# 2020-IP02: The role and value of CCS in different national contexts

**Key messages of this report:**

- CCS technologies are essential to a transition to a least-cost and reliable net-zero electricity system.
- The role and value of CCS changes in different regional contexts due to differing energy system characteristics, e.g. availability of renewable power and electricity demand profiles.
- CCS adds value in all power systems, and is uniquely valuable when deployed together with intermittent renewables.
- Negative emissions technologies such as bioenergy with CCS will be essential in offsetting residual emissions, especially in the context of a net-zero emissions system.
- Greater than 90% $CO_2$ capture rate reduces the system cost, and improves deployment prospects for CCS by increasing CCS capacity factor and reducing the requirement for negative emissions.
- Enhanced oil recovery (EOR) alone is not enough to encourage large-scale deployment of CCS
- Least-cost transitions ignore the broader socio-economic consequences of decarbonisation challenge.
- It is not a case of ”CCS **or** renewable power”, but rather ”CCS **and** renewable power”

The Coal Industry Advisory Board (CIAB) commissioned the study, “**The role and value of CCS in different national contexts**”, with the final report published in October 2019. The study was carried out by **Dr Niall Mac Dowell**, Reader in Energy Systems, and **Mr Yoga Pratama**, post-graduate student, both of Imperial College London (ICL).

Delivering the ambition of the 2015 Paris climate agreement requires a global transition to net zero $CO_2$ emissions by mid-century or shortly thereafter. Achieving this ambition will require a rapid and unprecedented transformation of global energy systems, with the power sector at the forefront of this transformation.

Since 2015, there has been significant focus around the world on setting national targets to deliver this aim. Norway, Sweden, the United Kingdom, and France have put in place legally binding targets for net zero emissions by 2050, with Norway and Sweden aiming for 2030 and 2045, respectively. Several other countries are in the process of proposing legislation, developing policy documents, or at least discussing “net zero” as an ambition.

Using a scenario-based approach, the project aimed to determine the role and value of CCS in different power systems around the world. This was achieved by applying ICL’s Electricity Systems Optimisation (ESO) framework to six distinct electricity grids:

- United Kingdom
- Poland
- New South Wales
- Indonesia (JAMALI)
- Texas (ERCOT)
- Wyoming (PACE)

ESO acts to minimise the cost of transition, whilst ensuring security of supply and complying with environmental targets. For each scenario, the cost-optimal capacity expansion, unit commitment and economic dispatch profiles were calculated for the period 2015 –2050.

For each case study, a scenario-based approach was adopted, with four distinct scenarios evaluated:

- **Business As Usual (BAU)**: prevailing policies are maintained, there is no carbon target, and all technologies can be deployed in line with historical build rates.
- **All Technologies**: there is a target of net zero $CO_2$ emissions by 2050, all technologies can be deployed in line with historical build rates.
- **No CCS**: there is a target of net zero $CO_2$ emissions by 2050, all technologies except for CCS can be deployed in line with historical build rates.
- **Renewables and Storage**: there is a target of net zero $CO_2$ emissions by 2050, only renewable power and energy storage technologies can be deployed.

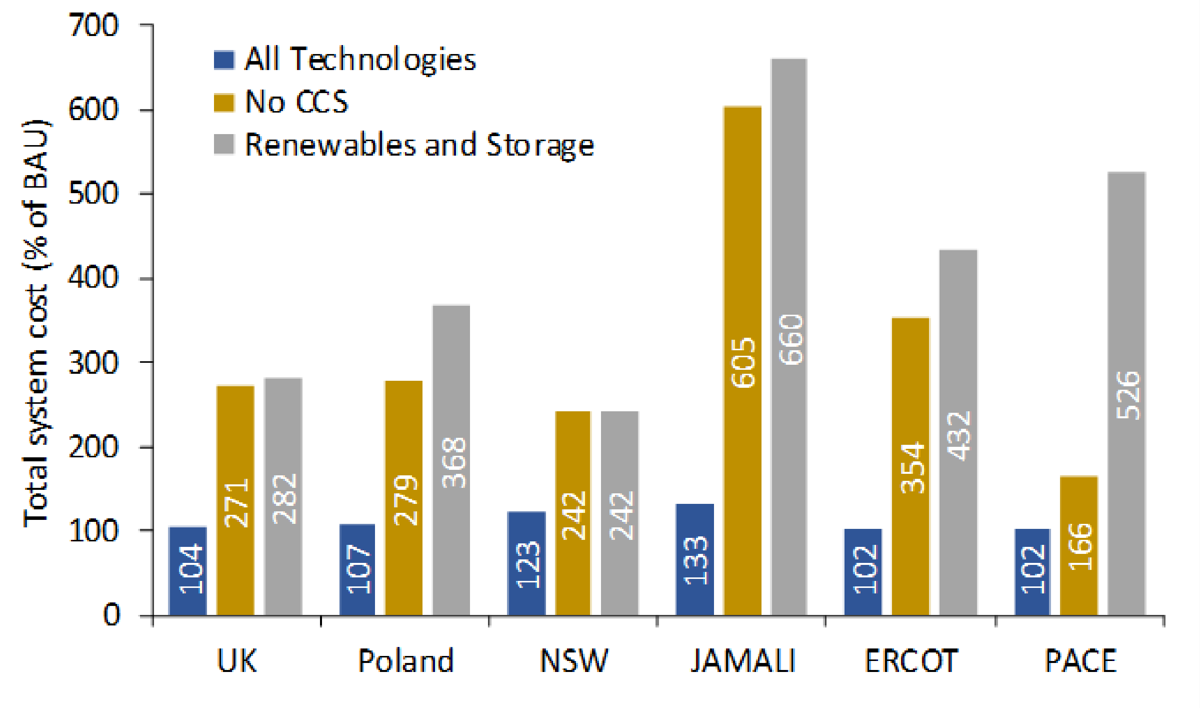
The core, overarching conclusion of this work is that, as illustrated in the figure and table reproduced below, regardless of national context, CCS is integral to delivering a resilient and cost-effective, zero emissions electricity system.

