“Workshop Prospects for the Implementation of CCUS Technologies

in Greece and SE Europe”

Identification and assessment of suitable geological underground formations in lignite and nearby areas in Greece for CCUS application

Yannis Bassias

Ινστιτούτο Ενέργειας Νοτιοανατολικής Ευρώπης (IENE)

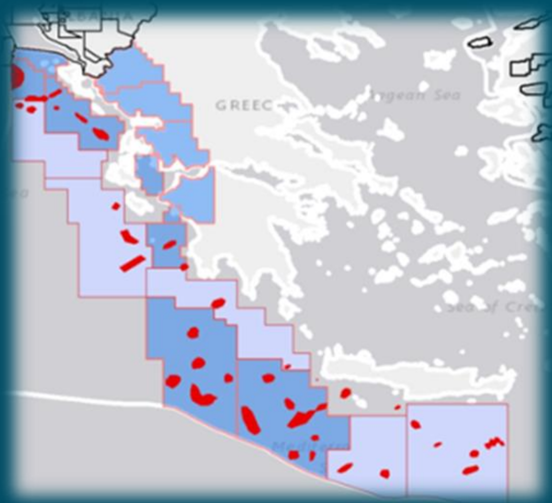
October 10, 2023

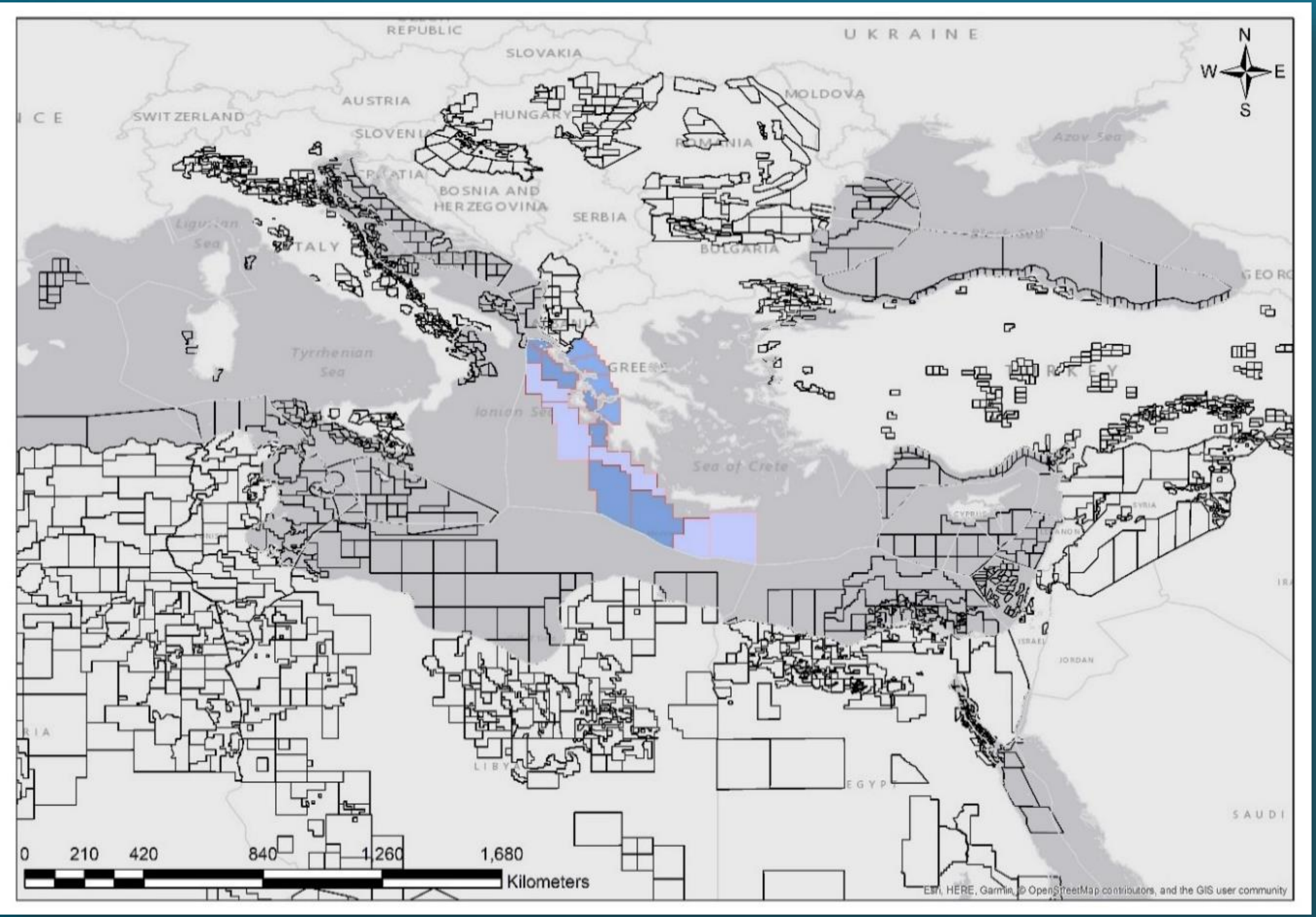
Once upon a time ....

