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The inclusion of Bio-energy with carbon capture and storage (BECCS) in Integrated Assessment Models: Assessing legitimacy within published climate discourses

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Abstract

This thesis assesses the discourses identified in the literature that is critical to BECCS and its inclusion in IAMs used in the construction of RCP2.6 through a Foucauldian inspired discourse analysis. Within this analysis, there is a recognition of the resilience and civic environmentalism discourses that challenge the dominant and incumbent discourses in climate governance; green governmentality and ecological modernisation.

This study has also assessed how the literature has implicitly and explicitly confronted the legitimacy that have offered credibility to the inclusion of BECCS in the construction of IAMs used for the achievement of RCP2.6. The predominately source and process-based legitimacy has been questioned via a thorough amount of research that investigates individual assumptions that are commonplace in said IAMs.

Keywords: BECCS, Discourse, Governance, IAMs, Legitimacy, Sustainable Development.

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Summary

This thesis assesses the discourses apparent in literature that is critical to the negative emission technology Bioenergy with Carbon Capture Storage (BECCS) and its inclusion in integrated assessment models (IAMs) used in the construction of Representative Concentration Pathway 2.6 (RCP2.6) through a Foucauldian inspired discourse analysis. Within this analysis, there is a recognition of the emergence of the resilience and civic environmentalism discourses that seek to challenge the dominant and incumbent discourses in climate governance; green governmentality and ecological modernisation.

This study has also assessed how the literature has implicitly and explicitly confronted the legitimacy that have offered credibility to the inclusion of BECCS in the construction of IAMs used for RCP2.6. The predominately source and process- based legitimacy has been questioned via a thorough amount of research that investigates individual assumptions that are commonplace in said IAMs. This new research, in turn, offers a fresh form of mostly process-based legitimacy that is arguably more credible than the processes used in the dominant discourses in climate governance.

Keywords: BECCS, Discourse, Governance, IAMs, Legitimacy, Sustainable Development.

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1. Introduction

1.1 Introduction to BECCS

Bioenergy with carbon capture storage (BECCS) is a Negative Emission Technology (NET) that is touted as being one of the key technologies to be implemented as a tool of mitigating the impending effects of climate change (Kriegler et al, 2013). The process of BECCS extracts CO₂ from the atmosphere both from the photosynthesis of the crop feedstocks (Williamson, 2016) and via the storage of liquefied (Williamson, 2016) CO₂ in depleted oil/gas reservoirs and saline aquifers (Gough & Upham, 2011) post-combustion. This dual technique of carbon dioxide removal (CDR) in conjunction with providing energy and biofuels (Gough & Upham, 2011) (where conditions permit) makes BECCS a particular point of interest in future climate change governance and policy making (Anderson & Peters, 2016).

The extensive implementation of BECCS over the 21st Century is included in 87% (101) of 116 climate scenarios that are consistent with >66% probability of limiting warming below 2 °C (Smith et al,2016). These scenarios are contributed, as part of the IPCC's Fifth Assessment Report (AR5), to the United Nations Framework Convention on Climate Change (UNFCCC). RCP 2.6 is the Representative Concentration Pathway that roughly corresponds with the target to limit global warming to 2°C, compared to pre-industrial levels. The 'well-below 2°C goal' was famously agreed upon as the benchmark to aim for (Geden, 2016) as part of the Paris Agreement at the 21st Conference of the Parties (COP21) to the UNFCCC. The 'well-below 2°C target' is more ambitious than what is represented in RCP2.6.

The astonishing requirements of BECCS, in many of the climate scenarios, demand that the NET will be responsible for sequestering more CO₂, in the second half of the century, than is emitted from all other sources across the globe during the same period (616GtCO₂) (Gough & Vaughan, 2015; Fridahl, 2017). As BECCS is still in an embryonic phase, predictions about its potential capacity are debatable when there has only been a small amount of research into spatially disaggregated implementation. However, it can be claimed that the concept of BECCS is attractive to policy makers (Anderson & Peters, 2016) as the facilitation of higher near-term emissions via the implementation and utilisation of BECCS allows time for further technological advancements to curtail the degree of near-term expense associated with many forms of emissions abatement (IPCC, 2014).

1.2 Aim and Research Questions

The aim of this paper is to analyse the rationales behind the climate discourses and forms of legitimacy prevalent in the scientific literature that discusses the inclusion of BECCS in climate scenarios. The paper contributes to the research on BECCS and its role in climate modelling. This thesis' unique contribution to research on BECCS is the analysis of how the NET's inclusion in IAMs is questioned (or not) in the analysed climate modelling literature.

The research questions for this thesis paper are as follows:

- Through which discourses does literature on climate modelling criticise the inclusion of BECCS in the IAMs used to model RCP2.6 scenarios?
- Which forms of legitimacy are drawn upon to criticise the inclusion of BECCS in the IAMs used for RCP2.6?

This study builds upon the literature on BECCS and its inclusion in the integrated assessment models used in RCP 2.6. The paper considers some of the political and economic rationales that have influenced and continue to influence discourse agendas involved in the realm of climate mitigation. The study also recognises the counter-discourses that are identified in the literature and the origin that they have arisen

from. It further contributes to the growing amount of literature on BECCS (Minx et al, 2017, Minx et al, 2018), and its role in climate mitigation, since the advent of COP21. This expanding body of literature requires an investigation into the discourses involved in their creation. Hence, this paper focuses on some of the emergent discursive narratives that are critiquing the legitimacy of the inclusion of NETs, such as BECCS, in the IAMs that have been used in the construction of RCP2.6.

2. Background – Climate Science & Climate Governance

This study includes a background section to provide a contextual overview of the research that has already taken place on the interlinking topics of the production of climate science, climate governance and governmentality, climate mitigation, and BECCS. The background section covers various factors that have contributed to the debate of the legitimacy in climate science and climate governance. It is imperative to provide a contextual background of this legitimacy in order to fully understand the current framing of BECCS in climate modelling projections and climate policy making. There are summaries of the history of CCS and the history of BECCS as well as a breakdown on the creation of climate modelling and the specific models used in RCP2.6.

