**Publishable summary (MAX 2 pages)**

Carbon dioxide emissions generated by fossil fuels utilisation are forcing a rapid increase in atmospheric carbon dioxide concentration, approaching 450 ppm by 2035 and resulting in a 77-99% probability of exceeding 2°C global warming. The increase in the average global atmospheric carbon dioxide concentration demonstrates that the plans for emissions reduction have not been put into action and additional solutions which could be disregarded decades ago, have to be included now. Direct air capture (DAC) enables carbon dioxide removal from the ambient air. This is an option mentioned by the Intergovernmental Panel on Climate Change as a measure to hit directly the cause of climate change. In order to have reasonable effect on global warming, DAC technologies have to be deployed on a scale directly linked to the global petroleum consumption, therefore at a scale of Gt of carbon dioxide removed per year. From the technological viewpoint, the removal of carbon dioxide at extremely dilute conditions is not an issue. Technologies for carbon dioxide removal directly from air have already been developed in the past. The real technological challenge is to concentrate and compress that amount of carbon dioxide at conditions compatible with long term geological storage by using renewable energy. Within the present Marie Curie Career Integration Grant Atmospheric Carbon Capture (ACCA) project, we have investigated a novel temperature swing adsorption air capture system which is based on a sequence of subsequent adsorption compressors powered by heat at 95°C to deliver an almost pure and already compressed CO2 stream, ready for geological storage. The process is inspired to the air revitalization system on the International Space Station that is also a temperature swing adsorption system used for carbon dioxide removal from the atmosphere at concentrations one order of magnitude higher than air capture.

Objectives of the ACCA project consisted of:

1. a theoretical proof of feasibility of the process: thermodynamic analysis of the process shows that, by exploiting the equilibrium properties of commercial and non-commercial nanoporous materials, carbon dioxide can be produced at specifications appropriate for geological storage. A final storage vessel can be pressurized with carbon dioxide at purities >0.95 mole fraction and specific thermal energy consumption <2.2 MJth molCO2–1 by using commercial zeolite 13X and low temperature heat. This has important implications on the availability of primary energy source to capture carbon dioxide at Gt scale. Solar thermal energy is the most abundant source of primary energy on the Earth. Its availability is well above the amount of primary energy required for air capture. Furthermore, heating is required at temperature levels which are appropriate for flat plate solar collectors, the cheapest technology to capture solar energy. Therefore the present process is viable for air capture.
2. an insight on the features of the best nanoporous material to be used and a screening of those seemingly promising: tailored nanoporous sorbents provide a step-change in performance. When the process operates with advanced zeolites such as Na-ETS4 (for carbon dioxide removal) and AQSOA FAM Z02 (for carbon dioxide storage), carbon dioxide can be purified at values >0.97 mole fraction.
3. the design of an experimental apparatus to prove the theoretical considerations: a lab-scale prototype that allows fast characterization of the process and the nanoporous materials has been designed, realised and is currently under testing. The lab-scale prototype enabled the identification of benefit and limitations of the proposed process to ground future scale-up.

Project Management: the original idea of the process was initiated by Prof. Stefano Brandani and his group at the University of Edinburgh (<https://www.carboncapture.eng.ed.ac.uk/>) and developed thanks to the ACCA project by Dr. Giulio Santori within the Brandani’s group. In four years, the ACCA project has also benefitted of the collaboration with a numerous other researchers and groups such as:

1. the Grupo de Pesquisa em Separações por Adsorção at the Universidade Federal do Ceara (Brazil), group leader: Prof. Celio Cavalcante. High pressure carbon dioxide and nitrogen adsorption measurements on AQSOA FAM Z02 have been performed by staff of The University of Edinburgh in visit to the laboratories of Cavalcante’s group at the Universidade Federal do Ceara.
2. Dr. Andrea Frazzica (CNR-ITAE, Italy) who provided samples of zeolite AQSOA FAM Z02 and has been visitor of the fellow’s group.
3. Dr. Angelo Freni (CNR-ICCOM, Italy) who has provided advanced nanoporous materials such as zeolite 13X foams.
4. Dr. Lucio Bonaccorsi (Universita Mediterranea di Reggio Calabria, Italy) who has kindly provided advanced nanoporous materials such as silanol-graphted dealuminated zeolite Y.

A larger audience was reached through dedicated web pages on the Carbon Capture group web site (<https://www.carboncapture.eng.ed.ac.uk/acca-atmospheric-carbon-capture>), special project pages on the web (<https://www.researchgate.net/project/Atmospheric-Carbon-Capture-ACCA>), general public was engaged to reflect on air capture through one press release on national newspapers (21/09/14, “una trappola per l’anidride carbonica nell’aria”, Corriere Adriatico press release) and the Scottish Carbon Capture & Storage Research Centre (<https://www.sccs.org.uk/expertise/projects/details/9/545>).

ACCA project has also contributed to the case for promotion of the fellow who was hired on a temporary 5 years long contract, then moved to permanent Lecturer one year later and Senior Lecturer in the end of the project (with effect on August 2018).

ACCA project has also helped the fellow to establish his research group on sustainable zero- and negative-carbon technologies (<https://www.eng.ed.ac.uk/about/people/dr-giulio-santori>). This group is currently composed by one post-doctoral research associate and two PhD students, with regular visits of international researchers from abroad (Italy, Mexico, China).

ACCA project has been developed thanks to the support of Ms. Charithea Charalambous who has developed large part of the investigations during her PhD studies and who was supervised by the fellow. Two undergraduate students have been also taking part to the research activities for their final year research project.

Finally, the fellow was been invited to provide the cover of Environmental Science Processes & Impacts Vol 18 (2016), two seminars. On 31/05/2016 he has delivered at The University of Edinburgh the envisage seminar: “Development of an atmospheric carbon capture technology: duty and technology fix chimera” and on 14/09/15 he has delivered the talk: “Open-cycle adsorption compression train” at [Sorption Friends meeting](http://www.sorptionfriends.org/oral-presentations/) (Milazzo, Italy).

The fellow has been also invited to provide expert advice on air capture to governmental and private bodies. On 5/04/2017 the Committee on Climate Change (BEIS Conference Centre, London) has invited him on the topic: “Greenhouse Gas Removal Options” and more recently (February 2018) consultant for a private company (undisclosed) to assess the feasibility of global-scale removal of carbon dioxide from the atmosphere.

Finally, the project results have been presented on the 12/02/2015 at the Air Capture Workshop (Institution of Mechanical Engineers, London), on 23-26/10/2016 at the Innovative Materials for Processes in Energy Systems Symposium and on 27-29/06/2016 at Heat Powered Cycles conference.