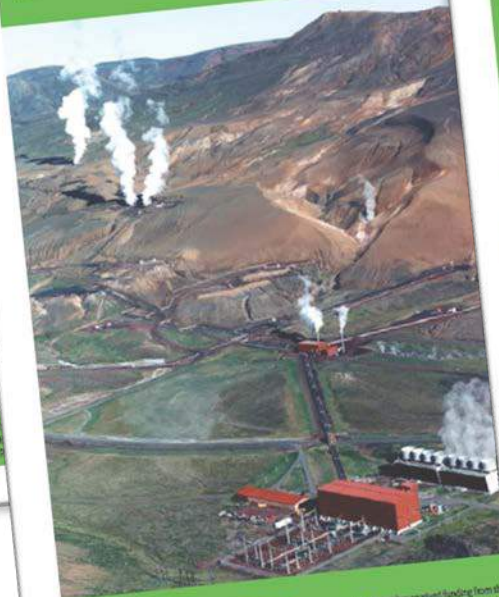


CHPM2030

# Report on Pilots

CHPM2030 Deliverable D6.2

Version: May 2019



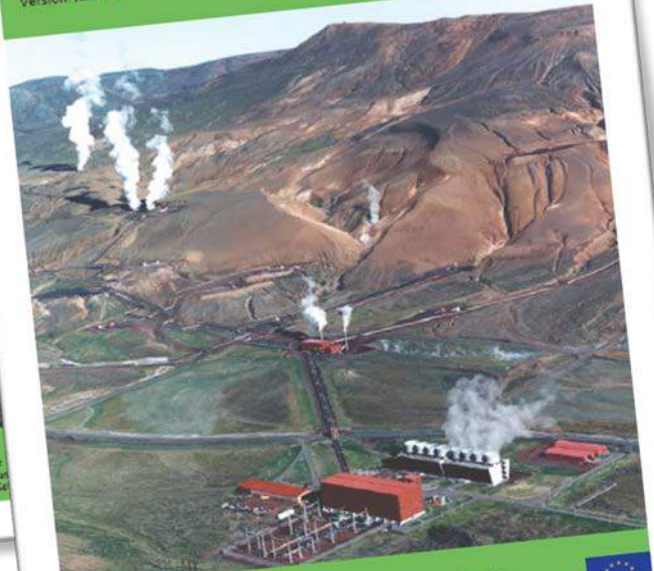
CHPM2030

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement n° 654103

# Roadmap for 2030 and 2050

CHPM2030 Deliverable D6.3

Version: June 2019



CHPM2030

This project has received funding from the European Union Horizon 2020 research and innovation programme under grant agreement n° 654103



# Conclusions

- CHPM2030 was a low TRL project, promising a proof of concept on lab scale.
- Some technology components were developed on lab scale, while other elements are readily available full scale.
- Parallel activities of technology development and a whole system dynamic modelling are special features of the project.
- Full loop concept was not achieved during the project implementation phase (was not even the purpose).



Thank you for your attention!

[www.chpm2030.eu](http://www.chpm2030.eu)

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