Water Production associated to CO_2 injection into a saline aquifer

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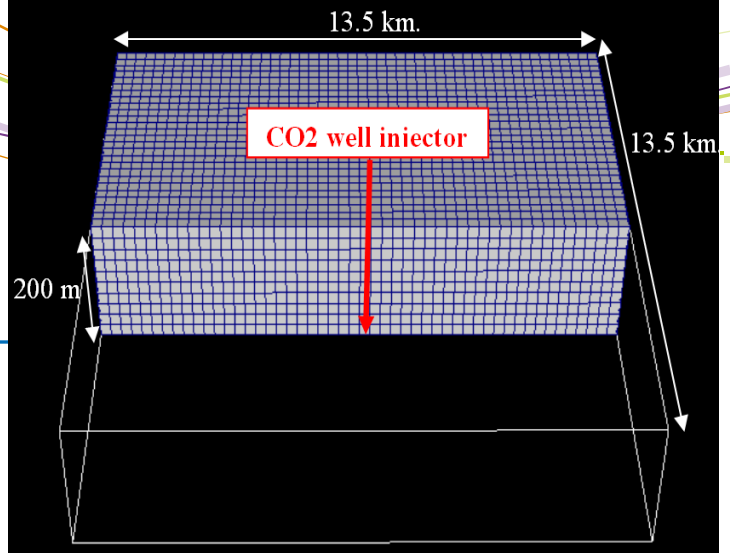
Overview

- Model setup and parameters
- Overpressure and CO_2 Storage Capacity Management
  - Stopping CO2 injection
  - Resident brine production
- Water Production Management
  - Desalination of the resident water production
  - Residual concentrated brine reinjection
- Economical aspects
- Final Conclusions

Model set up

Parameters and Conditions	Average Value
Porosity [%]	20
Permeability [mD]	200
Anisotropy ratio	0.1
Thickness [m]	200
Initial reservoir temperature Thickness [°C]	70
Initial reservoir pressure Thickness [bar]	100 at 1000m
Rock compressibility Thickness [1/bar]	4.35E-5
Irreducible water saturation [%]	15
Critical gas saturation [%]	5
Maximum water relative permeability	0.9
Maximum gas relative permeability	0.55
Salinity [g/l]	50



- Grid

	x	y	z
Number	50	50	10
Length (m)	250	250	20

- Boundaries
  - No flow conditions for every one.
  - No heat and fluid exchange with the upper and lower layers

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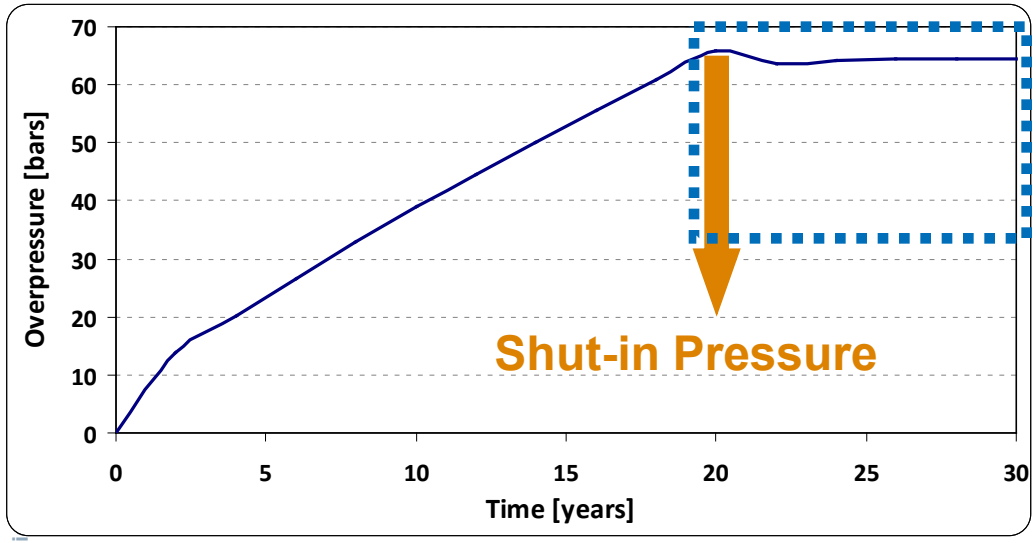
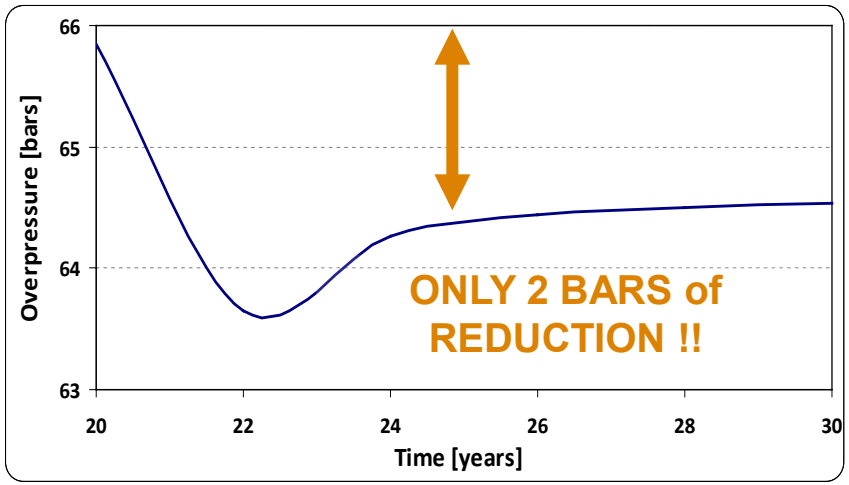
Solution 1: Stopping CO_2 injection

- Conditions
  - 1 Mt/y CO_2 during 20 years
  - Overpressure evolution during 10 years

