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Engineering for CO_2 geological storage

Robustness of BioCCS for GHG abatement and economic sustainability: A case study from the CPER Artenay project

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BioCCS workshop- 14/10/2010

Presentation outline

Can BCCS generate a profitable CO_2 sink?

- The Case Study
- Designing the CCS Chain
- Carbon and Energy Footprint Analysis
- Profitability
- Conclusions/recommendations

BioCCS Context

- Limited visibility on sugar beet price UE guarantees
- Doubts over UE support for sugar producers
- UE pressure on CO_2 emitters

BUT

- Ambitious European objectives for Bio Ethanol production in 2020
- Part of the CO_2 from Bio Ethanol production is pure

→*Carbon management as a new development pathway?*

Study objectives

Objectives

Pre dimensioning and testing

→ Rough designed and sensitivity on main assumptions

Dimensioning of an optimized case

Phase 1 — **Phase 2**

Beginning 2009 — **End 2010**

Tasks performed

- Process design
- Carbon & Energy footprint (CEF)
- Economics
- Geological study

- Process optimization
- Carbon & Energy footprint update
- Economics update

→Study based upon real data

Presentation of the Plant

Artenay Sugar Beet Refinery
(near Orleans, France)

Sugar Beet Processing

Sugar Production | Bio-Ethanol Fermentation | Natural Gas-Fired Boiler

CCS In 2015

Produces sugar and bio-ethanol

Uses NG-fired cogeneration energy

Current fermentation exhaust stream about 85% CO_2 → 100% purity assumptions
(as well as H_2O, O_2 and N_2)

Roughly 0.6 M hl (60 000 m³) of bio-ethanol per year resulting in 106,000 tons of CO_2

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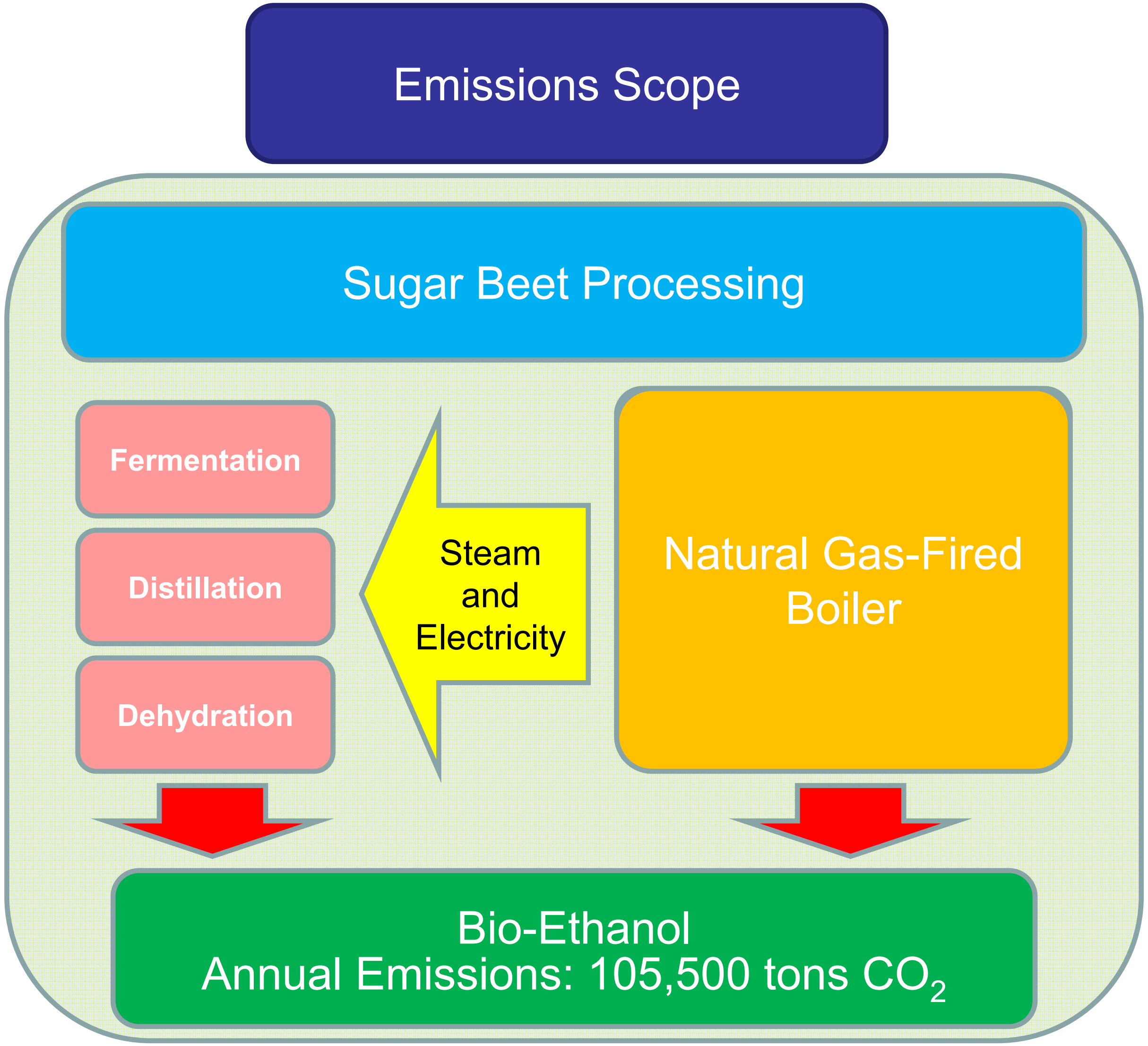
Study Assumptions

NG-Powered Process

Requires Capture
(8% CO_2 – exhaust stream mostly nitrogen)

60,500 tons CO_2 captured from cogeneration

45,000 tons pure CO_2 from fermentation



Design of the Compression Unit

Capture and Compression

NG boiler capture Technical Specs:

Post-combustion

Amine-based (MEA) process

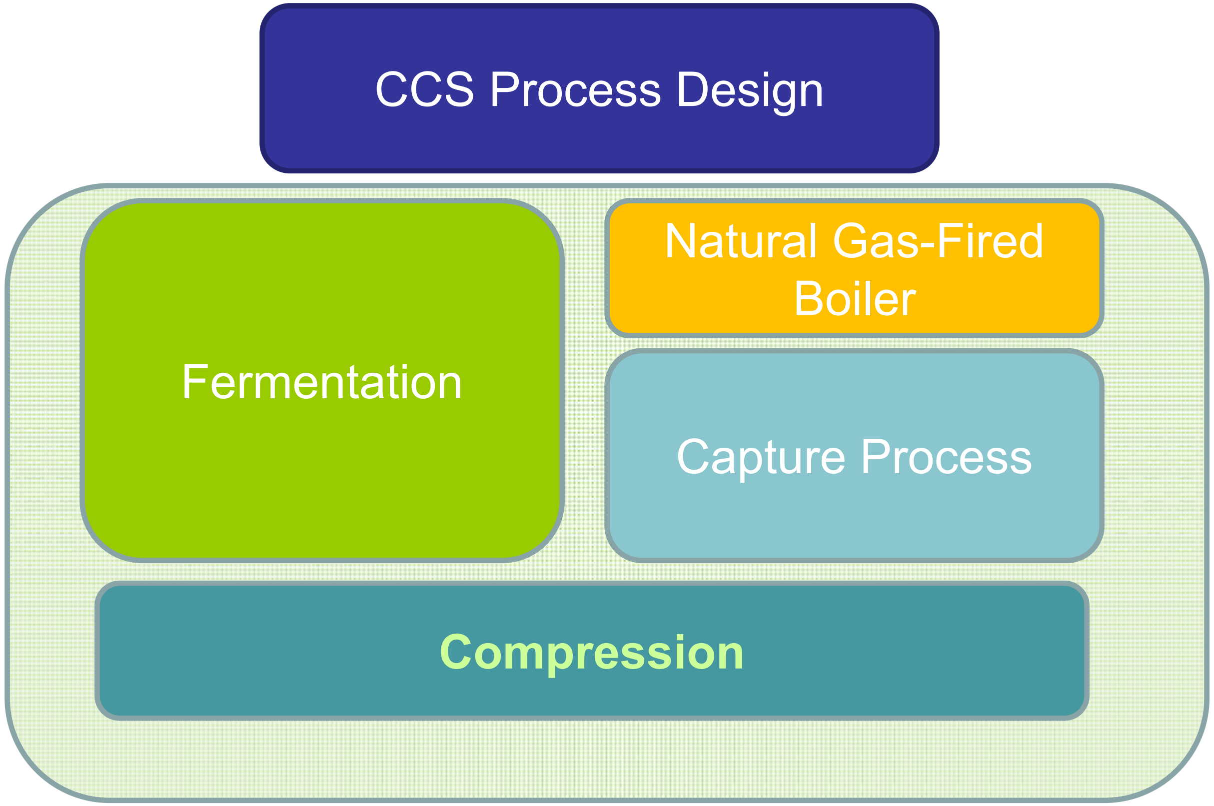
Assumed capture rate of 90%

Costs assumed to decrease due to technology improvements

Compression Technical Specs:

The gas is pressurized to >80 bar before transport

Slightly higher than critical pressure



Transport Scenario Design

Transport

Technical Specs:

CO_2 is transported in dense phase

Maximum pressure at inlet: 150bar

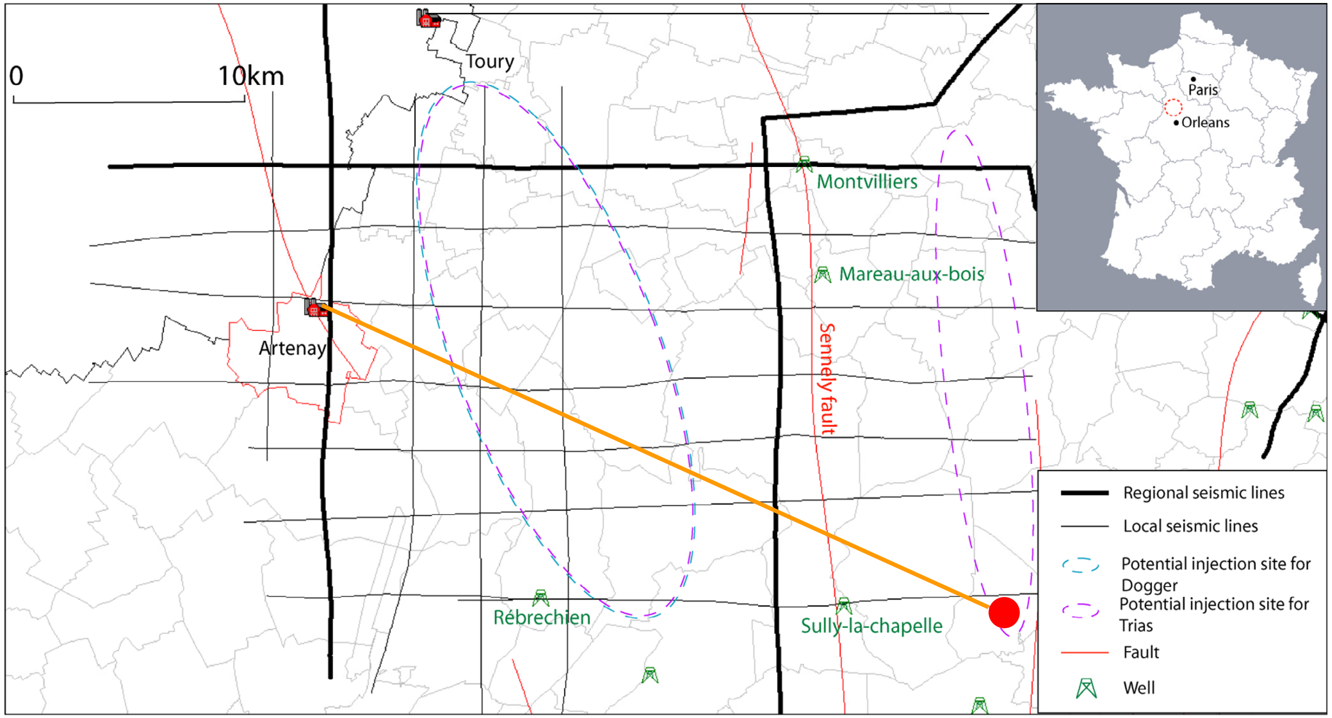
Roughly 30 km 4-inch diameter pipeline

No elevation differentials or obstacles

No intermediate pumping stations

Pipeline outlet pressure equals injection pressure at wellhead

Pipeline designed to accommodate maximum flow



Transport route

Injection site

Storage Feasibility and Design

Storage

Technical Specs:

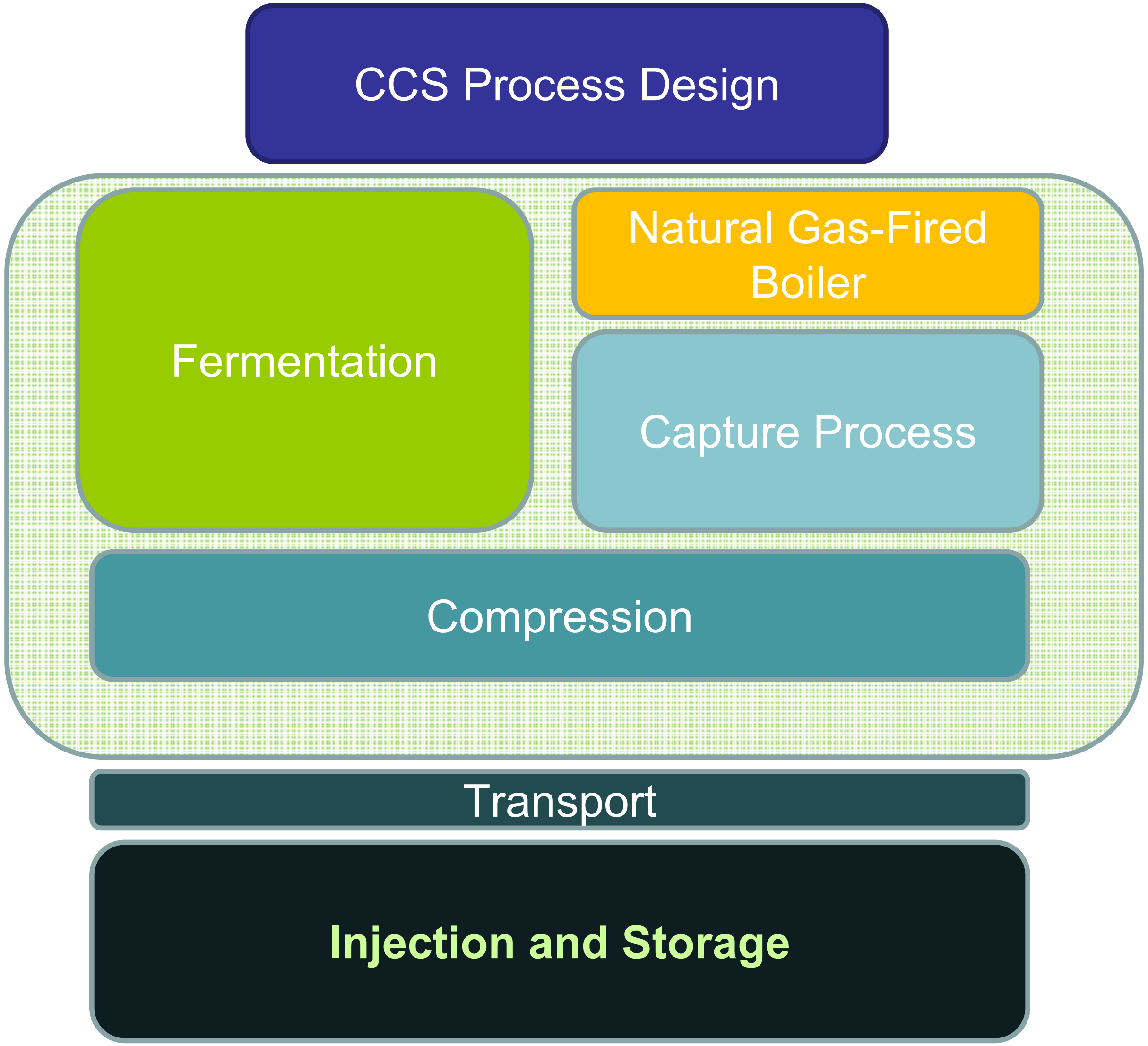
Effective injectivity: Uncertain

Thermal grad.: 3.5°C/100m

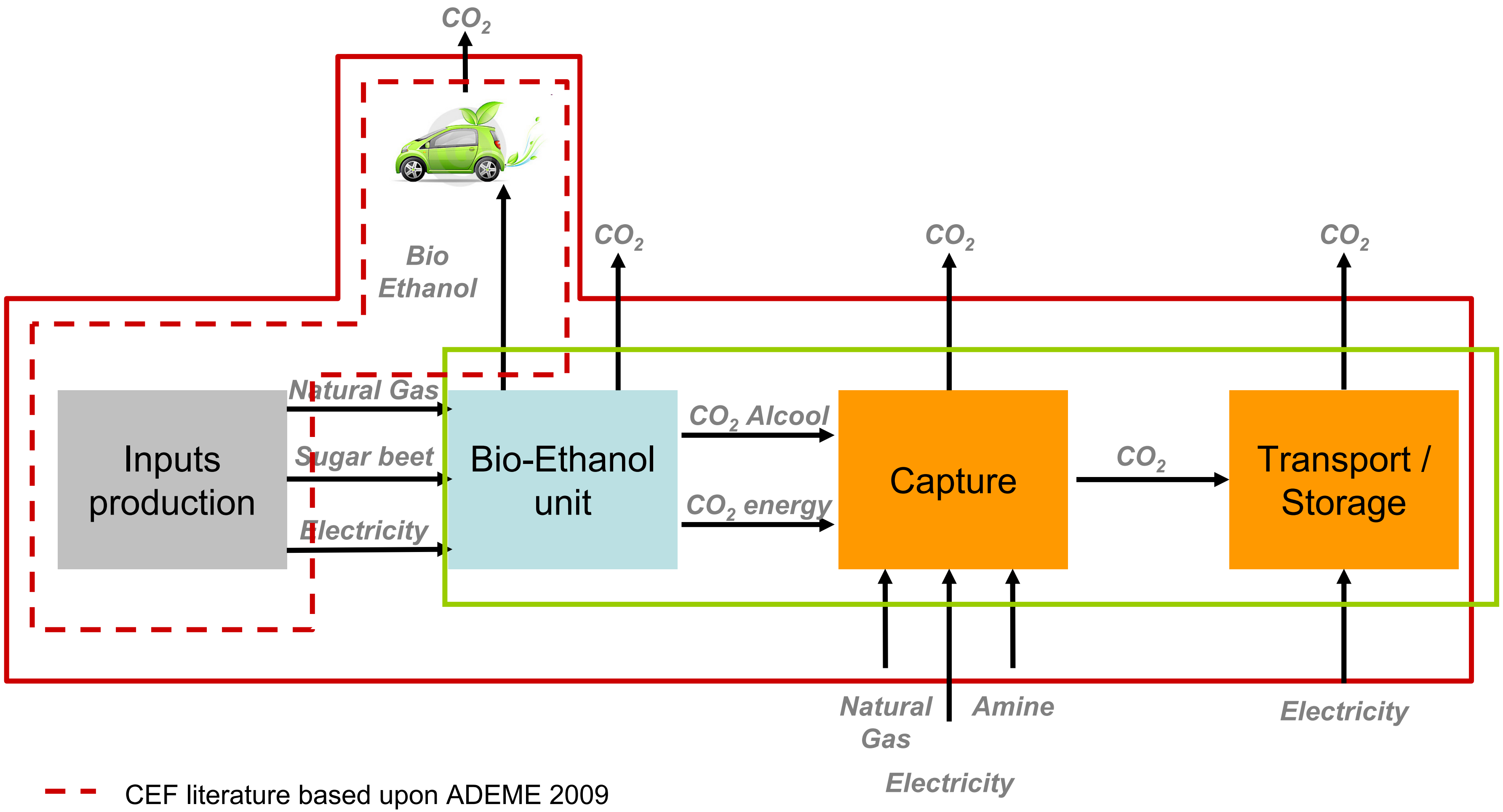
Depth: 2250m

Assumed Formation Pressure: 225 bar

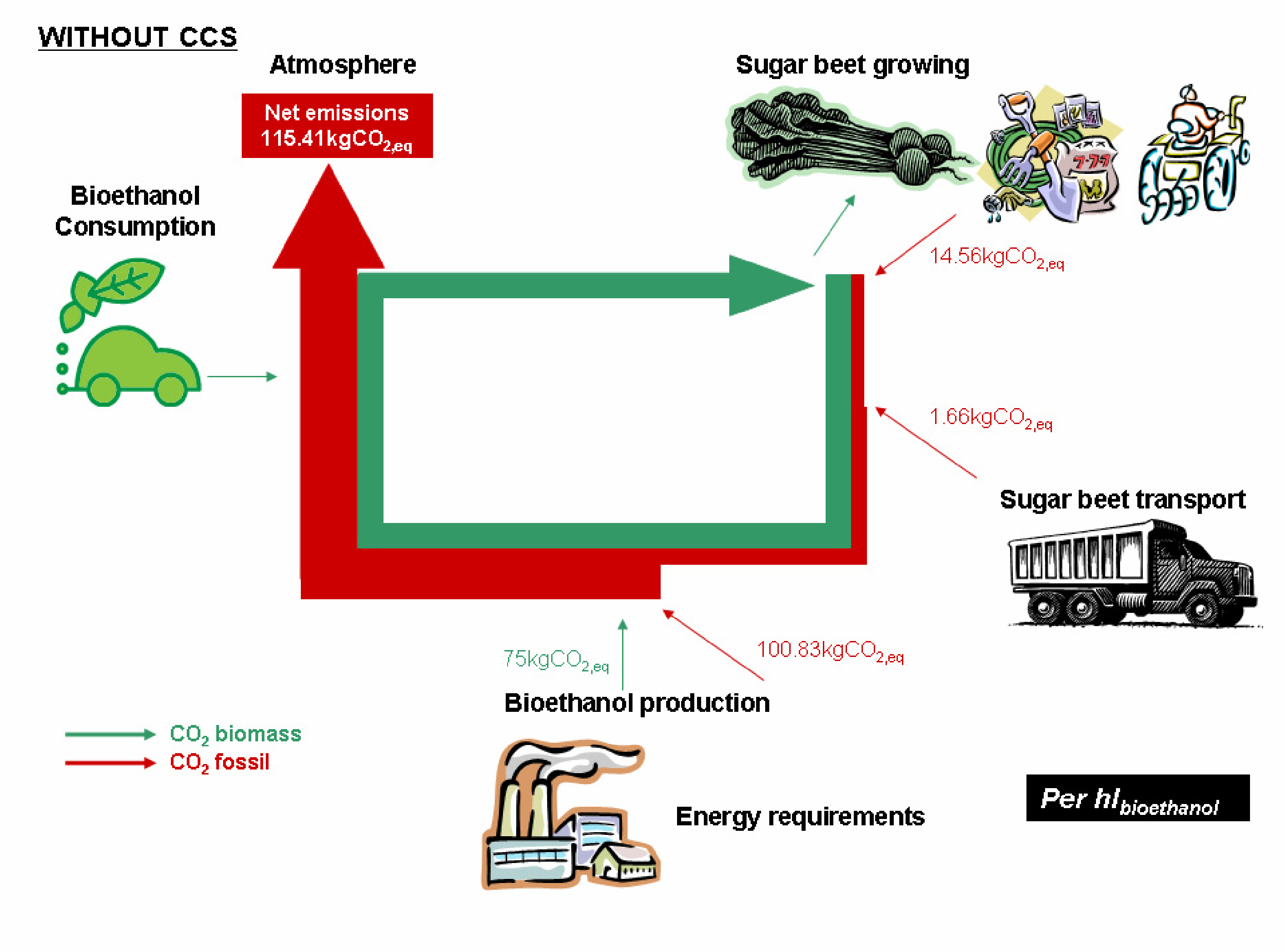
Injection pressure: must remain lower than 292.5 bar



Battery limits CEF / Economic study



- - CEF literature based upon ADEME 2009
