Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts

Rosa Cuéllar-Franca
and
Adisa Azapagic

School of Chemical Engineering and Analytical Science
The University of Manchester

LCA in CO_2 Utilisation
4th March 2015
Sheffield, UK

The importance of LCA in CCS and CCU systems

- To avoid mitigating climate change at the expense of other environmental issues
- To avoid shifting the environmental burdens from one life cycle stage to another

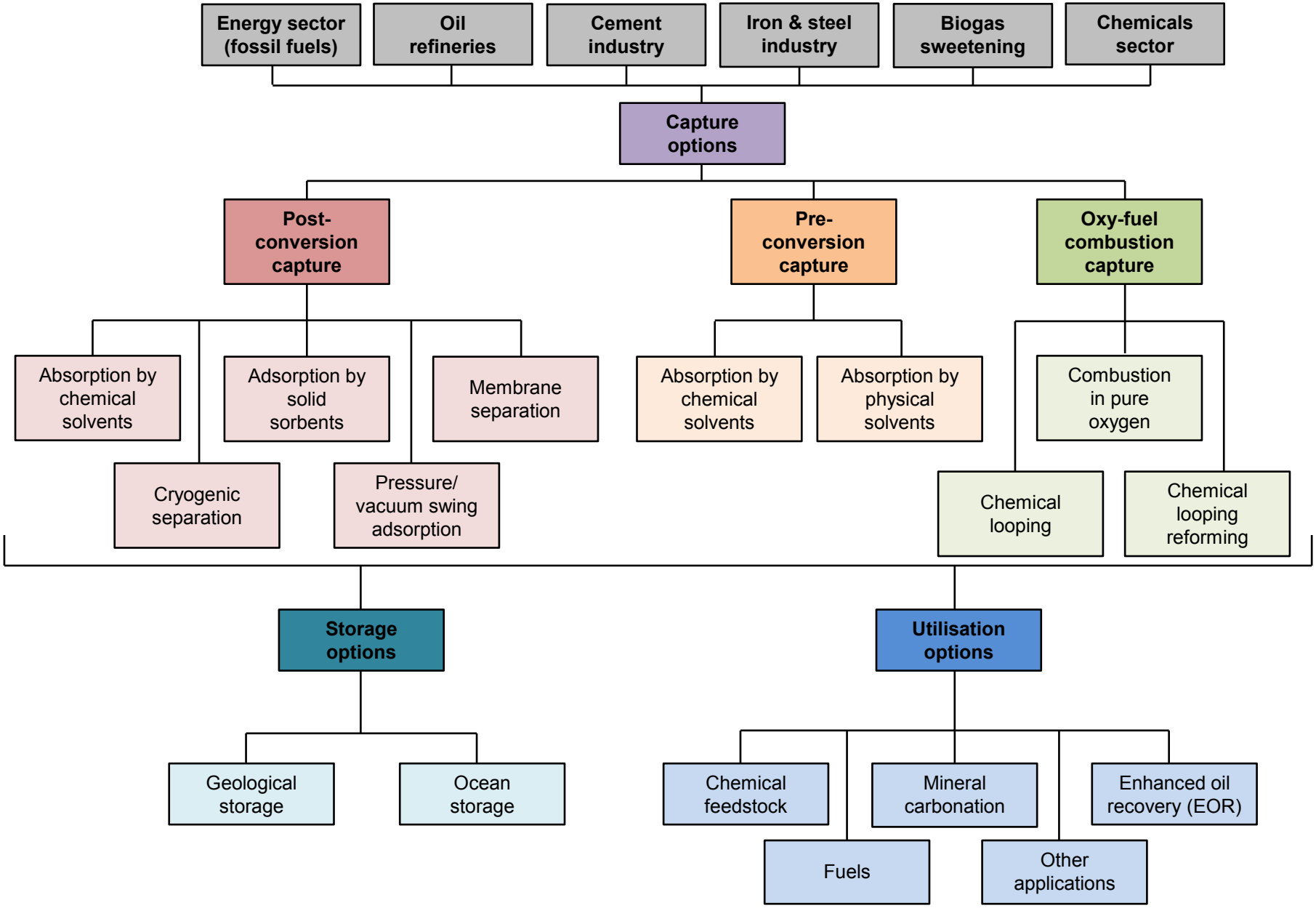
Foreseeing a future using CO_2

Overview

- Life cycle environmental impacts of
  - CCS and
  - CCU
- Comparison of environmental impacts of CCS and CCU technologies
- Presentation based on:

Cuellar-Franca, R and A. Azapagic (2015). Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts. *Journal of CO_2 Utilization,* 9, 82–102.