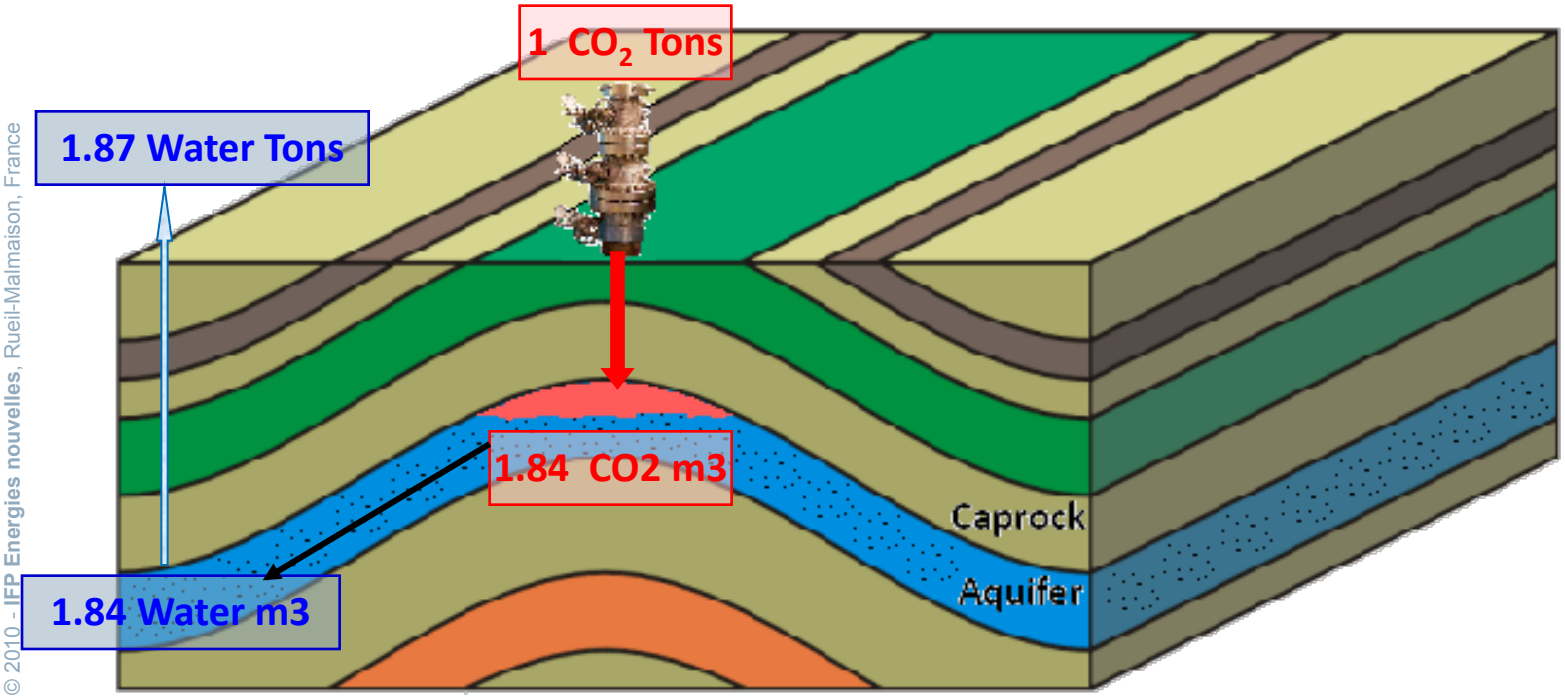




Solution 2: Water production

Idea: Avoiding overpressure

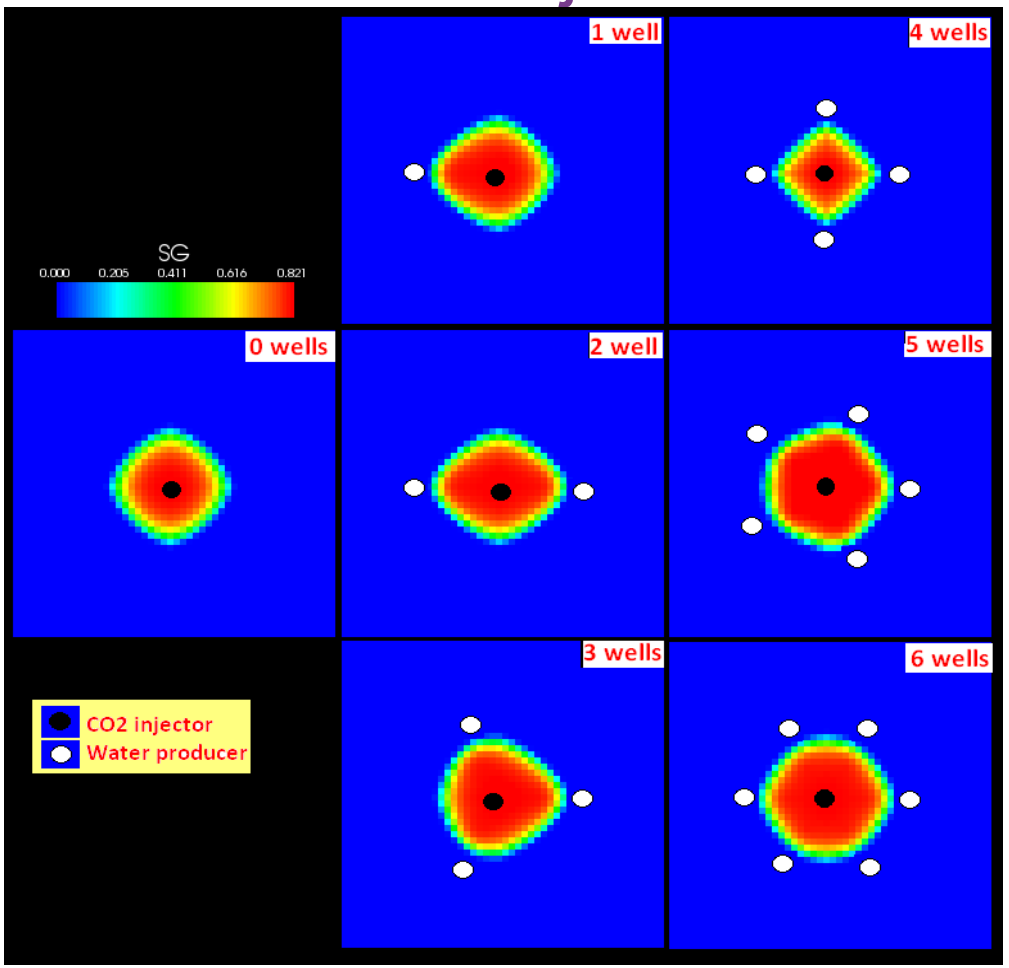
Reservoir pressure	138.5 bars
Reservoir temperature	70 °c
Rho Water – res. conditions	1.02 g/cm3
Rho Gaz – res. conditions	0.543 g/cm3