— CEF Geogreen based on real plant data
— Economics



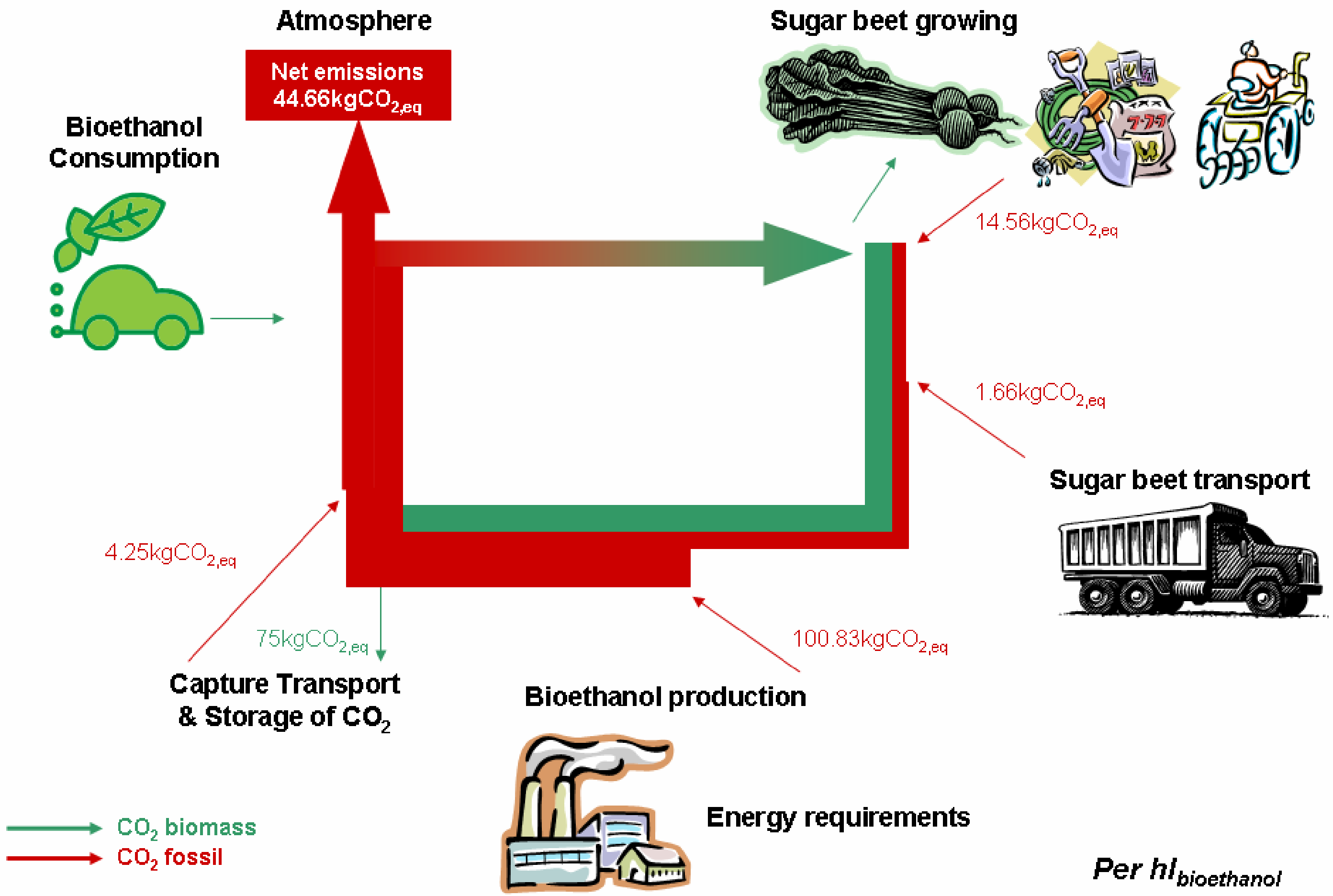
WITHOUT CCS
Atmosphere
Net emissions
115.41kgCO2,eq
Sugar beet growing
Bioethanol
Consumption
14.56kgCO2,eq
1.66kgCO2,eq
Sugar beet transport
75kgCO2,eq
100.83kgCO2,eq
Bioethanol production
CO2 biomass
CO2 fossil
Energy requirements
Per hlbioethanol