we had a hope to produce gas and oil
and deal with the associated CO_2

in four ways

→ to inject,
→ to store
→ to recycle
→ to export





.... still believe it ?

Workflow of geological storage

Principals

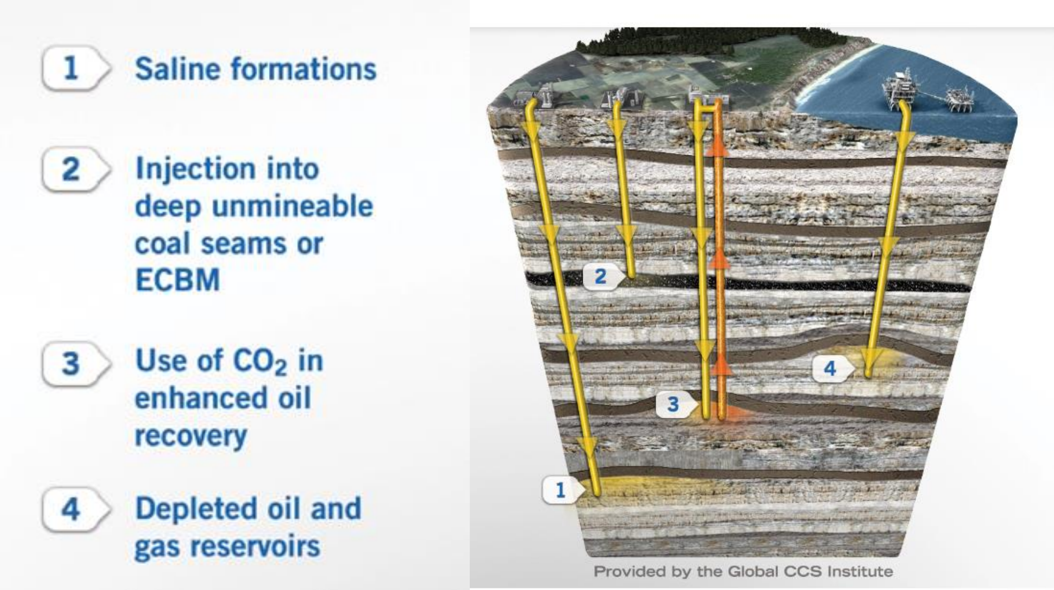
Mechanisms of underground storage

Mechanisms of *trapping*

Types of storage

Rock properties required

Pressure and temperature conditions required



Selection criteria for a subsurface storage complex

underground geological structure, the faults, and folds

stratigraphy, of the storage reservoir, of the caprock to identify possible *leakage* paths in the overlying layers