Solution 2: Water production

Overpressure decrease – constant injection rate

- Simulation parameters
  - 1500 m Injector-producers
  - 1 Mt/y CO_2 during 30 years
  - BHFP producers 100/72bars
  - Case 1 to 6 wells



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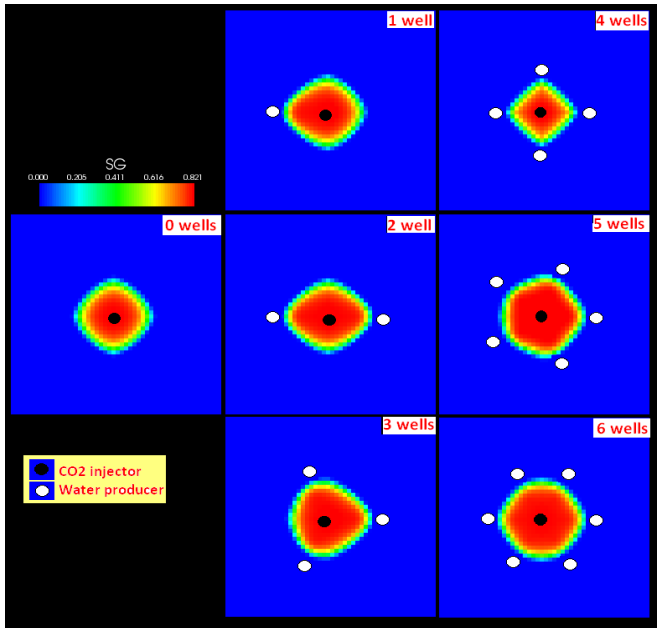
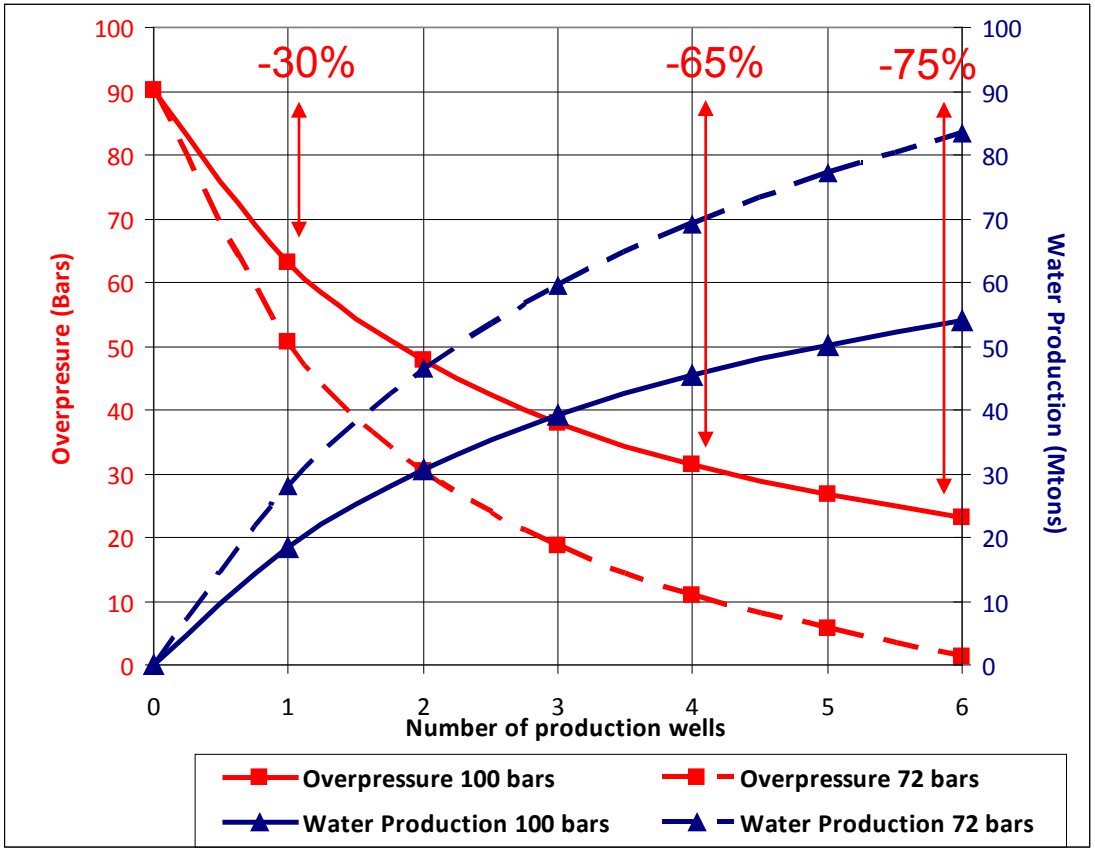
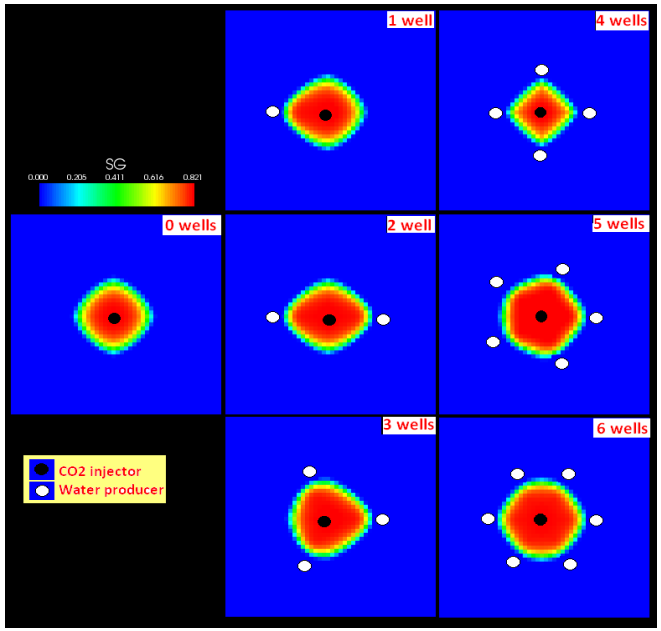