Different carbon capture, storage and utilisation options

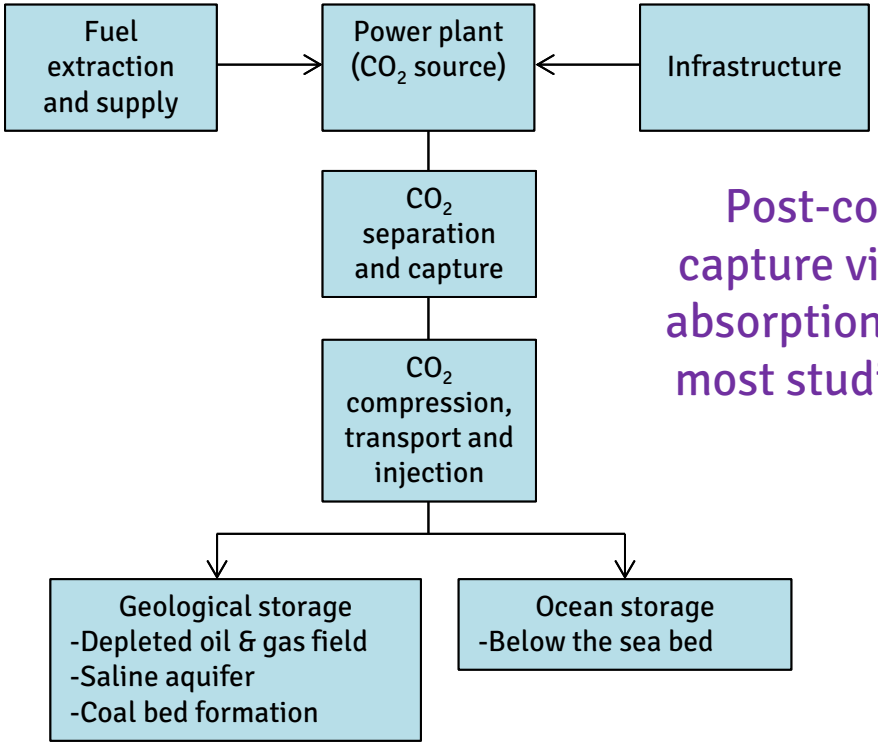


LCA studies on CCS

- LCA studies are mainly focused on CCS technologies for power plants
  - Pulverised coal
  - Integrated coal gasification combined cycle
  - Combined cycle gas turbine
- Variation in goal and scope
  - Comparison of different CCS technologies
  - Power plants with and without CCS
  - CCS vs renewable energy technologies

LCA studies on CCS

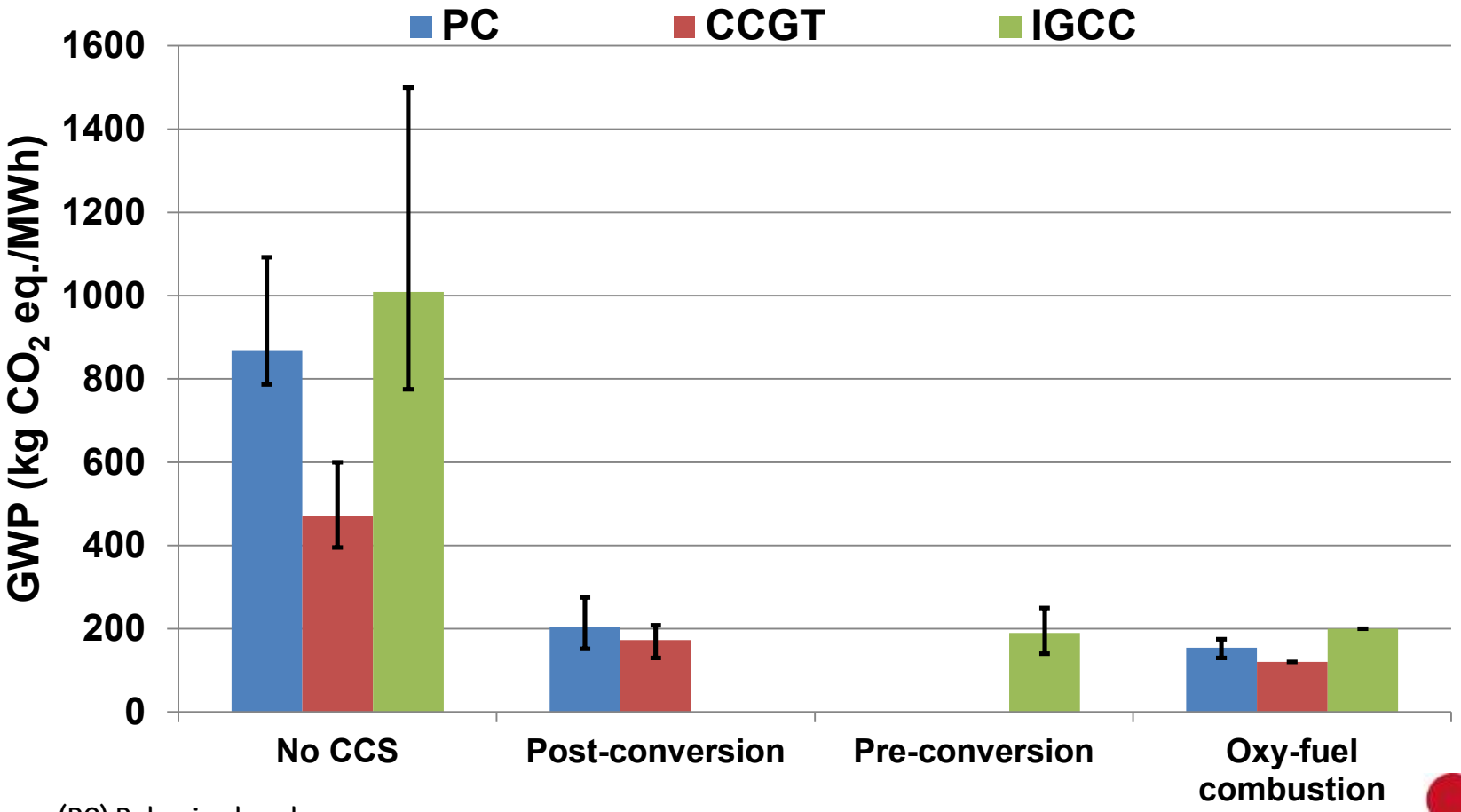
- Functional unit (unit of analysis) related to a unit of electricity generated
- System boundaries consistent across all studies