2.1 History of CCS

It is necessary to give a brief overview of the history of Carbon Capture and Storage (CCS) before focusing on the concept of BECCS. CCS is widely regarded as an essential technology if the world is going to meet the targets specified in the 2015 Paris Agreement (Anthony, 2018). Since the advent of CO₂ emissions being recognised as one of the primary drivers of global warming, there have been ideas of discounting the future costs of climate change through methods of climate mitigation, CCS being one of these methods.

Since Cesare Marchetti explored the idea of CCS via permanent underground storage in 1976-77, the concept has been utilised as a tool for mitigation. Especially when fossil fuel emissions became a prominent political concern during the 1990s (Evar, Armeni & Scott, 2012). With the advent of a CO₂ emissions tax imposed in Norway on off-shore industrial installations, it became economically attractive to have a method of CCS in place for energy companies such as Statoil (Evar, Armeni & Scott, 2012). Since then, there have been a handful of large-scale demonstration projects of CCS that have continued to capture and inject over a million tonnes of CO₂ per year (Evar, Armeni & Scott, 2012).

There are different CCS techniques but the one that BECCS primarily uses is post-combustion. BECCS can also be introduced at a pre-combustion stage of energy production via an integrated gasification process (Fantozzi & Bartocci, 2017). However, this process can involve significant upfront capital costs (Di Lorenzo et al, 2013) whereas post-combustion CCS technology can be added to certain plants via a retrofitting process. CCS is a popular option in IAM mitigation portfolios as it can be integrated into pre-existing systems without the necessity of large-scale and costly amendments to the system (Bui et al, 2018). BECCS has the “double benefit of mitigating emissions and generating energy, making it attractive from the cost-optimisation perspective of an IAM.” (Bui et al, 2018 pp. 1066). Despite the popularity of CCS (and specifically BECCS) in IAM decarbonisation scenarios, its current rate of deployment has not come close to reaching the levels that are indicated by the projections of the IAMs and decarbonisation roadmaps (ibid) with CCS only appearing within a smattering of the NDCs pledged at COP21. A recent model inter-comparison project, to which eighteen IAMs were contributed, found that the use of CCS, although varying widely from model-to-model, projected at least 600Gt (range of 600Gt-3050Gt) of CO₂ being captured and stored by 2100 (ibid). This amount is more than half than the required emissions reductions that are consistent with a 2°C pathway. This sheds light on the importance of CCS and the magnitude of its role in decarbonisation pathways (ibid).

Research continues into CCS and how to make it more efficient and cost-effective, especially in relation to the storage of the compressed CO₂. CCS can also be used as an option in existing fossil fuel power plants, see Anthony, 2018 for further information.

2.2. History of BECCS

BECCS started as an idea from Kenneth Möllersten, a Swedish PhD student that considered finding financial benefits for the Swedish paper industry from the carbon market after the introduction of the Kyoto Protocol (Hickman, 2016). This was taken up further by Möllersten and his PhD supervisors Jinyue Yan and Mats Westermark (Obersteiner et al, 2001). Möllersten later went on to work with his now colleague Obersteiner, the two scientists that were involved in the early stages of BECCS development (Hickman, 2016). This duo, along with a collection of other scientists, were quick to develop the idea after coming to the realisation that there was the possibility of obtaining double the amount of carbon credits for avoided emissions at a pulp and paper mill using the technique of CCS. In their 2001 paper titled ‘Managing Climate Risk’, they made reference to BECCS [then classified as purely BECS] on eleven occasions (Obersteiner et al, 2001). By utilising this new technological innovation as a tool to fix the ongoing climate change ‘dilemma’, the authors described the possible incorporation of BECCS into an extensive risk management scheme that focused on mitigation. Within the paper, the largest limitations recognised for BECCS are the projected high costs of installation with a single mention given to the required research needed in order to figure out how to use BECCS as a sustainable technology in a ‘wider sense’ (Obersteiner et al, 2001).

Obersteiner claims (Hickman, 2016) that, as the self-proclaimed founder of BECCS as a tool to allow for ambitious climate targets, that the use of the NET in a risk management scheme was misinterpreted and consequently misused in emission pathway scenarios within global climate governance. He criticises IAMs for being deterministic and for not allowing room for critical risk management thinking (Hickman, 2016). Much like Kevin Anderson, one of the critics of BECCS’ large-scale implementation (Anderson & Peters, 2016), Obersteiner states that BECCS should be used as a backstop technology that can be potentially used to deal with sudden climate feedbacks and abrupt shocks to the system, Obersteiner reiterates that plans for conventional methods of climate mitigation should be made with BECCS to be used only as an optional backstop if required (Hickman, 2016).

When interviewed (Hickman, 2016) about how the concept of BECCS came to realisation, Möllersten used interesting terminology when the idea first occurred to him about the potential capabilities of the BECCS model. From analysing the pulp mill that he was focusing on for the purpose of his PhD, he could conceive the extraction of three commodities from the mill processes; electricity, industrial heat and negative emissions (Obersteiner et al, 2001). Negative emissions were instantly recognised as a potential commodity, perhaps given the rise of interest in carbon markets around the same time. This labelling of negative emissions as a commodity could be seen as a precursor to how BECCS is considered as a cost-effective mitigation tool in climate modelling scenarios that contain assumptions about enviro-economic policies (Gough & Vaughan, 2015; Larkin et al, 2017) that include a market-incentive approach to the use of BECCS (Read & Lermitt, 2005).

As a group of scientists coalesced over the potential benefits of BECCS around 2001, it wasn’t long before there were thoughts vocalised about possible dangers of using BECCS on a planetary scale. David Keith (Hickman, 2016) appreciated the reversal of environmental damage through the mass-reduction of carbon emissions but was also quick to point out that the large-scale use of cropped biomass would carry its own dangers. BECCS continued on its journey towards global prominence in the climate change discourse, Keith stated that he feverishly pushed to have BECCS included in an IPCC special report on CCS in 2005 (Hickman, 2016). This could have been the tipping point that led to BECCS being included in emission pathway scenarios towards 1.5°C-2°C of global warming. Van Vuuren (Hickman, 2016) acknowledged model teams picking up on the idea of BECCS around 2005.