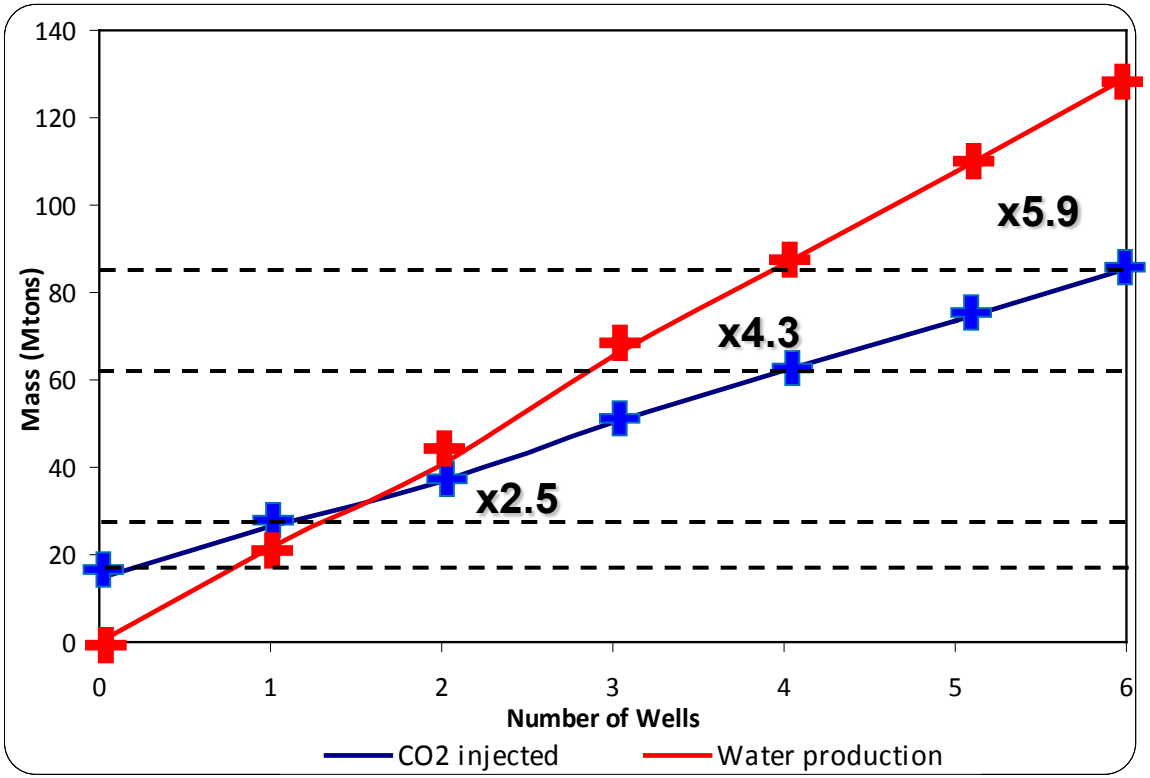


Solution 2: Water production

CO2 storage capacity increase – constant injection pressure

- Simulation parameters
  - 1500 m Injector-producers
  - 50 bars overpressure allowed
  - BHFP producers 100 bars
  - Case 1 to 6 wells





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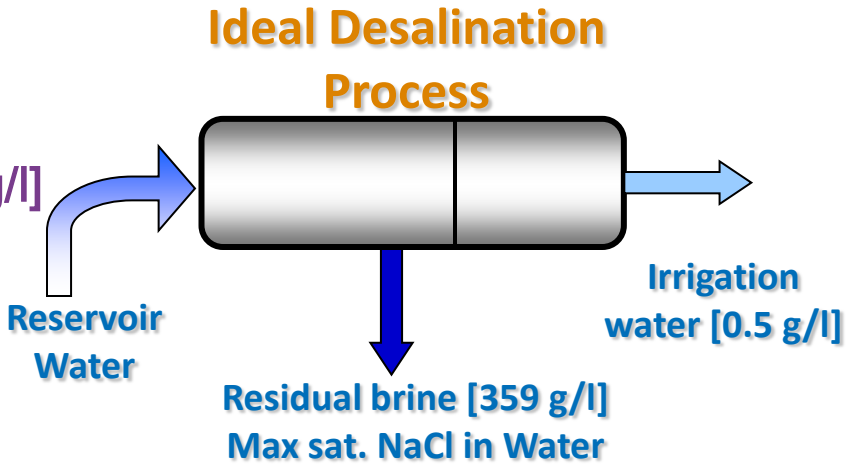
Desalination of the resident water production

- Technologies
  - Reverse Osmosis (47%) [40-50 g/l]
  - Multi-stage Distillation (37%) [> 50 g/l]
  - Nanofiltration (16%)