Post-conversion capture via chemical absorption using MEA most studied method

Most studies considered geological storage

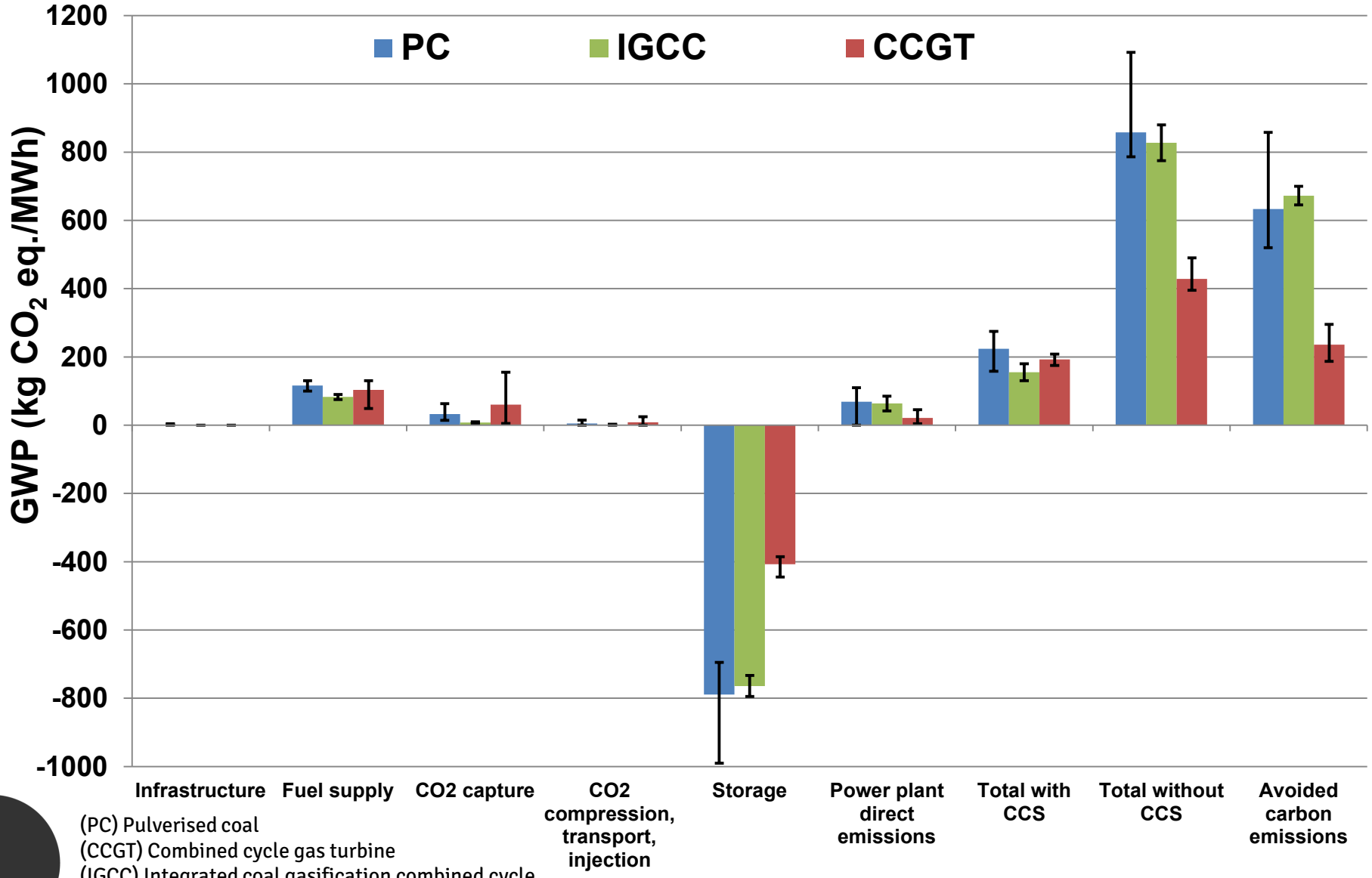
Global warming potential of PC, CCGT and IGCC plants with CCS



(PC) Pulverised coal
(CCGT) Combined cycle gas turbine
(IGCC) Integrated coal gasification combined cycle