shallow formations associated with aquifers

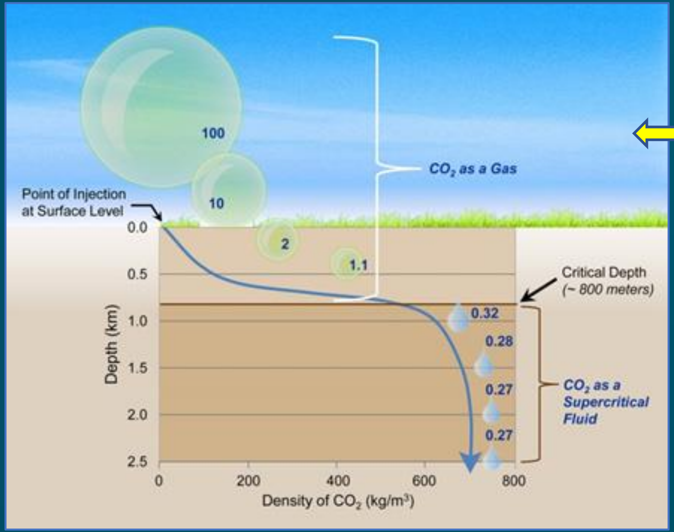
Acceptability of a site

Storage Resource

Injectivity

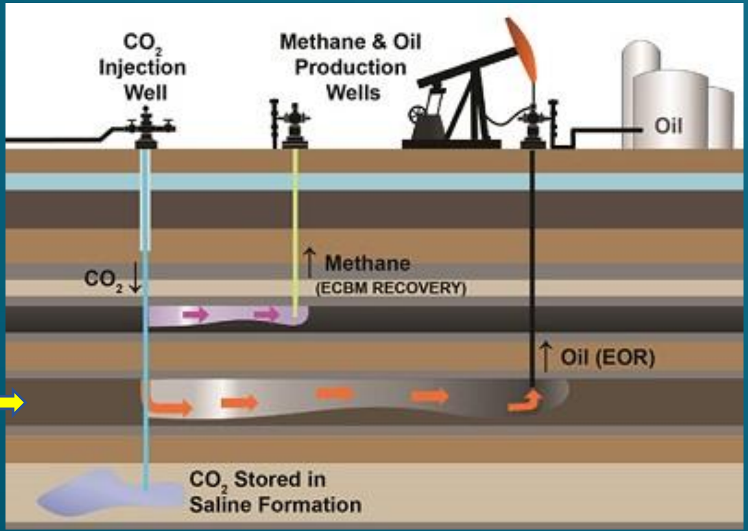
Integrity

Depth



The **Pressure Effect** on CO2 is a decision maker for the geological storage. The blue numbers show the volume of CO2 at each depth compared to a volume of 100% at the surface

EOR recovery process by which CO_2 is injected and used to drive the natural gas or oil towards a recovery well



It takes time

Selection criteria for a subsurface storage complex : ***2 and 5 years***

Assessment report : Follows the international and European legislation on the CO_2 geological storage

Operational phase : ***10 and 50 years***, includes the construction, preparation and injection

Final storage report : Once the geological model has been confirmed, the behavior of the storage complex understood , and there is no significant risk of CO_2 leakage, ***the site can be sealed***

Certification : A certificate should be issued by the competent authority ***confirming*** that the stored CO_2 ***will be safely held for hundreds of years***

The initial idea was … to contribute significantly to the economy of Western Macedonia with CO_2 subsurface storage

Provided that :

- the lignite was *not* phasing-out too *fast*
- *other products* would be produced before and after the lignite combustion
- production of *oil and gas* was to develop fast in Greece

But :

- the depth of the unmineable lignite sites in Ptolemais and Kozani are quite *shallow* to guarantee the supercritical conditions of CO_2 storage
- there was *no recognition* of the conclusions of the Academy of Science to produce **other products**
- the *low volumes* and the high **transportation cost** were critical since the CO_2 emissions account for only 60 Mt, while 10 Mt is probably already captured by the refining industry through the various chemical process lines.