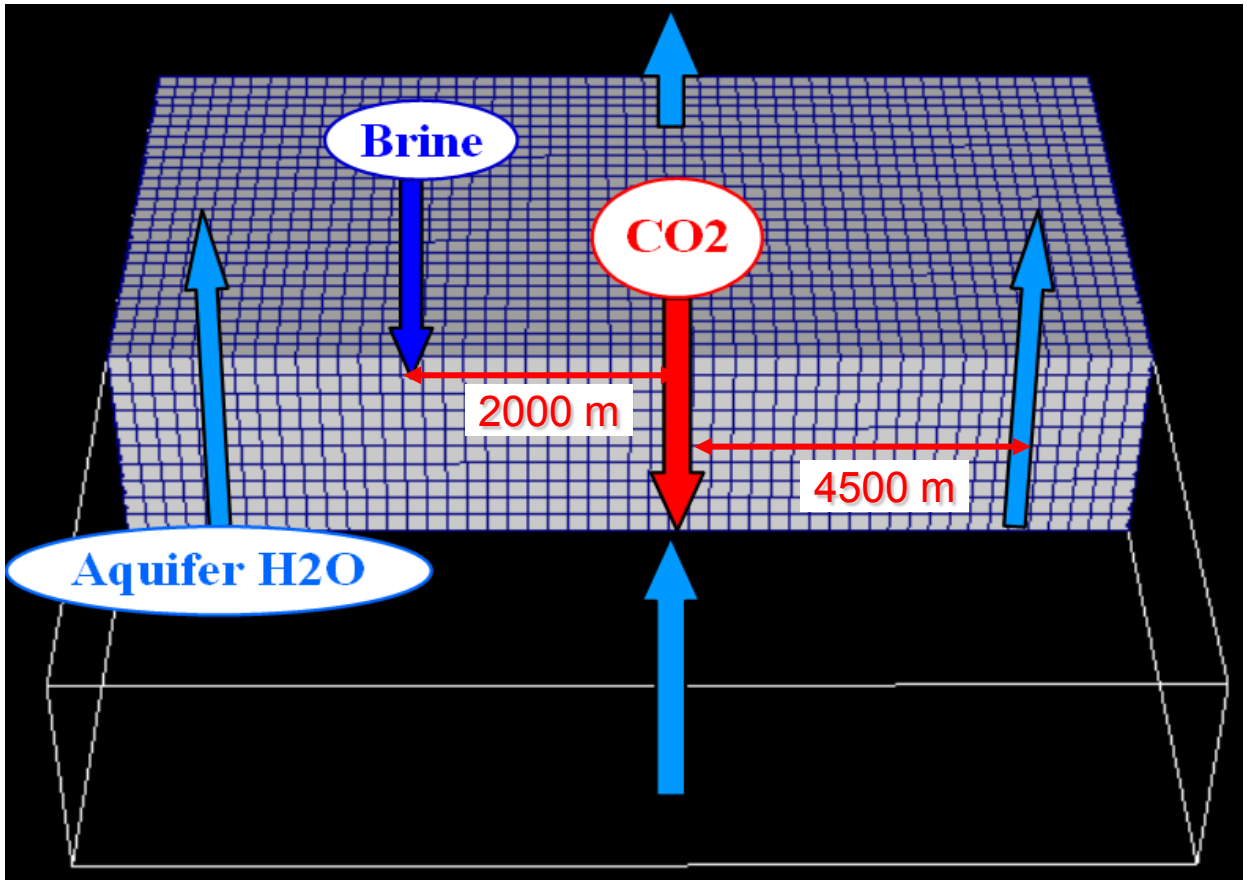
- Always residual concentrated brine
  - Reject to the sea
    - Take into account the local policies
  - Reinjection in geological formation

Reservoir salinity [g/l]	Resid. brine Re-injected Mass [%]	Irrigation water Mass [%]
35	12	88
50	17	83
89	30	70
120	40	60
150	49	51
170	55	45
200	62	38

Residual concentrated brine reinjection

Simulation

- Model



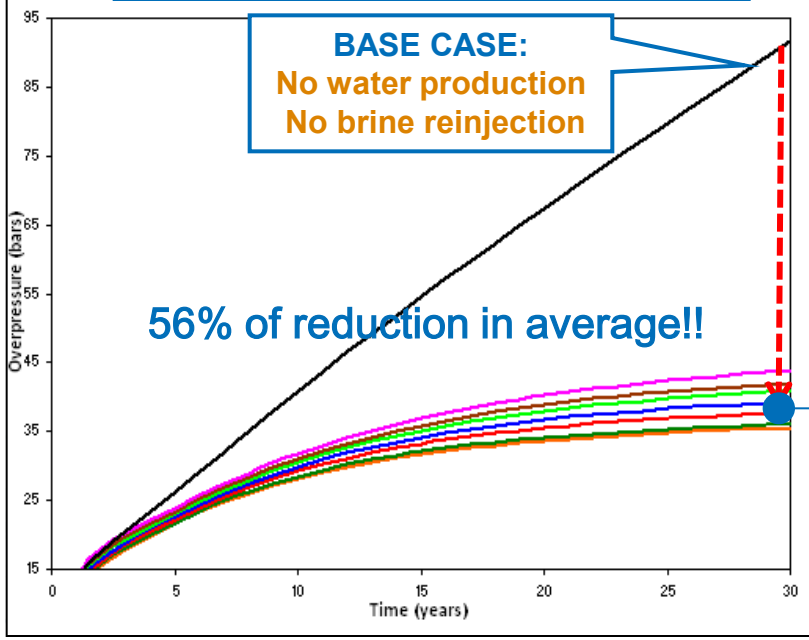
Residual concentrated brine reinjection

Simulation

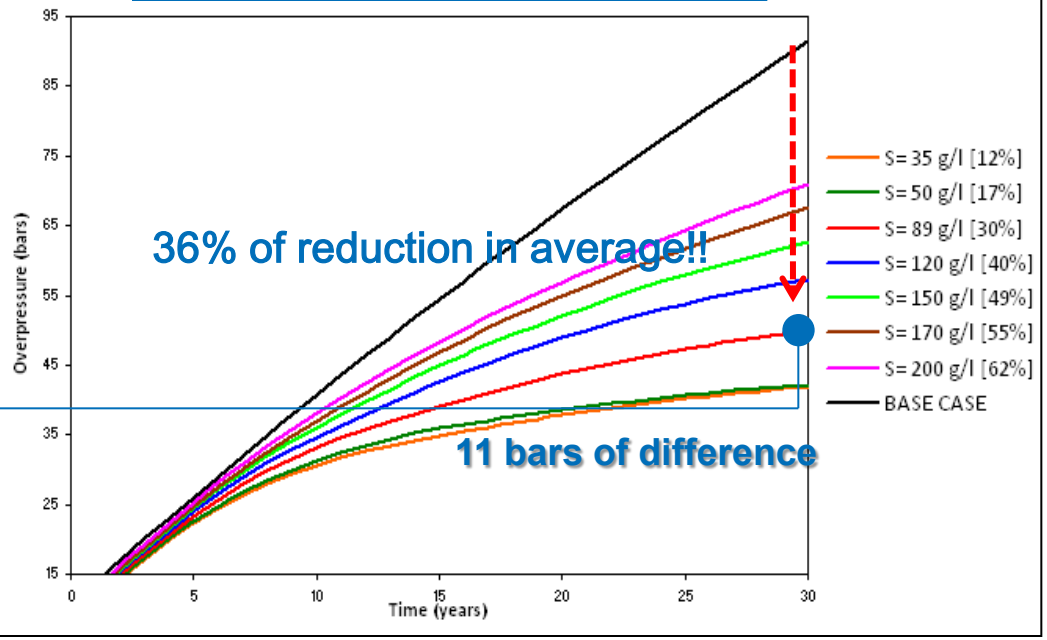
➡ **Both scenarios have the same water production history**