R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

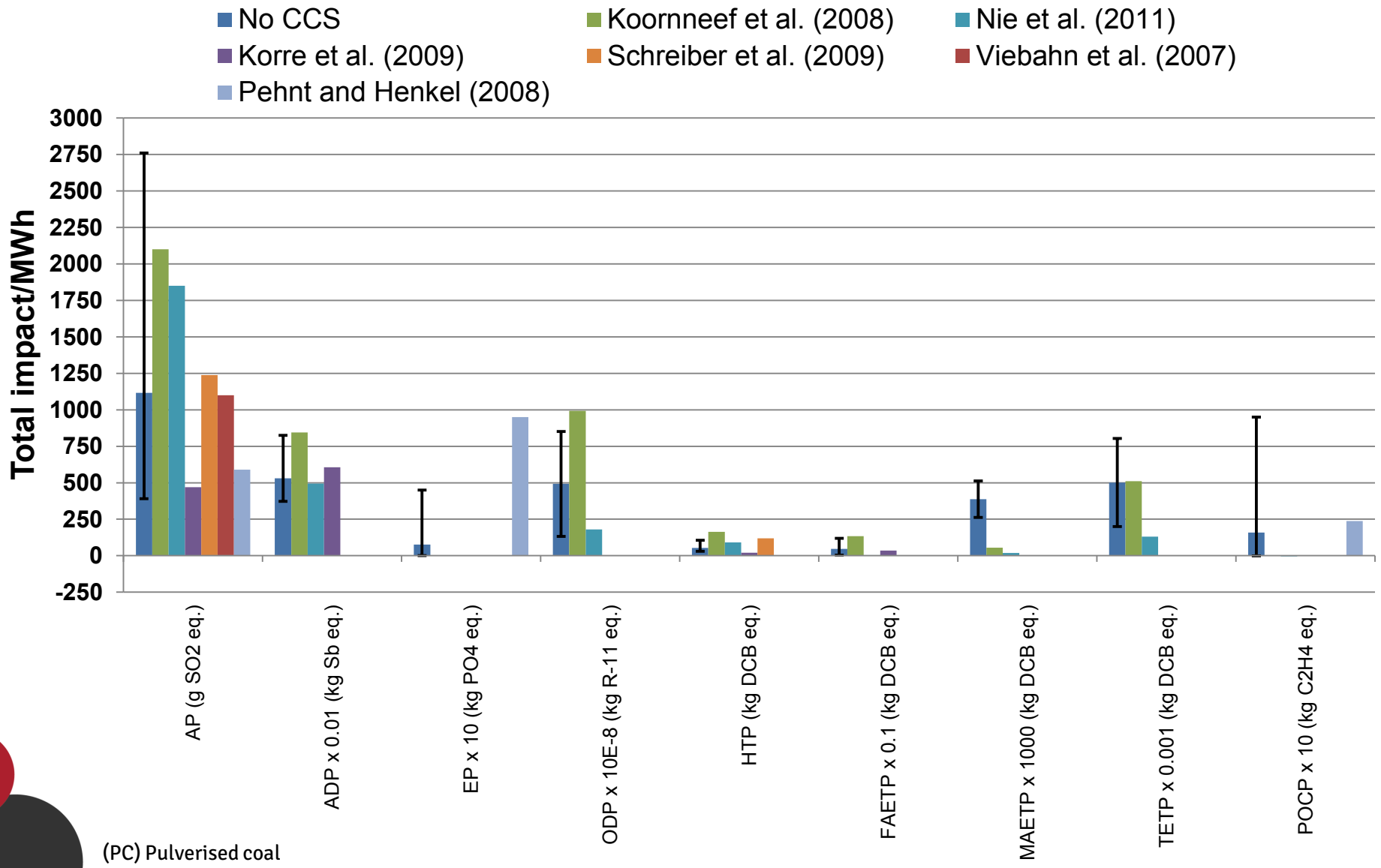
GWP of PC, IGCC and CCGT plants with CCS



(PC) Pulverised coal
(CCGT) Combined cycle gas turbine
(IGCC) Integrated coal gasification combined cycle