**Summary of results**

| | **BAU**<br>$ Bn | **All Tech.**<br>$ Bn | **No CCS**<br>$ Bn | **Renewables & Storage**<br>$ Bn |
|---|---|---|---|---|
| UK | 555.0 | 573.0 | 878.0 | 1,374.0 |
| Poland | 289.0 | 308.0 | 805.0 | 1,061.0 |
| New South Wales | 83.0 | 102.0 | 201.0 | 201.0 |
| Indonesia (JAMALI) | 588.0 | 780.0 | 3,554.0 | 3,876.0 |
| Texas (ERCOT) | 330.5 | 338.2 | 1,171.2 | 1,426.1 |
| Wyoming (PACE) | 45.8 | 46.6 | 57.6 | 241.0 |

Regardless of context, the exclusion of CCS technology from the portfolio of available options has the effect of increasing the cost of delivering a net zero system by between a factor of two and seven.

**Total system costs of decarbonised systems as percentage of the BAU costs**




An additional insight generated by this work includes the impact of seasonality of power demand on the value of CCS. Regions with a highly seasonal power demand, such as the UK or the ERCOT grid, will likely derive maximum value from including CCS owing to its ability to operate in a flexible, load-following manner. It might be anticipated that the electrification of other sectors, such as heating or transport, would enhance this value proposition.

Two other key observations are important to highlight. First was the rate at which power generation technology must be deployed in order to meet the net zero target. In the "BAU" and "All Technologies" scenarios, technology deployment rates were considered to be in line with historical precedent for each region. This is important as the deployment of power generation assets of *any* kind requires the coordinated interaction of a complex, global supply chain, which is unlikely to be able to significantly increase its output in the short term. Moreover, any demand for power generation deployment beyond the existing capacity of this supply chain is likely to exert an upwards pressure on costs throughout that chain. These system dynamics are not accounted for in typical energy systems studies, where costs typically are considered to reduce with deployment. In the case of the "No CCS" and "Renewables and Storage" scenarios, the rate at which power generation capacity needed to be deployed was unprecedented.

A second key observation is that, despite significantly relaxing the build-rate constraint, both the "No CCS" and "Renewables and Storage" scenarios were frequently unable to satisfy the demand for power. Putting that another way, removing the option of deploying CCS appears to either jeopardise the resilience of the electricity system, or require a significant reduction in energy demand, and also a substantial change in the way in which energy is used.

In the literature and in past practice, it has been common to assume that the $CO_2$ capture rate is capped at 90%, i.e. $CO_2$ capture technology can only abate a maximum of 90% of the emissions associated with a given power station. This means that there are inevitably residual $CO_2$ emissions which, in the context of a net zero emissions scenario, must be offset. However, it has been recently demonstrated that near zero emissions from CCS power plants is possible at a limited marginal cost relative to the cost of a conventional process with 90% capture[1]. In this study, it was observed that increasing the $CO_2$ capture rate beyond 90% had the effect of increasing CCS capacity deployed and also increasing the capacity factor of the underlying thermal power plants. Thus, future modelling exercises should recognise that greater than 90% capture is feasible, and may, in fact, reduce total system cost.

A final important observation from this study was that, in no system, was CCS observed to significantly reduce the deployment of renewable capacity. Further, in all cases, owing to their near-zero marginal cost, renewable power was found to dispatch ahead of CCS power. This remained true even in the case of the USA, where the 45Q and 48A tax credits for CCS were included. The effect of these tax credits was to privilege CCS-equipped coal, gas and biomass over their unabated counterparts, but not over the renewable alternatives. In other words, it is not a case of "CCS **or** renewables", but rather one of "CCS **and** renewables".

While this report and the supporting research has identified a clear value for the role of CCS, both in ensuring that electricity demand can be met and offering the lowest total investment to do so while decarbonising, it is important to note that only the power sector was considered in this work. While a full-economy decarbonisation is outside the scope of this work, it is likely that electrification would need to occur under such a scenario, and therefore the decarbonisation of the power sector is integral to this transition. Given that this study did not assume any increase in electricity demand, it is fair to conclude that the value of CCS discussed throughout the study report is a conservative estimate.

Following the views of its members, IEAGHG has had a focus on the "value" of CCS in recent years. The undue emphasis on the "cost" of the technology has been widely attributed, at least in part, to its lack of uptake. Concerns of cost notwithstanding, it is nevertheless true that CCS technology is technically mature and commercially available today. All elements of the CCS value chain -- capture, transport and storage -- have been demonstrated around the world for decades.

The value of CCS may refer to the benefits of the technology to provide more of the required power grid services or indeed to the broader economic and social benefits offered by a technology, e.g. the impact its adoption and deployment has or would have on GDP, jobs, welfare and international trade.

IEAGHG studies, completed and ongoing, that explicitly address the value of the technology include:

- IEAGHG, "Operating Flexibility of Power Plants with CCS", 2012/06, June, 2012.
- IEAGHG, "Valuing Flexibility in CCS Power Plants", 2017/09, November 2017.
- IEAGHG, "Beyond LCOE: Value of technologies in different generation and grid scenarios", to be published.
- IEAGHG, "Defining and measuring the value of CCS", Study to begin early FY2020.

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[1] IEAGHG, "Towards zero emissions CCS from power stations using higher capture rates or biomass", 2019/02, March 2019.