Then we turned to other areas

The Mesohellenic Trough in Western Macedonia with storage plays at shallow depths and possible gas reservoirs at deeper parts of the trough

The West Thessaloniki large basin and the Epanomi field in Central Macedonia with geothermal wells and known discoveries of gas and CO2 fields respectively

Prinos and S. Kavala in Eastern Macedonia with a series of partially depleted oil and gas reservoirs

Florina in Western Macedonia, should serve as a useful case of CO2 natural leakage to the surface

Capacity of CO2 storage by location in Greece

Acceptability criteria	MESSOHELLENIC TROUGH	WEST THESSALONIKI	EPANOMI	SOUTH KAVALA	PRINOS
Storage resource	216-1435 (Mt)	640 (Mt)	2 (Mt)	35 (Mt)	
Injectivity	Good 15 % porosity	Low porosity Low permeability	Low porosity to tight		
Integrity	2 confining zones at depth	1200	1600		
Depth	2500	900-2400	2600	1600	1600

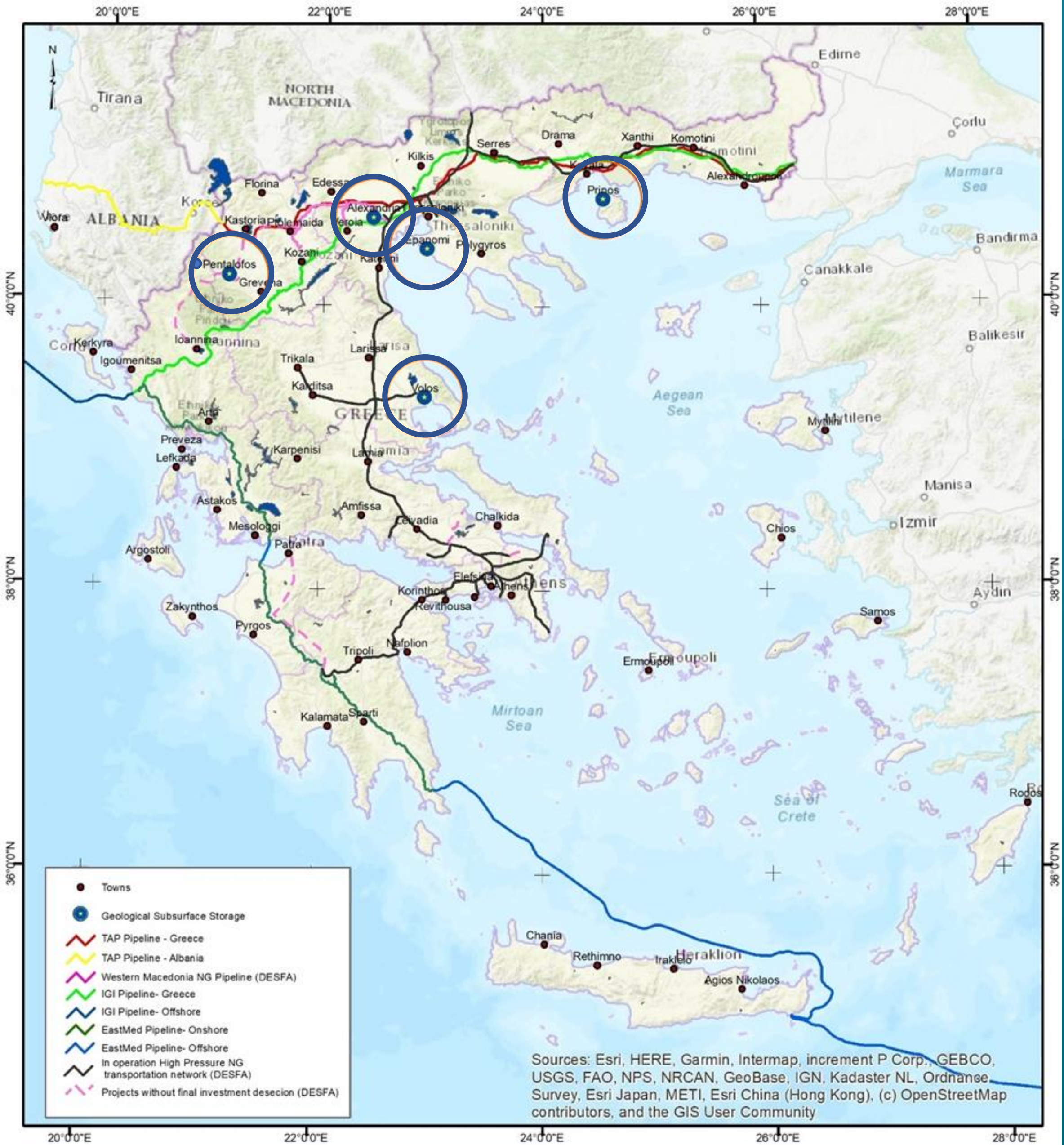
More than 10 years of Greek emissions

10 years of Greek emissions

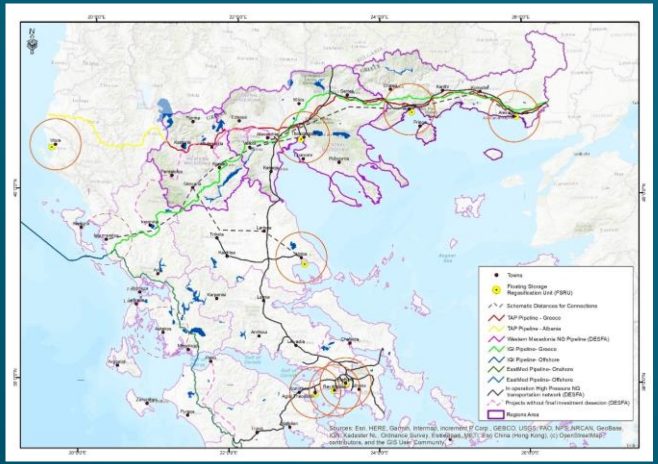
5 years of Greek emissions

GAS PIPES, PORTS, AND PLANNED FSRU FACILITIES

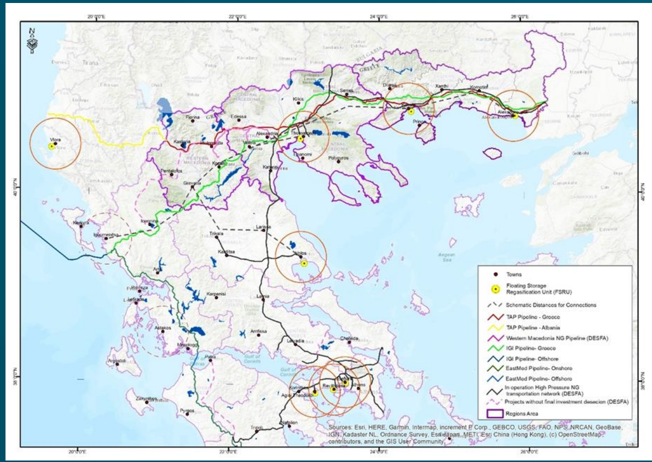
UNDERGROUND STORAGE LOCATIONS