R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

Other environmental impacts of PC plants with and without post-conversion CCS



(PC) Pulverised coal

R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

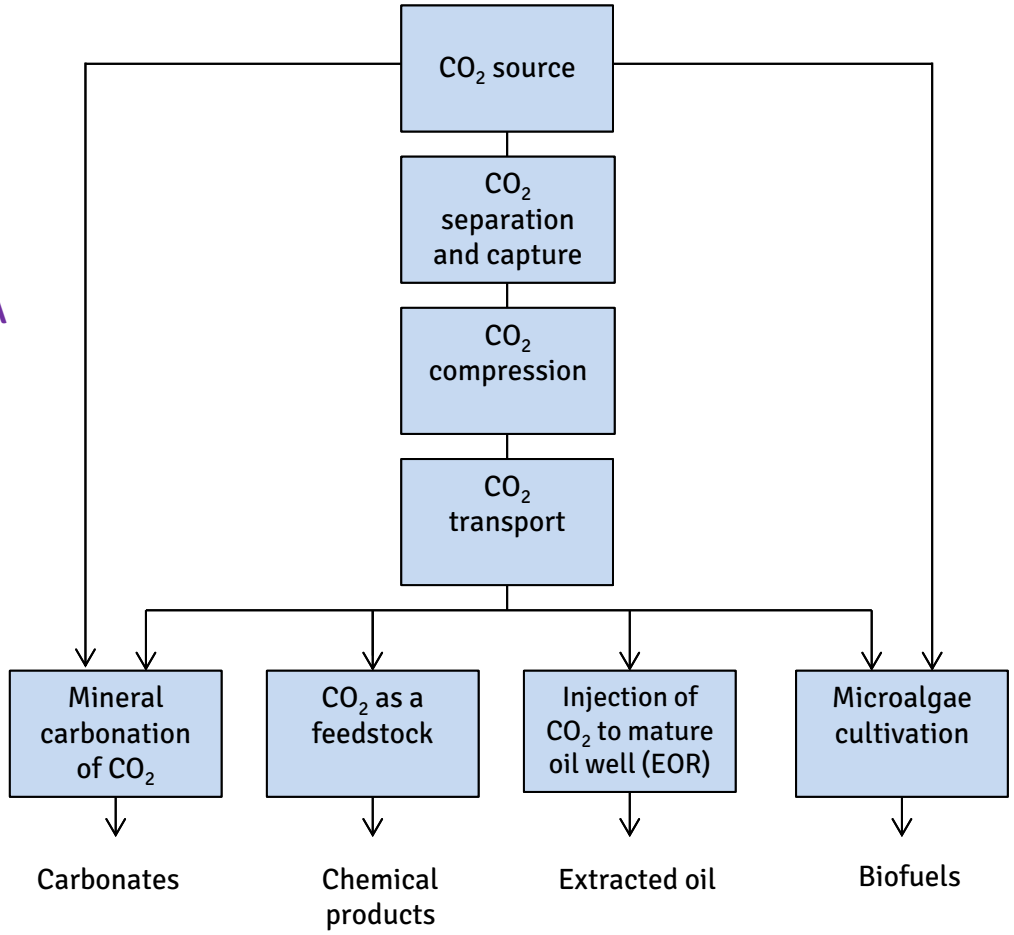
LCA studies on CCU

- LCA studies on CCU technologies for
  - Power plants
  - Chemical plants
- CO_2 utilisation options studied
  - Enhanced oil recovery (EOR)
  - Production of mineral carbonates
  - Chemicals
  - Biodiesel from microalgae

LCA studies on CCU

- System boundaries more or less consistent across all studies

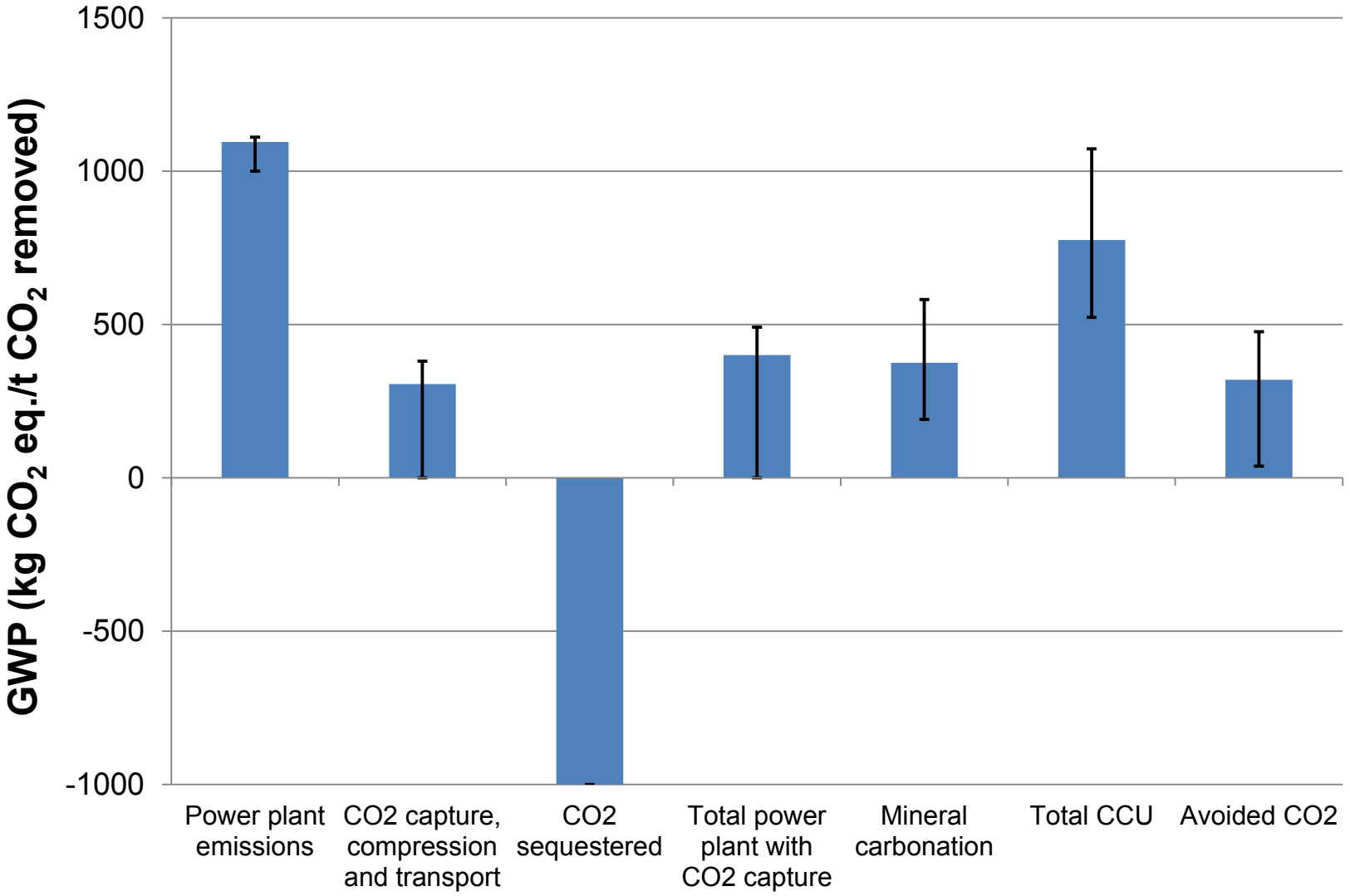
Post-conversion capture via chemical absorption using MEA most studied method