GHG balance for capture on fermentation (1) or fermentation and NG boiler (2)

Capture on 1 Fermentation unit: 100% efficiency

Storage in Triassic reservoir

Power from NG



GHG balance for capture on fermentation (1) or fermentation and NG boiler (2)

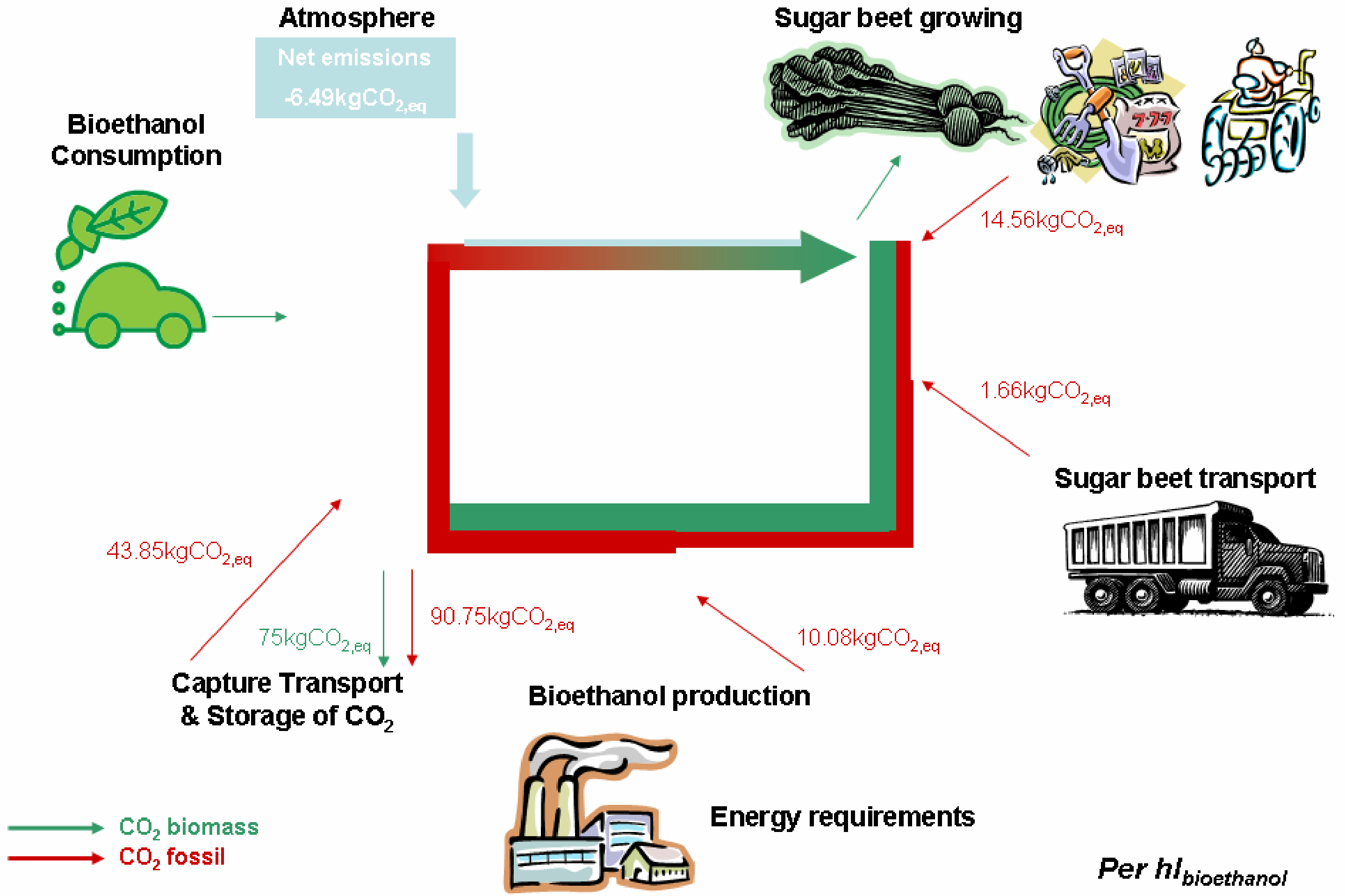
Capture on 1 Fermentation unit: 100% efficiency