It was around 2005 that the climate model scenarios with 450ppm of CO₂ in the atmosphere as a set target were perceived to only have a 50% chance of being achieved, therefore new scenarios were required to provide a better chance of limiting global temperature rise to 2°C. This requirement led to

IMAGE publishing a set of scenarios that included BECCS. These scenarios were published in 2007 but picked up further traction during an IPCC expert meeting where the scenarios were elected for further research to look into the climatic impacts, i.e. to see if they were conducive to the achievement of RCP2.6 (Hickman, 2016). Eventually this led to the compiling of AR5 in 2014 that contained 114 scenarios that aligned with RCP2.6 (Hickman, 2016), 87% of these scenarios contained BECCS as the stand-out NET.

As can be seen, BECCS, in little over a decade, has evolved from an idea to amass extra carbon credits for Swedish paper mills to a negative emission technology that seemingly underpins the majority of IPCC's climate modelling scenarios that limit global temperature rise to 2°C. BECCS has undergone a transformation from an industry-specific tool to one that is reliant on several different types of biomass feedstocks to be cultivated from various locations across the world. BECCS has undergone a drastic rise to prominence in climate science.

3. Global Climate Governance – The Creation of Climate Modelling

Global Climate Governance is probably best exemplified by the international treaties overseen by the UNFCCC. The concept of Global Climate Governance materialised onto the political spectrum on the back of the first Earth Summit (now titled Conference of the Parties) in Rio de Janeiro in 1992. However, this is not the only example of climate governance on the international stage; there is a multitude of predominately smaller mini-lateral climate forums that have sprouted up in recent decades representing the interests of a collection of stakeholders (Karlsson-Vinkhuyzen & McGee, 2013). Global environmentalism has been picking up traction since the 1990s and with its expanse in notoriety, climate science and its practitioners have received the necessary funding and technical support to amass immensely powerful tools of simplification. These tools make it feasible to take complex areas such as forests, deserts and other complex ecosystems and standardise them into an undifferentiated mass of orderable data that can be duly managed (Gupta et al, 2012). This form of simplification could be especially relevant in the current production of climate modelling scenarios despite complex IAMs attempting to extrapolate results from spatially disaggregated regions.

Global climate governance has brought about a previously unseen type of accountability which is unique in the sense that the global scale of the challenge complexifies the necessity of accountability on a regional level (Gupta et al, 2012). The formations of the global carbon market called for a spatial disaggregation of the entire global carbon cycle for purposes of accountability (Lövbrand & Stripple, 2011). Now the territoriality of carbon has been established, it is possible to theoretically register and measure stocks that 'belong' to signatories of international climate treaties such as the Kyoto Protocol (1997) and the more recent Paris Accord (2015). The quantification processes involved in climate science on a global level are complex to begin with but when trying to measure dynamic and changeable flows within a conventional geopolitical framework, the plot thickens. These complex methodological processes, necessary to report on a regular basis to the UNFCCC secretariat in Bonn, are further compounded by actors that are involved in the realm of climate politics. Although climate science has now been rendered intelligible to policy makers at a state-level, it can be said that it has possibly circumscribed the available responses to the impacts of climate change due to the convoluted abstraction process that preceded its legitimacy (Lövbrand & Stripple, 2011).

Climate models and scenario projections are integral aspects of understanding how governments can shape and formulate climate policies in order to ensure a transition to a sustainable and equitable future for all (van Vuuren et al, 2014). However, the inputs and influences on the production of these climate models can come under critique for being overly assumptive or omitting. Throughout the IAMs that include the mass roll-out of BECCS, the inclusion of the NET is based on a number of constraints and assumptions that are inherent within the models (Gough & Vaughan, 2015). The inclusion of these constraints and assumptions could be the result of how certain discursive narratives have shaped the manner in which climate mitigation is discussed and how certain NETs are considered.

For the purpose of context, here is an outline of how climate model scenarios come to fruition:

There is a base of five Shared Socioeconomic Pathways (SSPs) that are used to provide a conceptual foundation for a range of Integrated Assessment Models (IAMs) that analyse and make projections for future conditions in global society. These IAMs could lead to each level of the Representative Concentration Pathways (RCPs), which are projections of GHG concentration levels that result in radiative forcing (Ritchie & Dowlatabadi, 2018). The RCPs were developed and constructed by the IAM community, a community that continuously struggles to account for the nature of climate policy interventions and possesses embedded policy assumptions concerning mitigation (Kriegler et al, 2014). The ambitious pathway used in AR5, RCP2.6 has the benchmark radiative forcing that could be achieved via a myriad of climate policy options that have the likelihood of reaching the stated goal of the stabilisation pathway (Beck & Mahony, 2018). The construction of the RCPs for AR5 were outsourced to the IAM community so the IPCC could maintain their impartiality as solely an assessor opposed to a producer of climate science and knowledge (ibid). The IAM scenarios for the purpose of RCP2.6 (IMAGE) can be critiqued for being politically charged as well as being overly speculative and optimistic with their embedded assumptions (ibid), especially in regards to technological improvements and yield capacity in the latter part of the century. This form of modelling towards a fixed target of radiative forcing is a drastic change in the way that models are constructed. This shift in model construction laid the foundation for the vast inclusion of BECCS in the IAMs that may well not have been included in the conventional SRES¹ scenarios (ibid) offered by the IPCC.