LCA studies on CCU

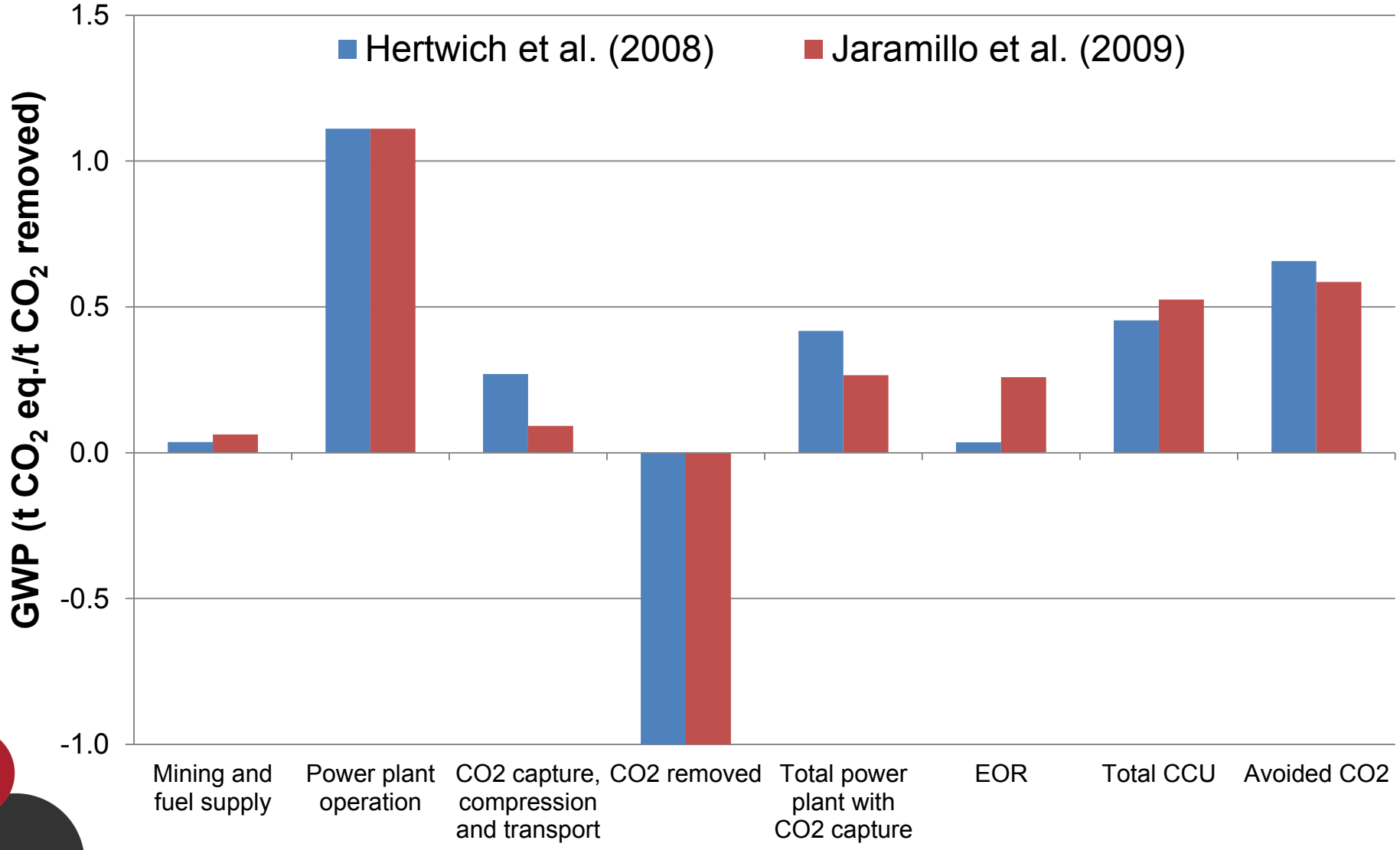
- Functional unit varied across the studies
  - Related to the main product
    - Electricity generated
    - Chemicals produced
    - Biodiesel produced
    - Extracted oil
  - Amount of CO_2 removed
  - Energy content in biodiesel
  - Distance travelled