- **OK** Reinjection scenario
  - 5 spot model
  - 1 Mt/y CO_2
  - 30 y simulation

NO Reinjection scenario



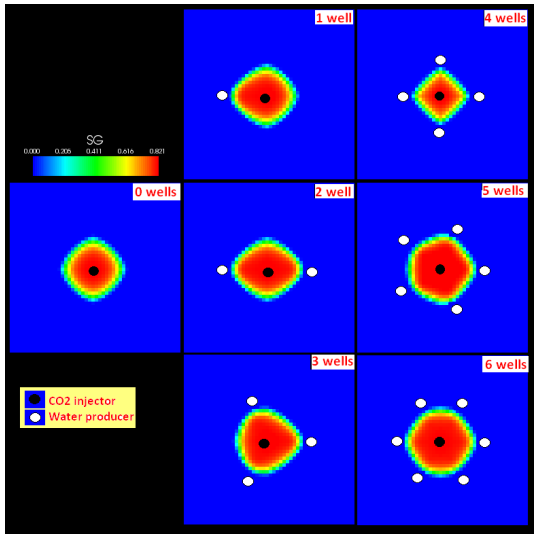
OK Reinjection scenario

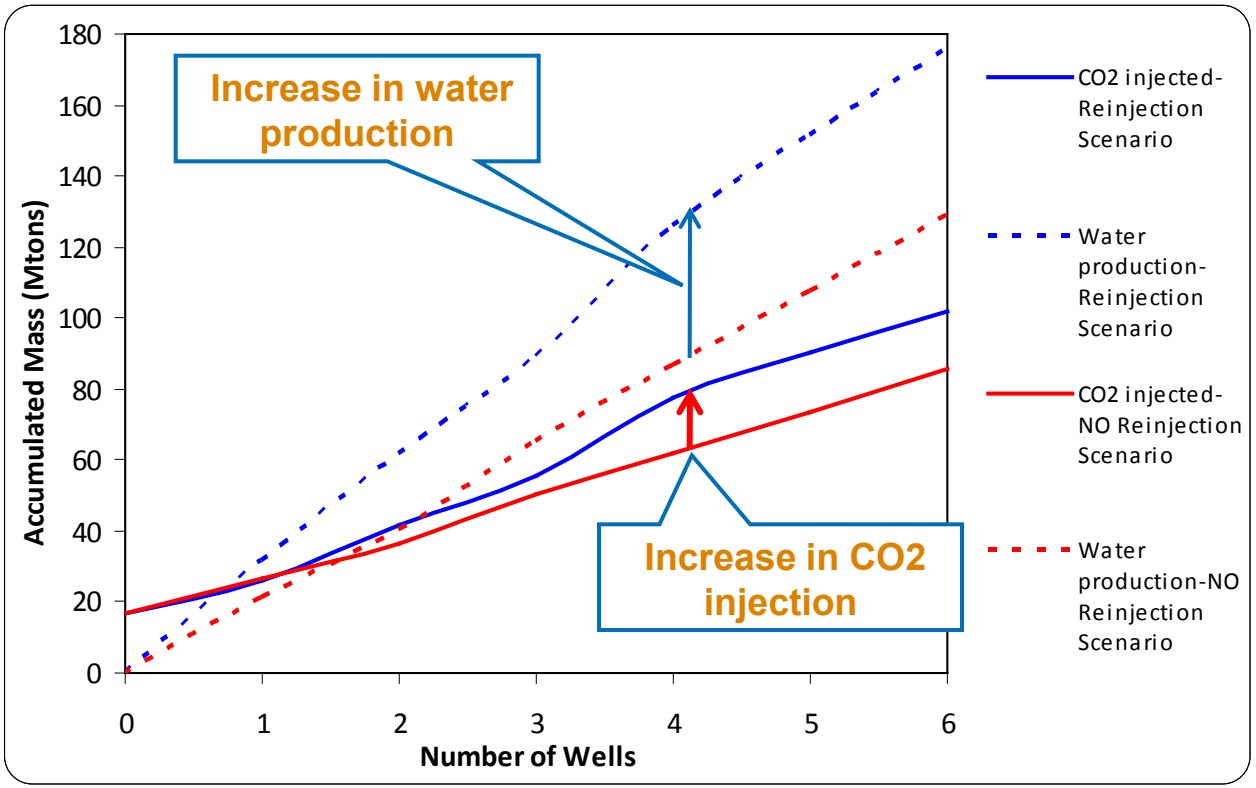


Residual concentrated brine reinjection

Simulation

- CO2 capacity for NO reinjection and OK reinjection Scenario
  - Maximum Overpressure allowed is 50 bars





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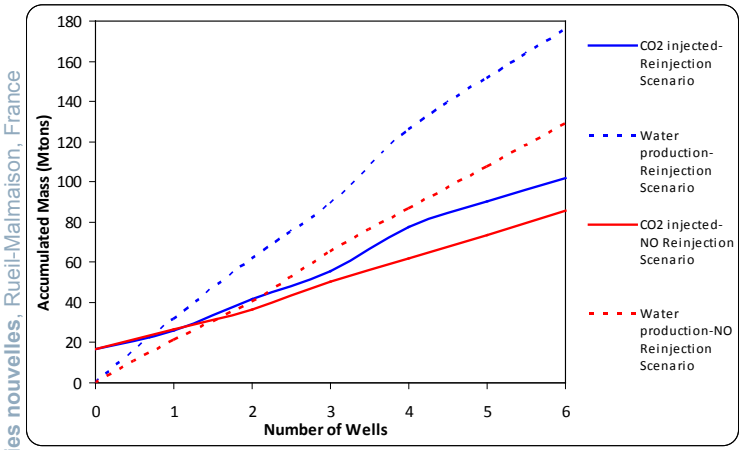