Capture on 1 Combustion unit: 90% efficiency

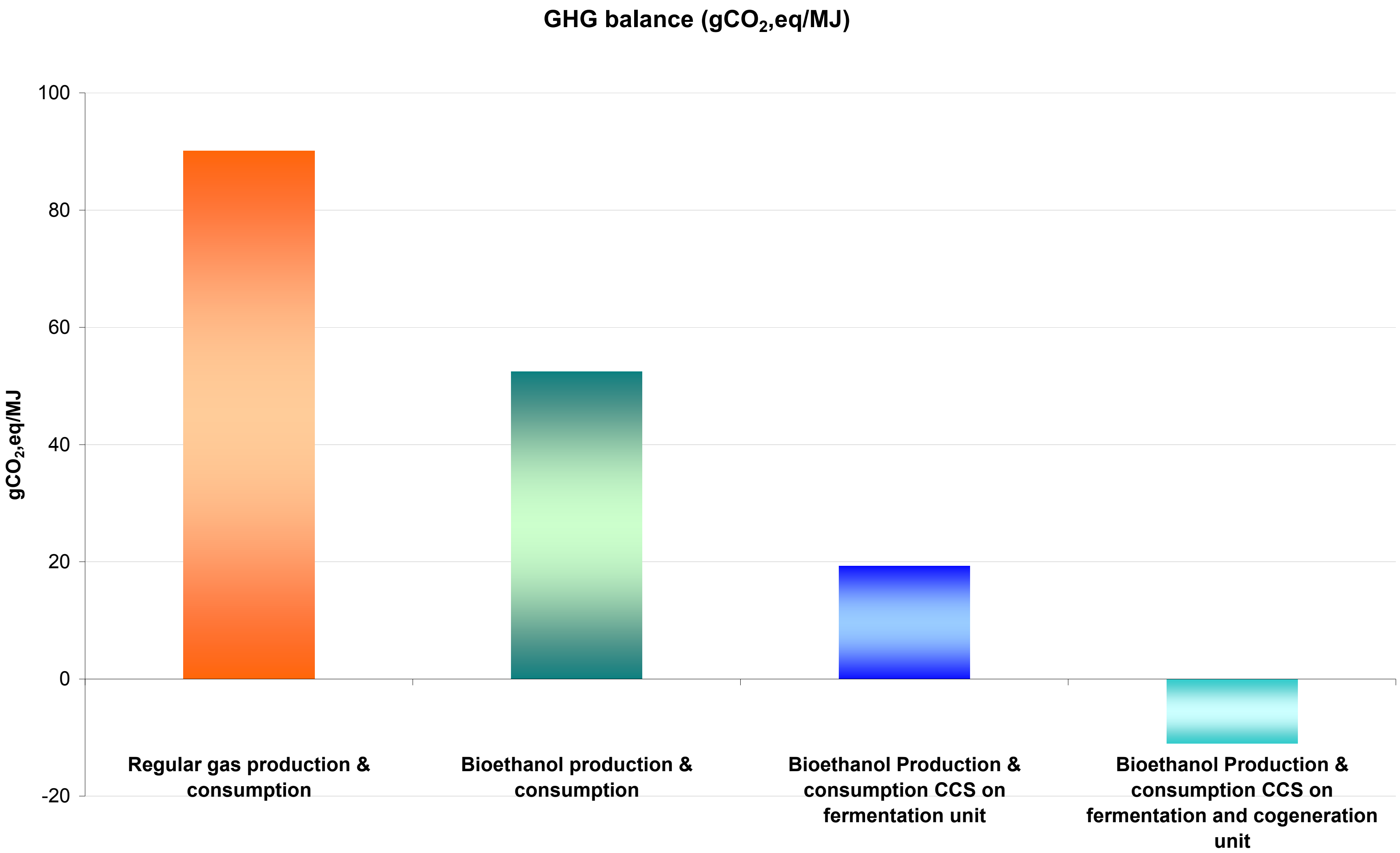
Storage in Triassic reservoir

No improvement for capture

Power and Steam from NG

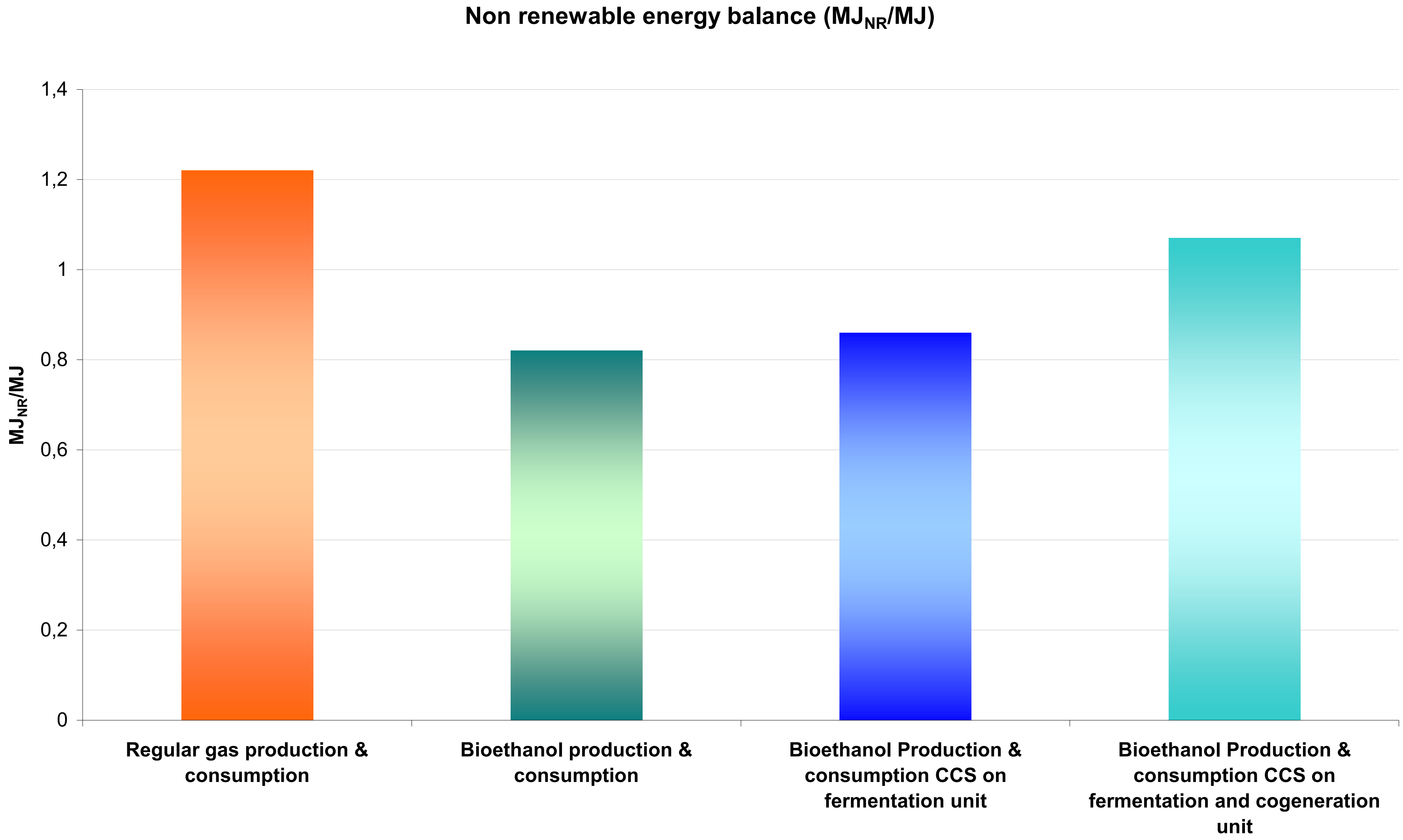


Findings



GHG balance (gCO2,eq/MJ)
100
80
60
40
20
0
-20
gCO2,eq/MJ
Regular gas production & consumption
Bioethanol production & consumption
Bioethanol Production & consumption CCS on fermentation unit
Bioethanol Production & consumption CCS on fermentation and cogeneration unit