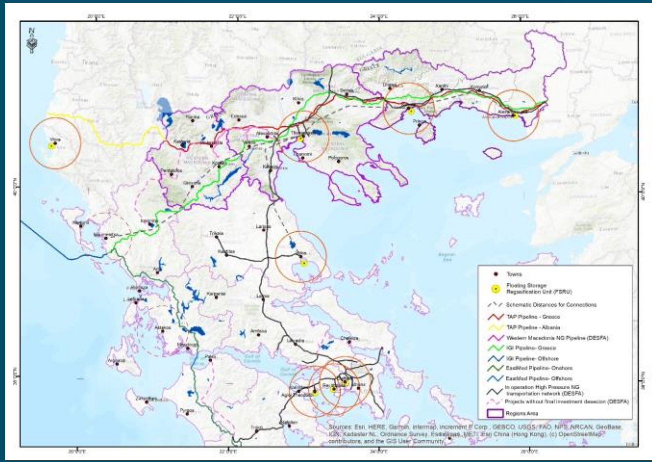
Grevena



Thessaloniki



Epanomi



Distance from port facilities (km)			Distance from industrial facilities (km)		
Grevena	Alexandroupolis	415	Grevena	Komotini power station	365
	Kavala	280		Prinos	300
	Volos	165		Volos National Gas Grid	165
	Thessaloniki	145		TAP close to Ptolemaida	65
	Igoumenitsa	125		Ptolemaida	60
				IGI close to Kozani	40
Thessaloniki	Igoumenitsa	275	Thessaloniki	Komotini power station	225
	Alexandroupolis	270		Volos National Gas Grid	180
	Volos	180		Prinos	160
	Kavala	135		Ptolemaida	130
				TAP close to Nea Magnisia	20
				IGI close to Nea Magnisia	20
Epanomi	Igoumenitsa	310	Epanomi	Komotini power station	250
	Alexandroupolis	295		Prinos	220
	Volos	220		TAP close to Nea Magnisia	180
	Kavala	160		IGI close to Nea Magnisia	165
				Ptolemaida	55
				Volos National Gas Grid	55

SOME FACTS

Fact 1 : The annual CO_2 release in Greece was 115 Mt in 2007 while in 2020 it was 60 Mt

Fact 2 : In 2019 the industry released 40.4 Mt

- 26 from lignite for electricity
- 5.4 from hydrocarbons
- 5.3 from cement factories
- 2.1 from metallurgy
- 1.6 from others uses