There is a huge range of data that is fed into IAMs, the sheer complexity of this range of data is near impossible (Wesselink et al, 2015) to quantify and measure when taking all external influences and drivers into account. Thus, there is a call to simplify and make comparisons (Pattberg & Stripple, 2008) in order to be able to break down the figures to a scale that can be contained within the boundaries of national and political borders. This simplification is deemed necessary when countries are required to submit their policies that are connected to future emission reductions. This compounding and then disaggregating of data make the figures conceivable and tangible for policy makers. However, the compiled information can be partially based upon historical trends in innovation and predicted progressions in politics as well as other projections that are vulnerable to external shocks and influences (van Vuuren et al, 2011a). Therefore, although the data is now supposedly understandable and useful for reasons of practicality, it may be misleading and could be an example of the dangers of reductionist science (Hulme, 2011). However, some may argue that the reductionism of science can lead to melodramatic climate determinism that can insert itself into contemporary public and political discourse (Hulme, 2011). The uncertainties involved in the creation of IAMs may explain why many modellers that work with IAMs insist that they are not making predictions about the future, but instead are exploring hypothetical development trajectories (Hansson, Haikola & Fridahl 2018).

Climate modelling is an inherently complex process that attempts to account for a large number of factors that are near impossible to quantify and predict with any great degree of accuracy (Geden, 2016). This, of course, produces a large amount of uncertainty due to the multitude of variables involved while trying to analyse such huge quantities of dynamic and changeable data (Foley, 2010). Consequently, the integrated assessment models are capable of producing a plethora of scenarios, some of which align with the specific criteria of individual representative concentration pathways (van Vuuren et al, 2014). As these models are run many times over, there are numerous possibilities for scenarios to be produced that consider different causal effects and probabilities of socioeconomic impacts on climate policy, global behavioural trends and climate sensitivity (van Vuuren et al, 2014). For the purpose of the IPCC's Fifth Assessment Report, there were 300 baseline scenarios and 900 mitigation scenarios collated (IPCC, 2014) from integrated modelling teams from around the world. The 900 mitigation scenarios contain many simplifications and differences in assumptions and therefore output generated by the different models can differ greatly. The authors of the Fifth Assessment Report note that "projections from all models can differ considerably from the reality that unfolds" (IPCC, 2014 pp.51). This span of scenarios has been constructed to reach certain mitigation goals and possess very different assumptions

¹ Special Report on Emissions Scenarios

about “energy demands, international cooperation, technologies, the contributions of CO₂ and other forcing agents to atmospheric CO₂eq concentrations, and the degree to which concentrations temporarily exceed the long-term goal” (IPCC, 2014 pp.51) i.e. overshoot the carbon budget with the plan to use negative emission technologies (predominately BECCS) to take the world’s carbon budget back within the desired parameters.

This paper will not delve into the intricacies of the science of BECCS that includes varying points of controversy. However, it is important to recognise that BECCS is not simply the capture of CO₂ via photosynthesis and then again during the combustion phase of the feedstock’s lifecycle (Fuss et al. 2012). Once the CO₂ has been captured, it must be safely stored in a location for up to some millennia. A location that is deemed impermeable can still be vulnerable to external shocks that could allow the CO₂ to seep back into the atmosphere and still contribute to exacerbating the catastrophic impacts of climate change (White et al, 2003). These grandiose storage locations are expected to be mostly depleted oil and gas reservoirs, and saline aquifers. This is where there are further potential issues at hand in regards to implementation. BECCS, like many other NETs, could be described as a moral hazard (McLaren, 2012) if it is not suitably governed. The purpose of BECCS is to reduce atmospheric levels of CO₂ on a global level, which of course is in the best interest of the entire global society. Alas, there is still potential for geopolitical skulduggery when it comes to selecting the locations of where to store this amassment of liquefied CO₂. The negotiations over the implementation of BECCS infrastructure will be intensely political and there are serious risks of injustice if not managed in an equitable manner (McLaren, 2012).

Although not fully corroborated in the realm of scientific academia, there is a concept titled ‘carbon colonialism’. This new form of colonialism refers to post-industrial countries imposing the greater responsibility of planetary-wide climate mitigation onto the Global South (Bachram, 2004). This imposition would manifest itself, in the context of negative emission technologies, by having large swathes of (mostly arable) land (Heck et al, 2018), for the purpose of growing bioenergy feedstocks, being gobbled up by private interests. These private interests would be acting under the remit of sovereign states that have ambitious mitigation goals due to breaching the carbon budget in the first quarter of the century (Sundin, 2017). Since the publication of AR5, the discussion over BECCS, and its inclusion in IAMs, has become highly politicised and controversial. This thesis study looks to investigate the relevant discourses and forms of legitimacy that are embroiled in this politicised discussion.

3.1 Integrated Model to Assess the Global Environment (IMAGE)

IMAGE is an Integrated Model to Assess the Global Environment (NEAA, 2014) and was put together by the Netherlands Environmental Assessment Agency. It is the Integrated Assessment Model that was used in the construction of RCP2.6. This section provides a brief overview of the model and highlights its connection and reliance to the use of BECCS.

IMAGE is an ecological-environmental model framework that runs simulations of human activities and what environmental consequences would stem from them. There are numerous summaries that are made available to the general public and policy makers which have easily understandable data and information. However, the science that goes into the model is not available as a downloadable software as the models are deemed ‘too complex and require expert use’ (NEAA, 2014). There is a 370-page document that is classified as an overview of the IMAGE climate model.

This 370-page overview includes IMAGE model simulations that have policy interventions that are especially relevant in the global energy sector. There is an assumption made that there is an imposed maximum or minimum share of the global energy matrix to be provided by non-fossil fuel energy resources such as conventional renewables, nuclear, CCS and bioenergy (NEAA, 2014). The policy

interventions that would bring about this political reform are difficult to foresee as the nature of international and geopolitical affairs can often be turbulent and unpredictable (Brooks et al, 2005).

“In the IMAGE framework under nearly all scenarios, the combination of bioenergy and CCS [BECCS], and CCS in general, plays a critical role in achieving the 2 °C target.” (NEAA, 2014 pp.95)

As can be seen from the quotes featured above and below, there is a direct reference to the use of BECCS in scenarios where emission reductions have been continuously pushed back.