GWP of mineral carbonation



R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

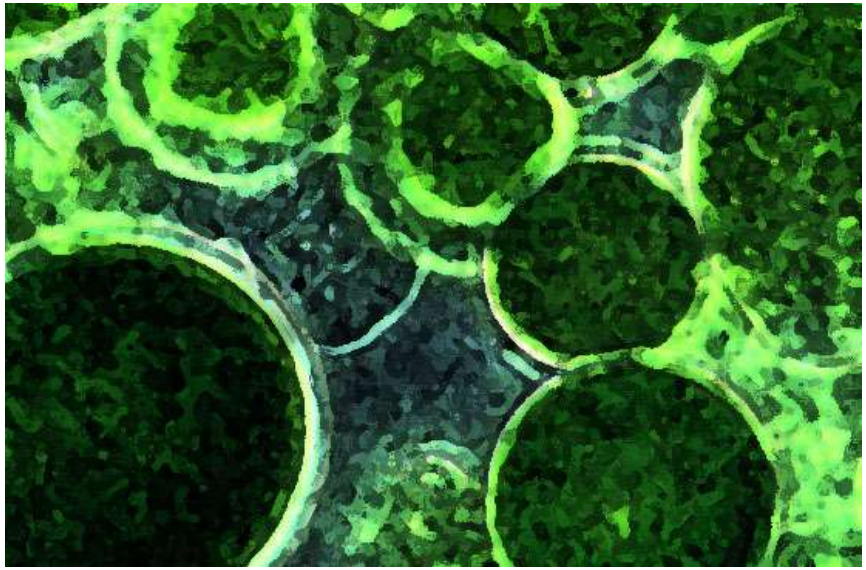
GWP of enhanced oil recovery



R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

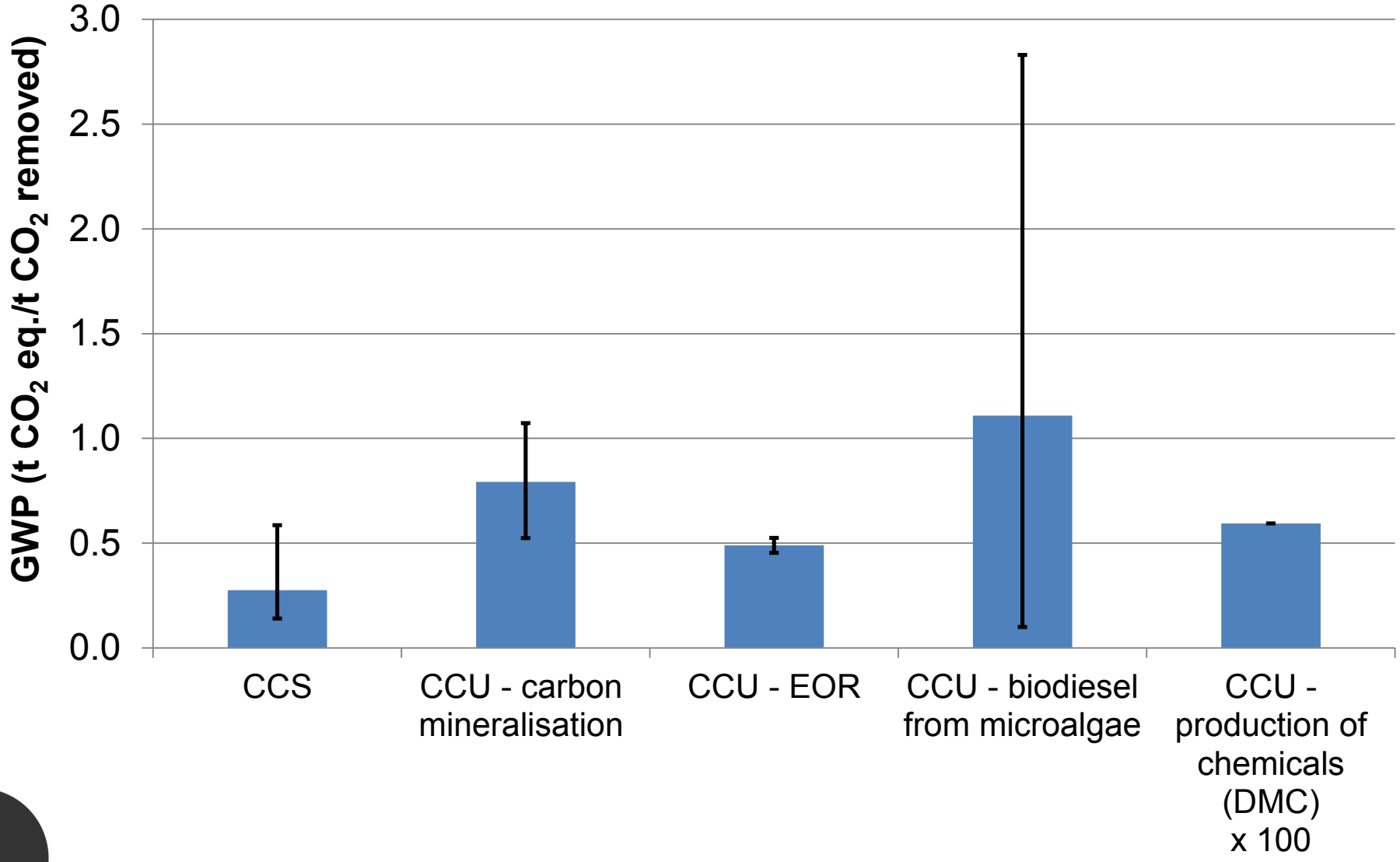
GWP of other CCU options

- Utilising CO_2 for production of dimethyl carbonate reduces GWP by 4.3 times compared to the conventional DMC process
- Capturing CO_2 by microalgae to produce biodiesel has 2.5 times higher GWP than fossil diesel