Fact 3 : Some industrial facilities do not need to store all emitted CO_2 because they convert part of it into other polymers and products with higher economic value (e.g. plastics, concrete, biofuels) while reducing the carbon tax.

Fact 4 : Investment scenarios must play between 10 and 40 years

Cost of CO2 storage

The cost of CO2 storage after initial studies, seismic and drilling, according to IEAGHG varies around 14.3 euros per ton. The main are :

- Injection 3 euros
- pre-feed 6 euros
- operating cost 2.5 euros
- close down of the storage site 1 euro
- *(transport scenarios, pipe, track or vessel are not included)*

- Annual CO2 emissions in Greece : 2020 60 million tons
  2007 115 million tons
- Estimated 60 Mt emissions in Greece represent 858 million euros (60 Mt * 14.3 million euros)
- Tax on carbon represents 6 billion euros, a multiple of 7.
- Transport cost is unknown and not included

and Europe ?

Overview of existing and planned CO_2 storage projects in Europe

BULGARIA
1. ANRAV [IF]

CROATIA
1. Petrokemija Kutina*
2. Bio-Refinery Project*
3. CCGeo [IF]
4. **CO_2 EOR Project Croatia***

DENMARK
1. **Greensand***
2. Bifrost*
3. Stenlille demo CO_2-storage
4. Norne
5. Ruby