“A delay in emission reductions limits the flexibility in the portfolio of emission reduction options. Such delayed scenarios rely more on the use of bioenergy with carbon capture and storage (BECCS), an option with uncertain prospects for large-scale implementation.” (NEAA, 2014 pp.307)

The model overview also includes information about the implications of heavy reliance on bioenergy, this includes impacts on food prices and competition for water that could be used for irrigation which is then diverted for the purposes of coolant in power plants (NEAA, 2014). The overview claims that the IMAGE 3.0 model possesses the capacity to generate a widely diverging set of indicators for different regions across the world; and can therefore incorporate numerous synergies and trade-offs that would be key discussions points within climate policy negotiations (NEAA, 2014).

IMAGE was used to develop RCP2.6 and helped in the coordination of work that went into the overall development of the RCPs (van Vuuren et al, 2012; NEAA, 2014). The remaining three RCPs (RCP4.5, RCP6, RCP8.5) were all developed with the utilisation of different climate modelling teams. RCP4.5 was developed by the GCAM modelling team. RCP6 was developed by the AIM modelling team. RCP 8.5 was developed in Austria using the MESSAGE model and also the IIASA Framework. (van Vuuren et al, 2011a)

The IMAGE overview states that the model is ‘relatively strong’ in the way that it portrays the physical world in its Earth system subsection, and also the resource and technology choices in the Human system subsection (NEAA, 2014). However, it goes on to describe several limitations in the model, one of which could be of imperative importance:

“A model run starts in 1970, which implies that 2010 is model output. The model is calibrated against historical data up to 2005 and to 2010, depending on the module, which has implications for applications that use IMAGE output for the 2010-2020 period” (NEAA, 2014 pp.52)

With model output starting from 2010, humanity is currently sitting in a period that is both unaccounted for in the models and does not correlate with the anticipated output produced by the models. There are also two other limitations that are mentioned that are related to the unpredictability of governance on a national level:

“Detailed, differentiated processes at local scale and national policies are represented as part of global region trends, without taking into account country-specific measures and processes.

The physical orientation implies that the model is well adapted to study technical measures to achieve policy goals, but less so to study specific policies. Some policies, such as a carbon tax, can be represented but others, such as R&D policies, cannot. The model has no representation of governance systems, which tend to be handled as exogenous (variant) scenario parameters serving as proxies.” (NEAA, 2014 pp.52)

These limitations shed light on the variances in the IMAGE model that cannot be adequately accounted for.

IMAGE contains a subcomponent named TIMER. The key takeaway point from the TIMER (The IMage Energy Regional) model component of the IMAGE IAM (NEAA, 2014) is that the energy forecasting model sets an assumptive permit price (i.e. a carbon tax) on emissions. This predicted carbon tax will make low and zero carbon energy providers comparatively more cost-effective than the conventional fossil fuel options (van Vuuren et al, 2007). This assumed price on carbon emissions can potentially catapult BECCS, along with other NETs, to the forefront of the minds of policy makers when considering cost-effective pathways when laying out mitigation roadmaps.

3.2 CO₂ as a Commodity

Carbon trading has proliferated the utilisation of CO₂eq to the extent where it acts as a tradeable form of currency available for exchange on the free market; it has become abstracted from the original sets of complex data that came to be a quantifiable form of GHGs. (Paterson & Stripple, 2012).

The fact that carbon (stocks and emissions) can be traded on the open market and is open to vulnerabilities and shocks in the market is due to the gradual process of standardisation in the manner that carbon stocks are measured and become commensurable (Paterson & Stripple, 2012). The ‘pixilation of carbon’ is a term coined by Paterson and Stripple (2012) to describe the degree of abstraction that takes place when attempting to quantify large amounts of carbon from various sources. “This virtualisation of carbon simultaneously embodies the moral character, or the virtue, of the commodity being traded.” (Paterson & Stripple, 2012 pp. 569) This quote from Paterson and Stripple, exemplifies the way that through the process of making carbon measurable on a virtual platform, it can then be easier to transform into a virtual commodity that is tradeable on the open market.

This carbon marketplace and the desire for offsets has paved the way for further commensurability and trading of other greenhouse gases (GHGs) (Bryant, 2015). Over recent years the commensurability of greenhouse gases and levels of emissions has opened a marketplace for CO₂eq (Ormond & Goodman, 2015) and, in turn, its abatement via a multitude of methods ranging from reforestation schemes to large-scale implementation of negative emission technologies. The materialisation of the concept of CO₂eq is an important example that can be used to understand the communication processes between climate scientists/researchers and climate policy makers. The science behind various greenhouse gases is complex and gases can have varying effects on the atmosphere depending on their concentration, locality and molecular make-up (Rao et al, 2017). However, for it to be understood at ease at the level of international policy making, it is desirable to discuss the accountability and adaptation to GHGs in a standardised form of numeric measurements (Paterson & Stripple, 2012). This global trading platform is founded upon data that has been compounded, simplified and abstracted (Rosen et al, 2004) through its long journey towards becoming measurable, comparable and ultimately tradeable (Rosen et al, 2004). In the pursuit of classifying CO₂eq as a currency, there has been a streamlining of science to such a degree that socioeconomic contexts are not duly considered during the divvying up of global mitigative responsibilities (Ormond & Goodman, 2015).

“One of the important effects of this way of understanding carbon market politics is to show how the imaginations of carbon commodities are immediately normatively infused in ways that render resistance problematic. As is well known, there are major critiques made of carbon markets, opposing them variously on the grounds that they fail to reduce emissions (‘climate fraud’) that they are essentially colonialist in the way they entail appropriation of atmospheric space by the North and externalisation of emissions reductions via offset projects (‘carbon colonialism’), that the atmosphere should simply not be commodified, that they act as a sort of ‘new indulgences’, with rich consumers assuaging their guilt via offsetting, or most recently that they constitute ‘subprime carbon’, with the possibility of bubble economies and collapses similar to the 2007–2009 financial crisis. These critiques have been widely adopted by what is often called the climate justice movement.” (Paterson & Stripple, 2012 pp. 569)

The marketisation of carbon, and in turn, greenhouse gases, draws parallels with the debate over the commodification of ecosystem services (Costanza et al, 2014). By using marketing frameworks in global climate governance there is a risk that the discussions around the implementation of negative emission technologies such as BECCS fail to address the idiosyncratic practicalities at a local level; both in terms of feasibility of implementation and projected negative externalities that could arise as a result (Gough & Vaughan, 2015).