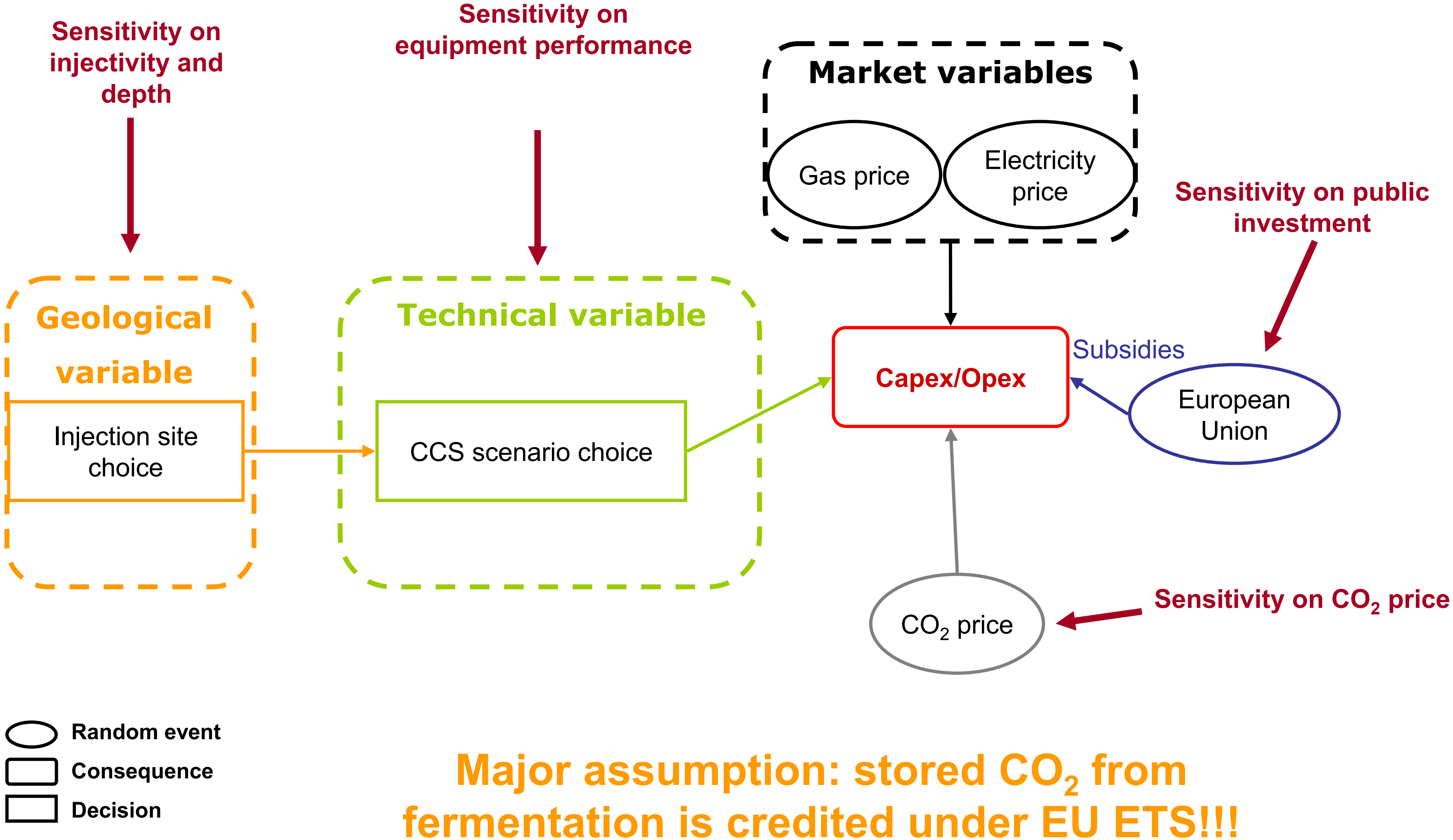
Findings


Non renewable energy balance (MJNR/MJ)
MJNR/MJ
1,4
1,2
1
0,8
0,6
0,4
0,2
0
Regular gas production & consumption
Bioethanol production & consumption
Bioethanol Production & consumption CCS on fermentation unit
Bioethanol Production & consumption CCS on fermentation and cogeneration unit

Findings

- On BioCCS pathway
  - Capture on fermentation only allow a GHG emission decrease of 60% and increase non-renewable energy consumption of only 4%
  - Capture CO_2 on both fermentation and combustion unit creates a carbon sink but non renewable energy consumption increases by 40% as compared to BAU
- Comparison with regular gas production and consumption pathway (data ADEME 2009)
- In order to limit CCS non renewable energy consumption, a **biomass boiler will replace the NG boiler in the second phase of the project**

Preliminary economics : Assumptions and simplified influence diagram



Major assumption: stored CO_2 from fermentation is credited under EU ETS!!!

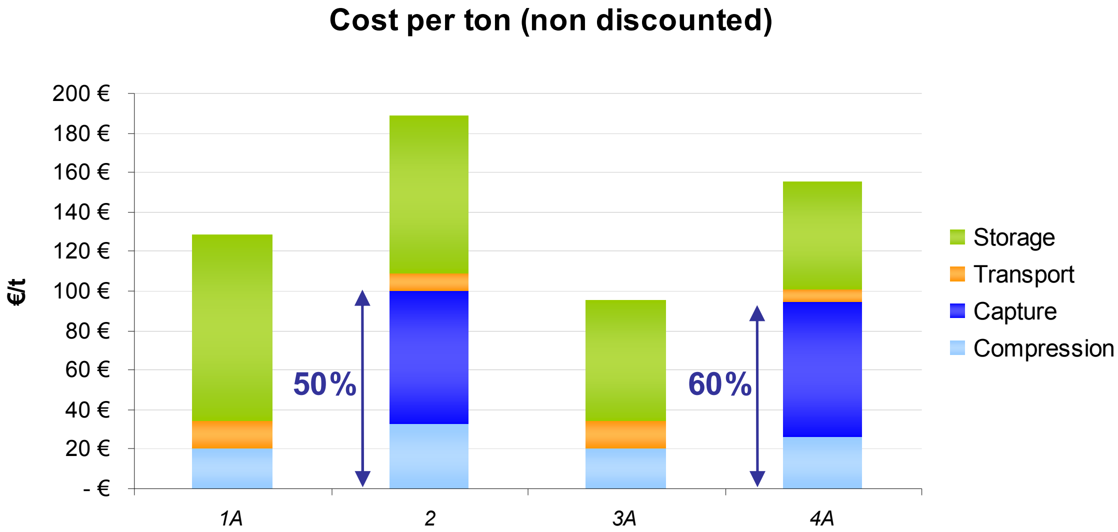
Main results

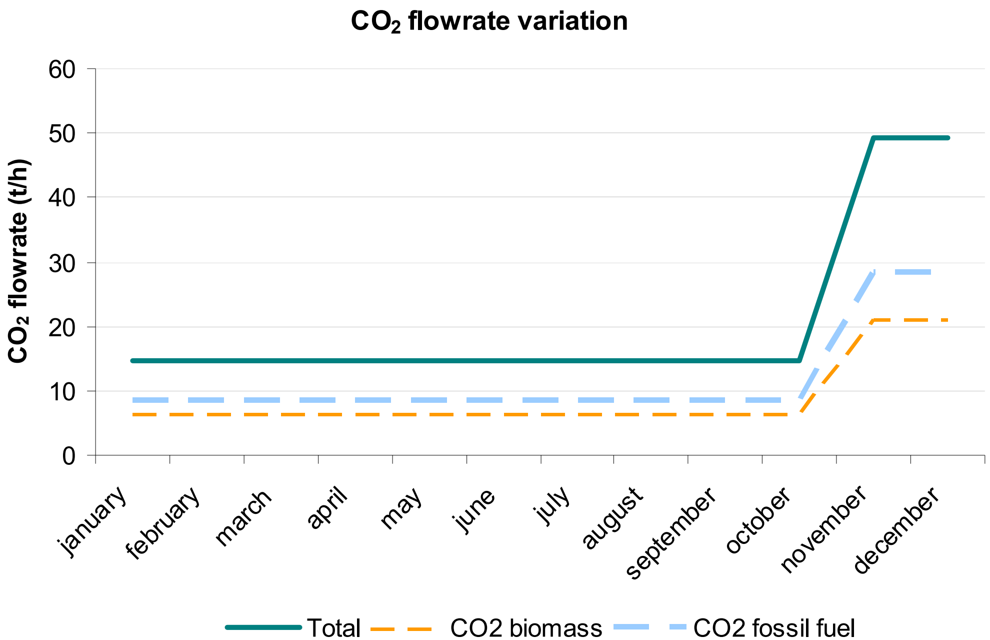
- Investments between 20 and 60 MM€

- Elevated cost per ton abated as compared to McKinsey analysis
  - Between 91€ and 188€/t against 35 et 50€/t