FRANCE
1. Pycasso*

Combined with oil production →

GREECE
1. Prinos CCS

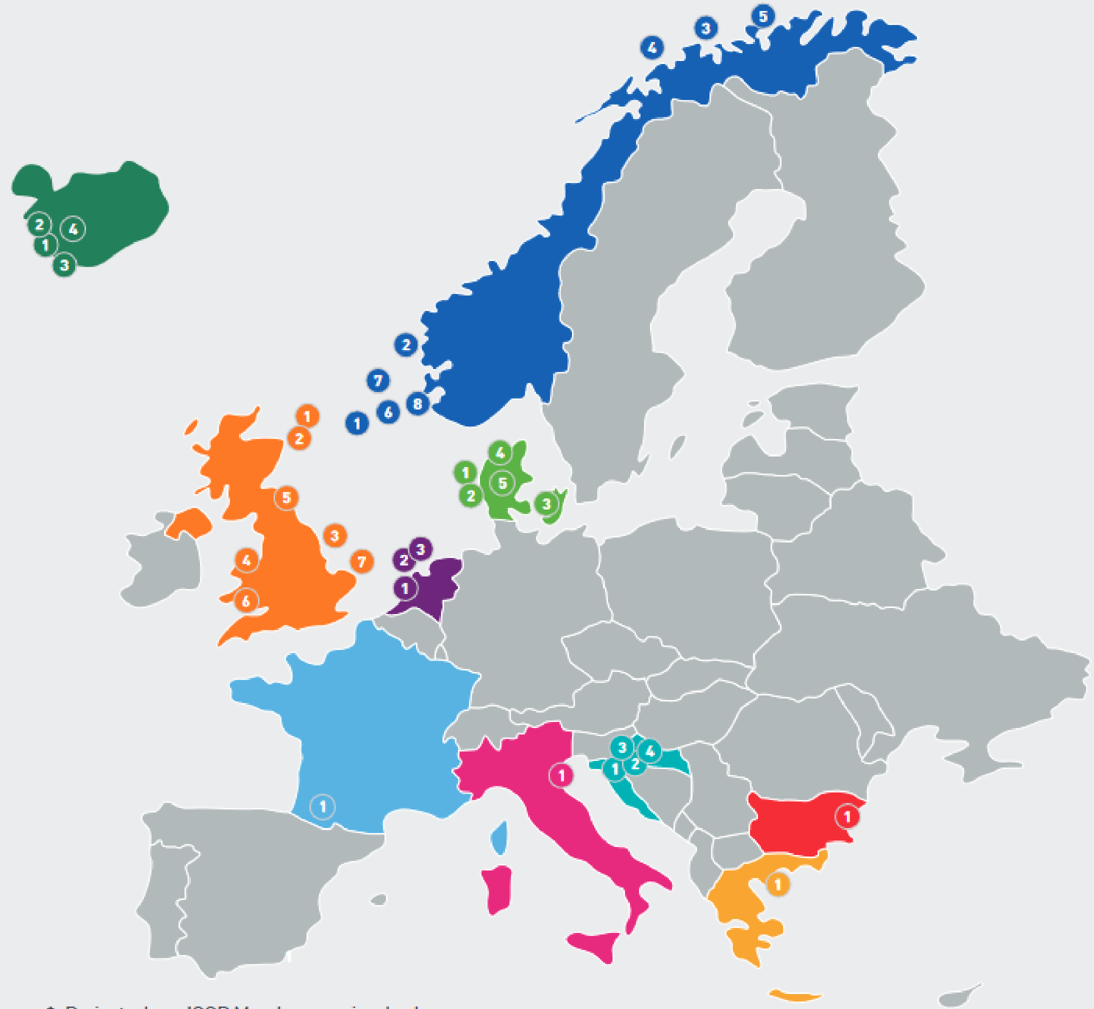
ICELAND
1. **Orca**
2. **Silverstone** [IF]
3. Coda Terminal [IF]
4. Mammoth

ITALY
1. Ravenna CCS*

THE NETHERLANDS
1. Porthos* [PCI]
2. Aramis* [PCI]
3. L10 CCS*

NORWAY
1. **Sleipner***
2. Longship (includes Northern Lights)* [PCI]
3. Barents Blue
4. **Snøhvit***
5. Smeaheia*
6. Trudvang*
7. Luna*
8. Havstjerne*

UK
1. Acorn*
2. Caledonia Clean Energy
3. Zero Carbon Humber*
4. HyNet*
5. Net Zero Teesside*
6. South Wales Industrial Cluster
7. Bacton Thames Net Zero initiative*