3.3 The Emissions Gap

Millar et al (2017) report on the inconsistencies between the projected emission pathways, from 2010 to the current date, and what has been observed in reality. The decoupling of projections and reality between 2010-2017 hints at the world's emissions following a pathway that aligns with a pathway with a greater radiative forcing than 2.6. Therefore, there are calls for more stringent and rapid mitigation measures to be implemented (Millar et al, 2017). BECCS is notably absent from the vast majority of the NDCs submitted to the UNFCCC as part of the Paris Accord. This absence has contributed to the dubbed 'emissions gap' (Millar et al, 2017) between NDCs and the emissions scenarios that are consistent with 1.5°C – 2°C of warming. The below quote from Anderson and Peters (2016) exemplifies the notable absence from official climate policy discussions involving nation member states that take part in UNFCCC climate negotiations.

“Given such a pervasive and pivotal role of negative emissions in mitigation scenarios, their almost complete absence from climate policy discussions is disturbing and needs to be addressed urgently.” (Anderson & Peters, 2016)

The scenarios that align with RCP2.6 require a rapid decarbonisation in much of the global infrastructure. “Rapid decarbonization relies on societies being able to swiftly replace existing capital with new investments at massive scales. Inertia within the economic system is an important constraint on realizable mitigation pathways” (Millar et al, 2017 pp. 745). The associated capital displacement that would come as a result of replacing and retrofitting the existing fossil fuel infrastructure will have significant economic ramifications for certain business stakeholders. These stakeholders with vested interests could allegedly have an influence on the international climate negotiation process and subsequent policy making (Kreitman & Masson, 2017).

“[B]usiness uses a range of political strategies to influence directly or indirectly the formation, maintenance, and disintegration of global environmental regimes. They are indeed recognized for using their technological knowhow and expertise in innovation to find solutions to specific climate change and energy problems, such as the substitution of fossil fuels for renewable ones, and for directly influencing the global climate change regime through participation in some of the country official delegations. Influence can also be indirect through the structural power of large corporations in the economy or the implicit threat of relocation (Levy and Newell 2005). This refers to the ability of multinational corporations to influence the formation and functioning of governance through their dominant position in the global economy, which allows them to shape mainstream ideology and state-policy formation.” (Andrade et al, 2015 pp. 380)

The influence of accredited business and industry non-governmental organisations (BINGOs) at multi-lateral negotiations has been well-documented and assessed (Andrade et al, 2015) in recent years and there is growing concern over the level of influence that these organisations, and the companies that fund them, have at the highest level of climate governance (Greens/EFA, 2018). One of the roles of BINGOs is to represent the interests of their members in the political processes via offering position papers and networking with relevant political stakeholders present at international negotiations such as the UNFCCC's annual Conference of the Parties. This array of formal and informal lobbying facilitates the implementation of political strategies that stem from the private-sector (Andrade et al, 2015) into the negotiations process. The below quote from Andrade et al's (2015) work on 'The Role of the Private

Sector in Global Climate and Energy Governance’ summarises the manner in which business actors can enforce their agenda on climate policy negotiations.

“In the negotiation of many international regimes, business actors have a formal voice on advisory technical panels and in the process of production and revision of scientific reports. These actors also play a role of knowledge-broker, providing technological and economic information in the form of technical papers and constructing what is and is not policy-relevant knowledge, as well as funding scientific projects. When analyzing multinational corporations’ political strategy on climate change, Kolk and Pinkse (2007) show that their type of political activities can be characterized as information strategies to influence policy makers toward market-based solutions, rather than withholding action on emission reduction.” (Andrade et al, 2015 pp. 380)

The persistent presence of business interests as knowledge-brokers pushes the green-growth agenda that is touted by the green governmentality and ecological modernisation discourses that are entrenched in the neoliberal economic paradigm. The influence of these business interests on climate governance can result in the widening of the ‘emissions gap’ as inertia and inaction continue to plague the progress of international climate negotiations and policy making.

3.4 Transition from Fossil Fuel Dependency

“The need for the ‘next’ energy transition is widely apparent as current energy systems are simply unsustainable on all accounts of social, economic, and environmental criteria.” (Grubler, 2012 pp. 8)

Now humanity has been described as entering the Anthropocene (Dalby, 2016), there has been discussion of the necessity for reaching ‘peak emissions’ (Grubler, 2012) and establishing strict carbon budgets (Anderson & Bows, 2011) that can be adhered to at levels varying from countries’ territories and globe-spanning corporations (Krabbe et al, 2015) to an individual citizen (Paterson & Stripple, 2010). There is an impetus for the achievement of an energy transition that does not result in a self-reinforcing positive feedback loop (Meadows & Wright, 2012) that has historically rewarded innovative technological breakthroughs and efficiency savings with renewed demand, otherwise known as the rebound effect or Jevons paradox (Clark, Auerbach & Longo, 2018). This perpetual motion that has spurred exponential growth in various sections of society (ibid) needs to be addressed if humanity’s global activity is to sustainably stay within the parameters of the planetary boundaries (Rockström et al, 2009). Therefore, a projected increase in future energy demand will have to be met by a portfolio of energy sources that will not exceed any of the stated planetary boundaries and can lead the world towards a decarbonised economy (Garcia et al, 2017).