	NO Reinjection Scenario	OK Reinjection Scenario
Number of wells	Comparison with zero wells case (CO2 injected mass)	Comparison with zero wells case (CO2 injected mass)
0	1,00	1,00
1	1,82	1,55
2	2,53	2,45
3	3,49	3,27
4	4,30	4,57
5	5,09	5,32
6	5,91	5,98

5 spot configuration

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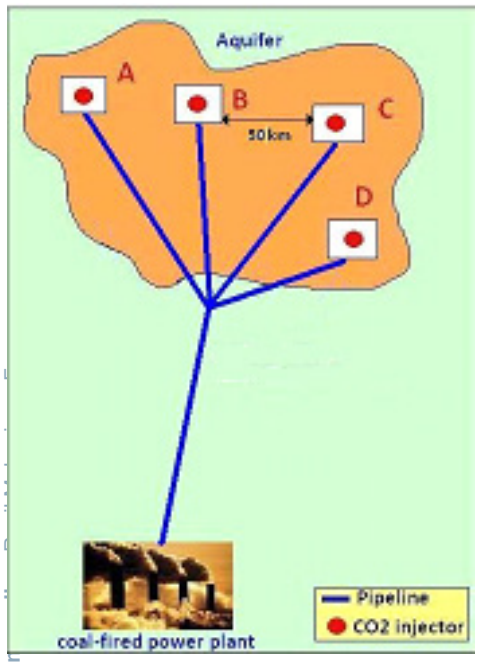
Scenarios 100Mt CO_2 injected

Passive Management

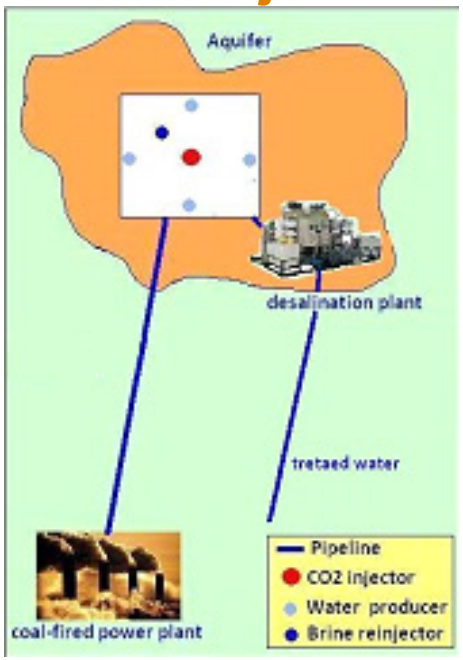


300 km pipe (100 km + 4x50km)

4 sites: 4 CO_2 injection wells

need rig move

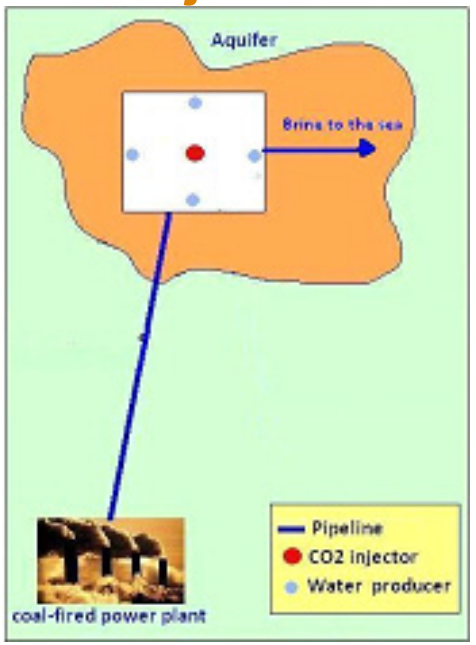
Active Management "brine reinjection"



200 km pipe (100 km + 100km)

1 site :1 CO_2 injection well
4 prod. well
1 Wat prod. well

Active Management "brine rejected to sea"



150 km pipe (100 km + 50km)

1 site :1 CO_2 injection well

4 prod. well

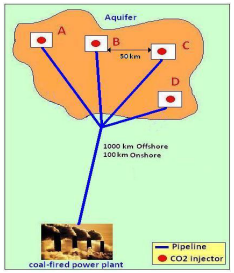
ONSHORE Economical Analysis

PCRM Scenario 4 CO2 injector

Expenses (M€)		(€/ton)
CO2 Capture	4000.0	40.0
Onshore transport	*318.0*	*3.2*
Offshore transport	*0.0*	*0.0*
Transport	318.0	3.2
Caracterisation cost	*40.8*	*0.4*
Drilling cost	*9.7*	*0.1*
Monitoring cost	*196.0*	*2.0*
CO2 Storage	246.5	2.5
Water Desalination Cost - primary treatment	0	0
Water treatement Cost - secondary treatment	0	0
total expenses including industrial water	4564.5	45.6
total expenses including drinkable water	4564.5	45.6

Revenues (M€)		(€/ton)
CO2 avoided	3000.0	30.0
Industrial Water Revenue	0.0	0.0
drinkable Water Revenue	0.0	0.0
total revenues including industrial water	3000.0	30.0
total revenues including drinkable water	3000.0	30.0

CO2 Capture + Transport + Storage Balance	(M€)	(€/ton)
Total cost	4564.5	**45.6**
Cost - Total revenues (CO2+industrial Water)	1564.5	**15.6**
Cost - Total revenues (CO2+drinkable Water)	1564.5	**15.6**

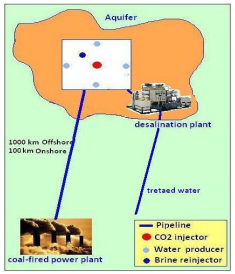


ACRM Scenario (Brine reinjection)

Expenses (M€)		(€/ton)
CO2 Capture	4000.0	40.0
Onshore transport	*212.0*	*2.1*
Offshore transport	*0.0*	*0.0*
Transport	212.0	2.1
Caracterisation cost	*10.2*	*0.1*
Drilling cost	*11.5*	*0.1*
Monitoring cost	*49.0*	*0.5*
CO2 Storage	70.7	0.7
Water Desalination Cost - primary treatment	126	1.3
Water treatement Cost - secondary treatment	239.4	2.4
total expenses including industrial water	4408.7	44.1
total expenses including drinkable water	4648.1	46.5