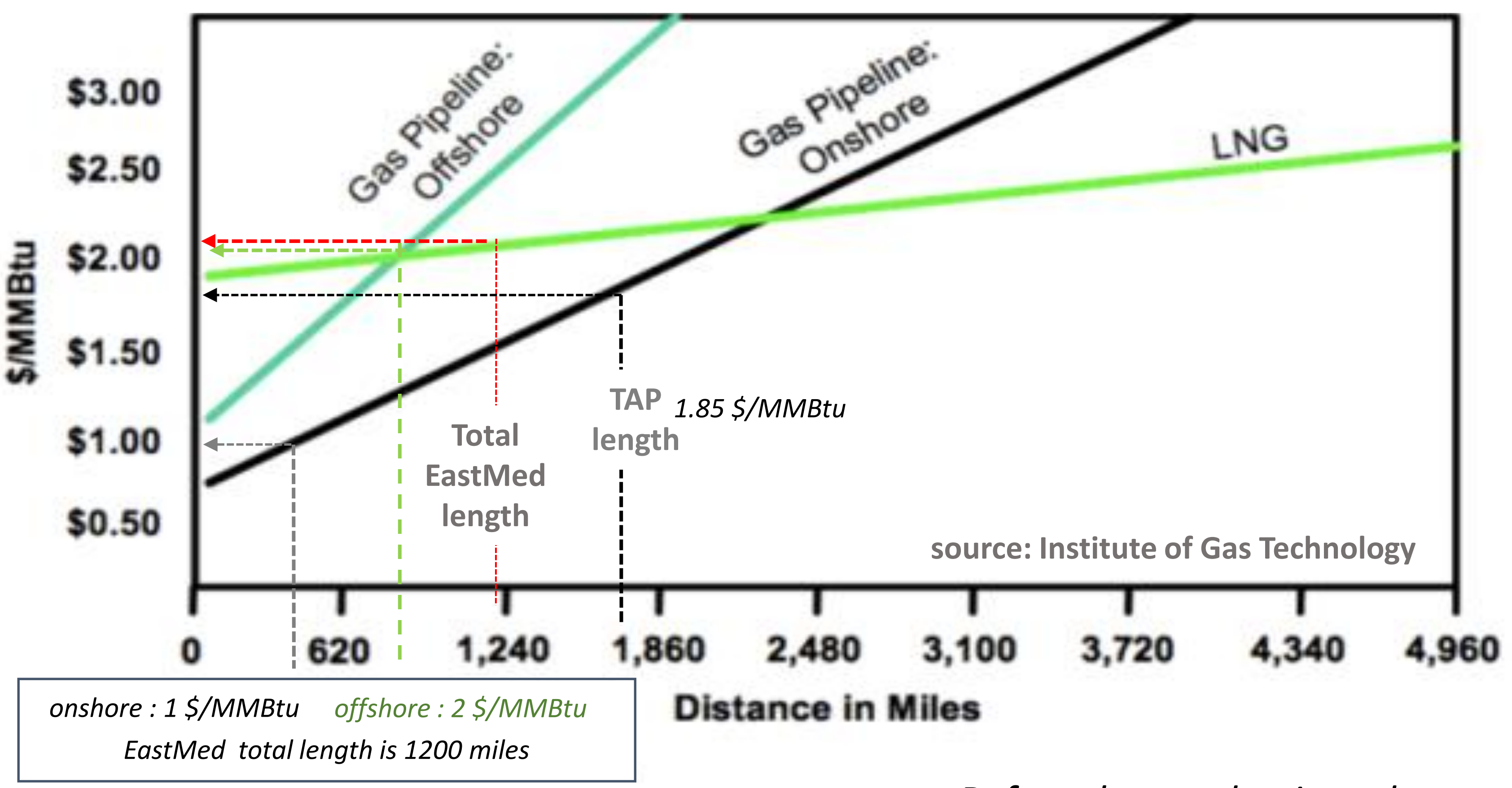


* Project where IOGP Members are involved
Projects listed in **bold** are in operation
[PCI] – Project of Common Interest
[IF] – Project supported by the EU Innovation Fund

EU	**16 projects** - 35 $MtCO_2/yr$ by 2030
Europe	**35 projects** - 105 $MtCO_2/yr$ by 2030

Gas transport economics are known …. Not of CO_2 and H_2

It will be difficult to figure out which side these correlations will tilt with CO_2 or H_2 transportation cost after some years of practical experience



Before the pandemic and war

CONCLUSIONS

It seems that benefits for Macedonia can come if there is a combination of three projects

1. presence of methane and its possible exploitation
2. underground storage geometries to store thermogenic gases
3. creation of a commercial transit pole to the Balkans and Italy