Since the inception of Agenda 2030 and the seventeen associated Sustainable Development Goals (Unstats.un.org, 2015), there has been a renewed call for a clean and equitable energy transition. A transition away from fossil fuel dependency and towards a combination of renewably sourced alternatives. Goal 7 of the SDGs, and its principal three targets and subsequent six indicators, focuses on “ensuring access to affordable, reliable, sustainable and modern energy for all” (Unstats.un.org, 2015 pp. 8). The application of BECCS can potentially play a large-role in meeting this aspirational goal as well as being directly connected to the potential achievement of Goal 8 (sustainable economic growth and decent work) and Goal 13 (climate action) (Honegger & Toussaint, 2017). However, playing a significant role in the achievement of these SDGs can potentially pose a challenge or perhaps even work in direct contrast to the achievement of other SDGs that include Goal 2 (food security and sustainable agriculture), Goal 6 (clean water and sanitation), and Goal 15 (sustainable use of terrestrial ecosystems, sustainable forest management, combatting desertification, halting and reversing land degradation and halting biodiversity loss) (Honegger & Toussaint, 2017). For mitigation pathways and roadmaps to be deemed sustainable, they must consider the multiple impacts and resource-constraints that are factors connected to the implementation of BECCS on a large-scale.

Despite these projected trade-offs between SDGs that would occur as a result of widespread BECCS implementation, there are publications that recognise the potential that BECCS, as a flexible process, possesses in enabling an aggressive transition strategy towards the production of low-carbon energy (Sanchez et al, 2015; Sanchez & Kammen, 2016; Bui et al, 2018). BECCS' cost-effective potential is apparent by its near omnipresence in IAMs. These integrated assessment models have been referred to as "state-of-the-art" scenarios (Bui et al, 2018 pp.1067) that include CCS/BECCS dependent scenarios which are expected to cost significantly less than non-CCS scenarios.

3.5 Integrated Assessment Models – Precision and Legitimacy

Integrated Assessment Models (IAMs) have become popular with policy makers due to their holistic and interdisciplinary design combined with their objective of reaching optimal levels of cost-efficiency for the necessary transition away from high-emitting forms of industry in order to mitigate the effects of climate change (Stern, 2016). The IAMs used for the purpose of achieving RCP2.6 are geared towards emissions abatement in a cost-effective manner with a level of radiative forcing set as an ultimate goal, climate modellers have chosen to allow these models to produce projected scenarios that foresee an overshoot situation (Mander et al, 2017) and consequently call for the use of NETs (predominately BECCS) to be implemented over the course of the century, thus legitimising BECCS' inclusion in the IAMs. The reasoning behind this decision to allow an overshoot scenario in the models (consequently creating tangible options for policy makers to base decisions on) could be derived from the perceived political and public acceptance (or lack thereof) of stringent abatement measures in the near-term (Sundin, 2017) that would result in rapid emissions reductions but would demand a rapid decarbonisation of global industry as well as a re-evaluation of the incumbent economic model (Barry, 2012).

In an effort to reduce complexity within climate modelling processes, especially within integrated assessment models, there is a search for categories of similarity for the basis of measurement in order to quantify previously unquantifiable qualities (Cooper, 2015). This can lead to an abstraction that is far removed from conventional meanings and connotations (Cooper, 2015). According to Pindyck (2015 pp.100), "IAM-based analyses of climate policy create a perception of knowledge and precision that is illusory and can fool policymakers into thinking that the forecasts the models generate have some kind of scientific legitimacy."

The advent of carbon markets set the precedent for the standardisation process that has simplified aspects of climate science in order to produce tangible and understandable datasets that can be discussed, debated and traded on the international stage (Paterson & Stripple, 2012). In Paterson and Stripple's account on 'virtuous carbon' (2012), they allude to the battle between what is technologically and ethically possible in the construction of the carbon markets. For carbon trading to be effective and successful, it required the virtualisation of carbon stocks to assure commensurability. The pressures on members of the scientific and academic realm have resulted in an omission of complex data, through the standardisation of data, in order to present statistics and information that are governable and ultimately politically acceptable (Bowen & Wittneben, 2011).

There are doubts that arise over the legitimacy of the accuracy in quantifying the carbon cycle. The process of morphing overtly complex socioecological systems into a set of numerical values for the basis of climate governance requires a substantial degree of guesswork and estimation. This guesswork is based on highly technical and well-researched estimations, but it can be argued that it is still guesswork nonetheless (Yocum, 2016). The standardisation of how carbon sequestration can be quantified can raise questions about who benefits from the homogenisation process. This duly asks questions about the overall effectiveness of climate policy as the climate governance arrangements can empower or disempower different sections of society respectively (Gupta et al, 2012). Policies and scientific practices involved with accounting for carbon are, in essence, quantifying and statistically aggregating nature. This aggregation is a result of simplifying carbon stocks, stored in biomass, into units that can be calculated, compared and traded. This process allows this quantification to standardise carbon to an extent which makes it understandable and sufficiently tangible to be useful in the production of IAMs and global mitigation schemes. Social scientists have alluded to this process of

rendering forests [biomass] legible through their carbon content will only result in “other forest-related values and governance objectives, such as securing biodiversity or local livelihoods” (Gupta et al, 2012 pp. 727) being obscured. The standardisation of forests and their embedded carbon for administrative purposes to be utilised by the global economy is by no means a neutral process (Gupta et al, 2012). The knowledge practices that go into the commensurable process are susceptible and vulnerable to intervention; increasing the possibility of alterations and constraints in how the world’s ecosystems are represented (Gupta et al, 2012). The meticulous methods of accountancy in the carbon market can possess a black-box nature that hides the contingent and emergent nature of the data that is supposedly quantifiable (Yocum, 2016). The black-box characteristics of the IAMs can result in the production of result summaries for policy makers that may not show the complex set of data and methods used in their creation (Pindyck, 207).

There are claims that creating climate abatement and mitigation policies on the back of the projected findings of IAMs is a dangerous avenue to steer down as there is a veneer of scientific legitimacy that shrouds the process of formulating the models (Pindyck, 2017). It can also be argued that economists play too large of a role in the process of climate modelling and that their projections on the fate of GDP in relation to climate change effects are little more than conjecture. Pindyck (2017) states that “as economists, we need to be honest and forthcoming about what we do and do not know about climate change and its impact ... environmental economists should not claim that IAMs can forecast climate change and its impact” pp. 112).