Revenues (M€)		(€/ton)
CO2 avoided	3000.0	30.0
Industrial Water Revenue	55.9	0.6
drinkable Water Revenue	503.1	5.0
total revenues including industrial water	3055.9	30.6
total revenues including drinkable water	3503.1	35.0

CO2 Capture + Transport + Storage Balance	(M€)	(€/ton)
Total cost	4648.1	**46.5**
Cost - Total revenues (CO2+industrial Water)	1592.2	**15.9**
Cost - Total revenues (CO2+drinkable Water)	1145.0	**11.5**

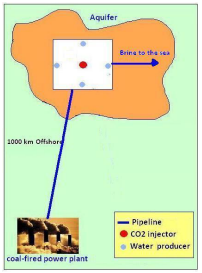


ACRM Scenario (Rejecting water to the sea)

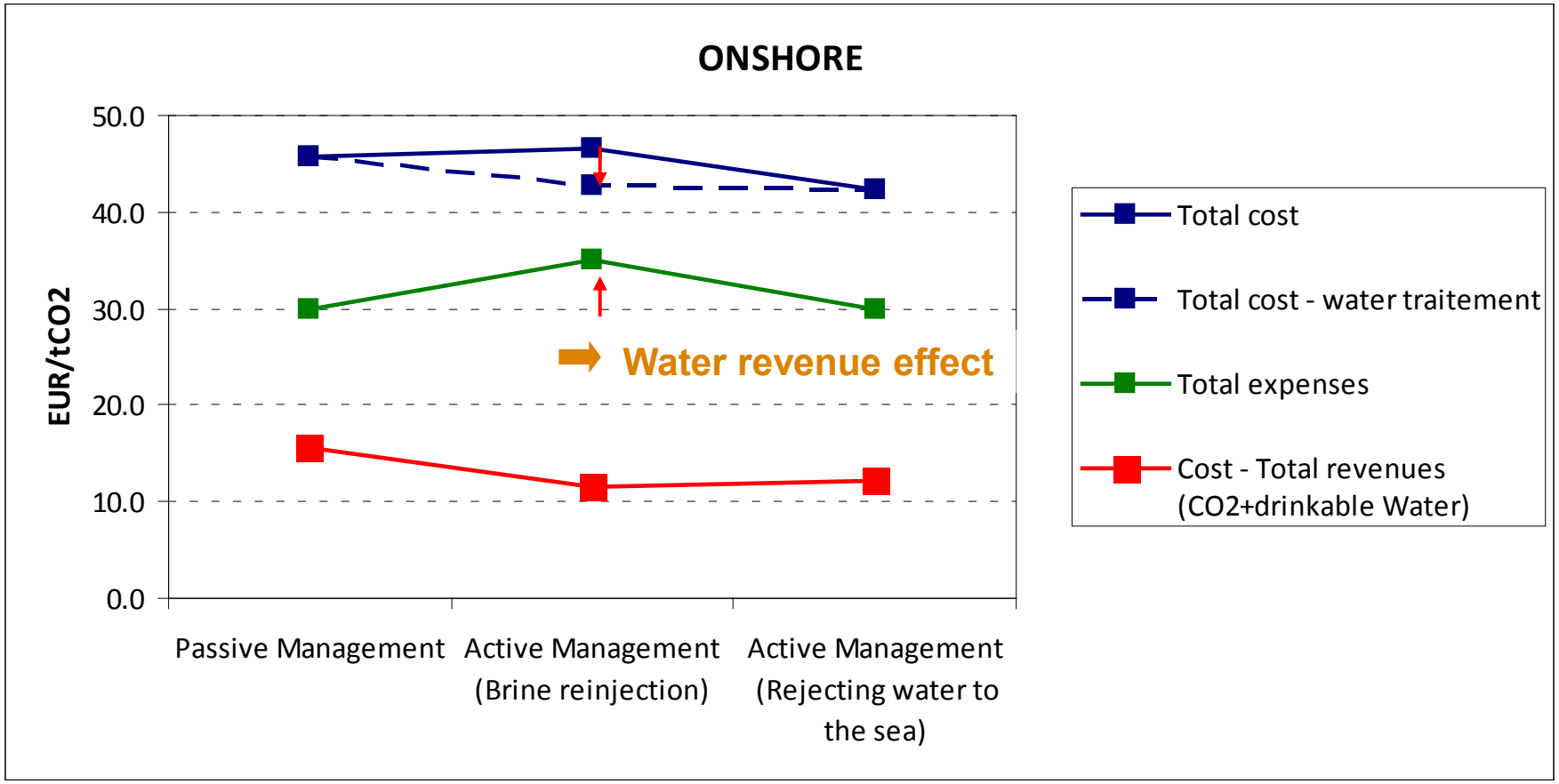
Expenses (M€)		(€/ton)
CO2 Capture	4000.0	40.0
Onshore transport	*159.0*	*1.6*
Offshore transport	*0.0*	*0.0*
Transport	159.0	1.6
Caracterisation cost	*10.2*	*0.1*
Drilling cost	*9.7*	*0.1*
Monitoring cost	*49.0*	*0.5*
CO2 Storage	68.9	0.7
Water Desalination Cost - primary treatment	0	0.0
Water treatement Cost - secondary treatment	0	0.0
total expenses including industrial water	4227.9	42.3
total expenses including drinkable water	4227.9	42.3

Revenues (M€)		(€/ton)
CO2 avoided	3000.0	30.0
Industrial Water Revenue	0.0	0.0
drinkable Water Revenue	0.0	0.0
total revenues including industrial water	3000.0	30.0
total revenues including drinkable water	3000.0	30.0

CO2 Capture + Transport + Storage Balance	(M€)	(€/ton)
Total cost	4227.9	**42.3**
Cost - Total revenues (CO2+industrial Water)	1227.9	**12.3**
Cost - Total revenues (CO2+drinkable Water)	1227.9	**12.3**



Economical Analysis – Summarize Onshore



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Final conclusions

- Water production decreases largely reservoir overpressure
- Water production increases largely CO_2 storage capacity
- Effects in overpressure and storage capacity from brine reinjection are not considerable
- Active reservoir management could be economically feasible, comparing with passive management.

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