MANCHESTER 1824
The University of Manchester

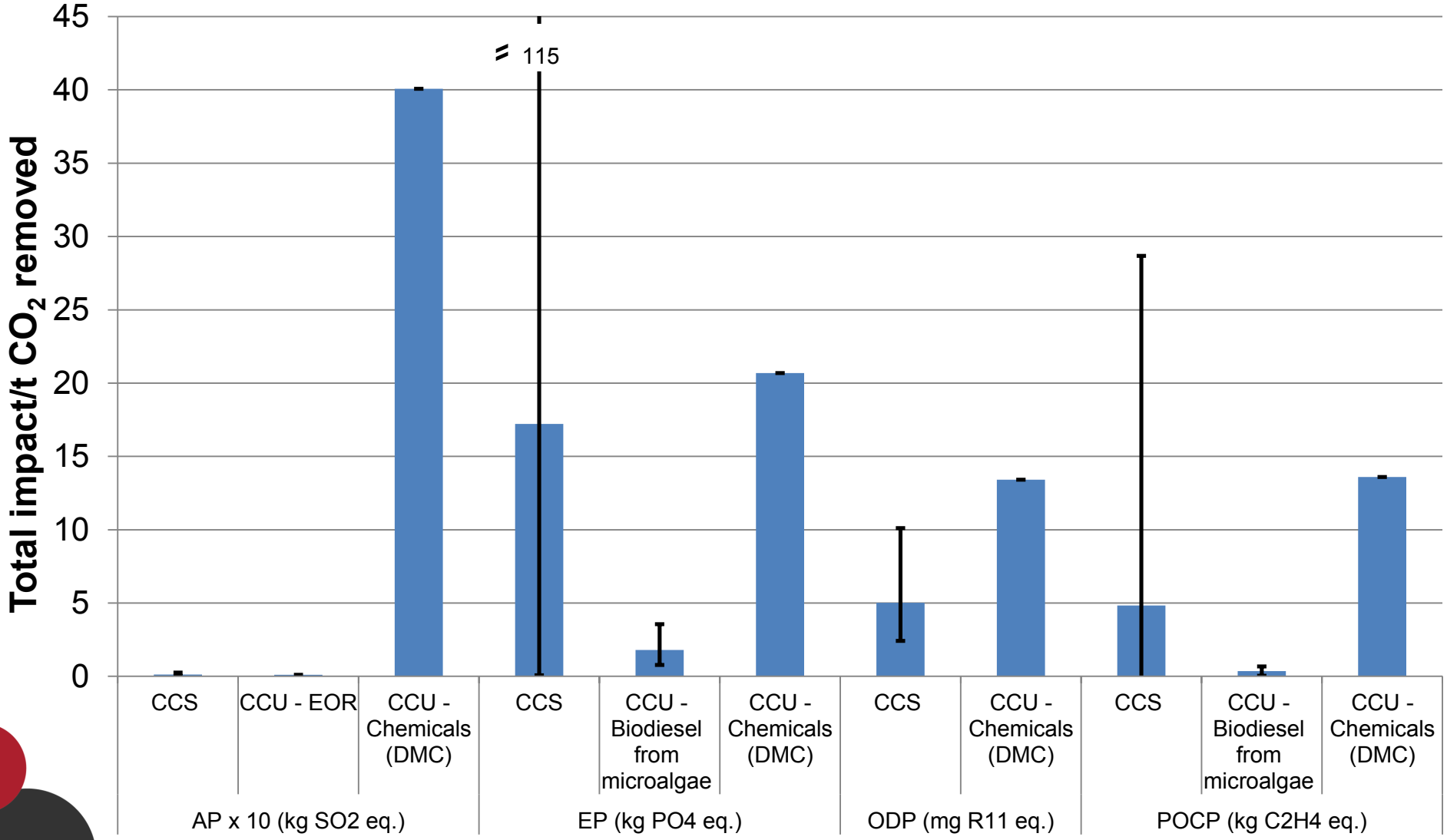
GWP of CCS and CCU options



R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

MANCHESTER 1824
The University of Manchester

Other environmental impacts of CCS and CCU



R.M. Cuéllar-Franca, A. Azapagic/ Journal of CO_2 Utilization 9 (2015) 82-102

Conclusions

- CCS studies suggest that the GWP from power plants can be reduced by 63-82%
- Other environmental impacts are higher with than without CCS
- For CCU, CO_2 savings depend largely on the utilisation option
- The average GWP of all CCS options is significantly lower than the GWP of any CCU options considered

Recommendations

- Specific guidelines for application of the LCA methodology to CCS and CCU technologies
  - Definition of system boundaries
  - Establishment of a standard functional unit
- Consideration of wider range of environmental impacts from CCS and CCU
- Consideration of different allocation methods
- Assessment of the uncertainty in the data and results
- Studies of different sources of CO_2

Further information

Cuellar-Franca, R and A. Azapagic (2015). Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts. *Journal of CO_2 Utilization,* 9, 82–102.

Foreseeing a future using CO_2

Acknowledgement