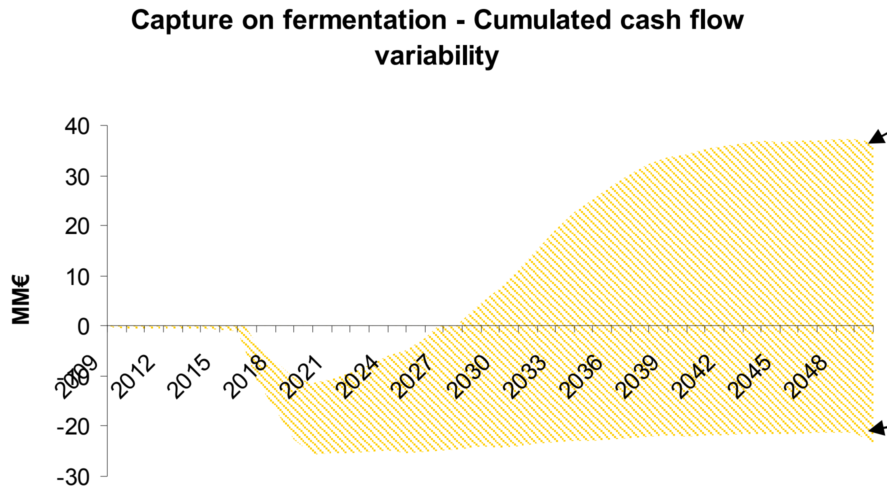
- NG CO_2 capture is very expensive (+50%) considering the small volumes captured from the NG boiler

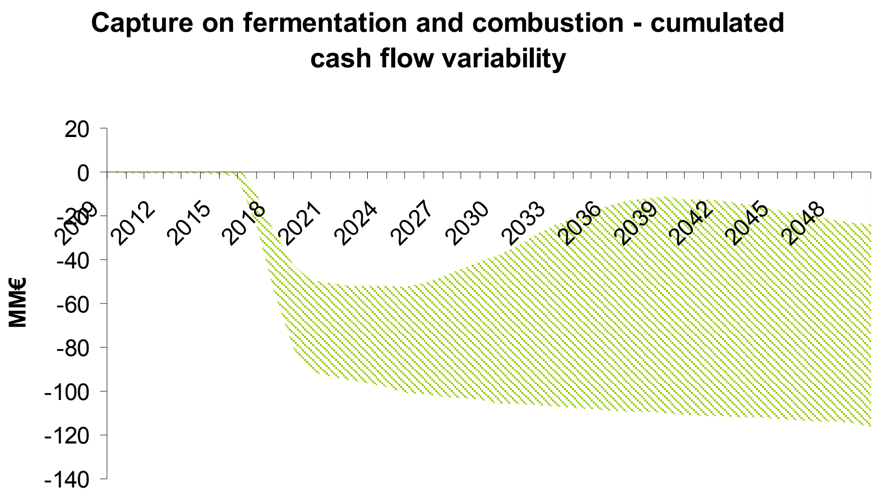
- Storage cost
  - small volume
  - Sugar beet harvesting campaign issue: if injectivity is low, needs for several wells





CCS on fermentation is interesting from the economic standpoint





- Upper limit:
  - IEA 2008 price model 450ppm
  - Base price en 2020: 50€/t
  - 30% CAPEX subsidies
  - 0% inflation; 4% discount
- Lower limit:
  - IEA 2008 price model 550ppm
  - Base price en 2020: 35€/t
  - 0% CAPEX subsidies
  - 2% inflation; 8% discount

2nd phase

Biomass co generation unit investment preferred to capture on NG boiler?

Conclusion LCA/economics for Artenay project

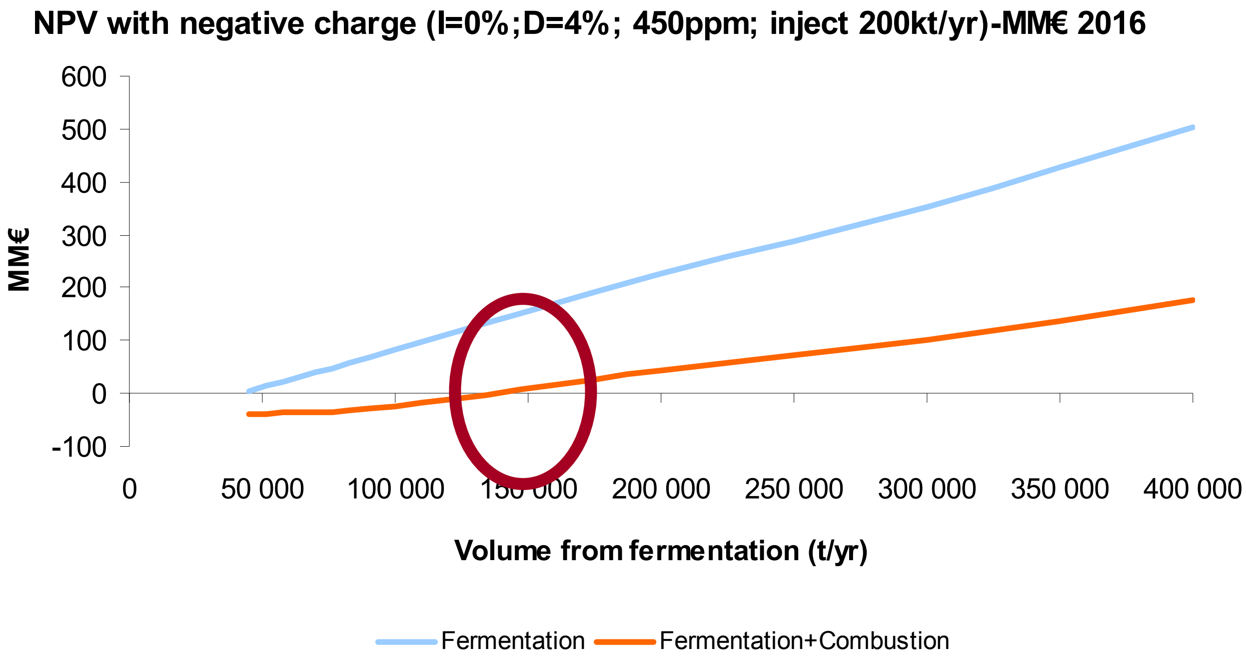
- Capture on fermentation only:
  - Allow a GHG emission decrease of 60% with a non renewable energy over consumption of only 4%
  - Is the only possibility to get a return on investment (NPV between 0 and 20 MM€) if CAPEX subsidies are over 25% and inflation is low
- Capture on fermentation and NG boiler:
  - Creates a carbon sink at the cost of a high non renewable energy over consumption (+40%)
  - Is not economically viable for the given assumptions due to high capture over cost and small volumes (~100kt/an)

BUT

BCCS offers a return for capture on fermentation **AND** NG boiler when Bio Ethanol production increases

➔ ~330kt/yr of CO_2

➔ ~2 millions hectolitres of Ethanol/yr



Recommendations

- Focus effort on significant Bio Ethanol production unit
- Optimize design in function of CO_2 emission variation due to sugar beet harvesting campaign
- Explore subsidies and Private Public Partnership opportunities
- Lobby for integration of biomass CO_2 storage into EU ETS

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Thank You for your Attention!

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