IAMs are produced so the information and data from their results can be utilised in the application of problem-solving in the realm of climate mitigation. To conduct research in order to reach results that are applicable to problem-solving in a societal context fits a narrative that promotes the ‘usefulness’ of scientific knowledge (Lövbrand, 2011). This duty to measure has arguably created a model that is far removed from conventional climate science. It has manufactured a global carbon economy that allows policy to create budgets and baselines; thus, determining nations’ future rights to emit (Ormond & Goodman, 2015). This aspect of the co-production of science opens up a new range of questions surrounding the subjectivity of whom has the authority to deem science useful and who is it useful for. With an extensive number of experts being involved in global climate governance, there are considerable opportunities for political and corporate intervention with the science-policy interface (Gupta et al, 2012). The guesswork and estimations involved in climate science, purportedly has the potential to gain credibility when the stated facts and figures begin to resonate with particular climate narratives (Yocum, 2016) that are popular in incumbent political circles and the current ‘risk-society’ paradigm (Storm, 2009). In his 2010 assessment of the global climate modelling process, Paul Edwards brings attention to the ‘fuzziness’ of the boundaries that exist between data, theory and algorithms. The below quote exemplifies this critical issue.

“[there is] a fuzzy boundary between data, theory, and algorithms, a place deep within the practical, everyday work of general circulation modeling where modelers combine measured quantities with code to calculate the effects of processes too small, too complex, or too poorly understood to be modeled directly. These are the “semi-empirical” parameter schemes by which modelers handle sub-grid-scale processes, known as the “model physics.”” (Edwards, 2010 pp. 337)

This background section has laid out the evolution of CCS and BECCS over recent years and it also provides an overview of the creation of IAMs and what assumptions are involved in that process. With this section setting a relevant context for the thesis study, the following sections on the theoretical framework and methodology will allow the reader to see how the analysis was operationalised.

4. Theoretical Framework and Analytical Approach

An epistemological framing is required for this study for the purpose of narrowing the area of focus in what can be a very broad and dynamic field. Climate science and policy making contains varying platforms of governance that possess a myriad of factors that make for interesting analysis. However, in the interest of focusing on a specific topic and due to limitations related to time and resources, it is necessary to employ one main theoretical concept in this study.

4.1 Climate Discourses

The discourses that have been selected for analysis in this thesis study are either offshoots or bear influence from Michel Foucault's interpretation of governmentality (Foucault, 1986; Barry et al, 1996) and the power dynamics that exist within the governmentality discourse. "Power is not possessed or held, but rather circulates via networks that work through and produce different bodies, discourses, institutions and practices." (Foucault, 1980 as cited by Rutherford, 2007 pp.295) Foucault's teachings on power and governmentality have influenced a large amount of work on governmentality theory. However, scholars and academics that are familiar with the vast array of work produced by Foucault are aware that it can be tricky to deduce a strict methodological framework. Therefore, we should use his concept of governmentality as a guide or analytical tool-box to help analyse past and present forms of governance (Walters, 2012; Bäckstrand & Lövbrand, 2016).

The discursive concepts (Hajer & Versteeg, 2005) of green governmentality, ecological modernisation, resilience, and civic environmentalism provides an adequate framework for the study of the interplay between incumbent bodies of governance and the production of climate science and policy. These four discourses can be categorised into two separate nodes of discursive influence that are on display in the setting of climate governance. This section gives an overview of each of the four climate discourses and their dynamic relationship with one another.

The motivation for choosing this theoretical approach for the study was founded in prior work on governmentality that used Foucault's teachings as a theoretical base. This prior research and interpretations of Foucault's theory of governmentality sets a precedent that allows this study to focus on BECCS and how its inclusion in IAMs can be interpreted by considering aspects of eco-managerialism (Oels, 2005), based on one of Foucault's notions of productive power found in decentralised non-sovereign sections of power and knowledge (Oels, 2005). Foucault's understanding of this form of governmentality is that its power stretched further than sovereignty, and in its ubiquity, this notion of power has laid a foundation for environmental and governmental discourses to manifest on the global stage. Now, there are dynamic flows between the most prevalent discourses involved in global climate governance, some of the most notable being green governmentality and ecological modernisation. These two discourses possess an embedded influence of market-based neoliberalism. This inter-weaving of discourses and the narratives that emerge from their multiplicity have been challenged by counter-discourses in recent years; firstly, the resilience discourse in a reformist sense and then secondly, by the more radical and transformative civic environmentalism discourse.

By utilising the ideas put forward by Foucault on governmentality and power to set the theoretical and analytical framework, it is possible to operationalise an analysis of the contrasting and overlapping factors between the constantly evolving narratives within global climate governance and climate mitigation efforts. From this analysis of narratives, one can better comprehend the political rationalities in climate governance that are timely in an era of great uncertainty (Geden, 2016).

These rationalities, considered with a Foucauldian outlook on power, can be understood as a strategic situation unintentionally enforced through a number of intended actions by individuals and groups of actors involved in the environmental and governmentality discourses (Oels, 2005). Foucault makes the point that power relations are founded in a field of knowledge that sustains them, and vice versa. Therefore, exercises of power within these discourses do not use specific and objective tactics but rather,

they are an embodiment of all prior actions and decisions made within the discourse. Thus, in the chosen context, this theory allows choices and decisions to be made in the world of climate mitigation, but within a constrained setting that contains well-established parameters (Foucault, 1986). There is a range of discursive practices that Foucault would consider as asserting power, in this context, through the use of knowledge and language (Oels, 2005). The discursive practices identified in the chosen literature for this thesis study are commented upon in the results and discussion section. As there is a multiplicity of discourses present at any given time, there can be an overlapping of strategies of power between the discourses, especially as the discourses are not necessarily homogenous, nor do they have a loyal followership (Oels, 2005).

Foucault argues that the power of governance is no longer divided up in the conventional sense of sovereign states and instead relies upon an informal hierarchy of networks (Oels, 2005). In climate governance, this can be seen as shifting mechanisms of power away from nation states and towards a form of 'soft governance' where individual actors with transboundary economic interests can carry more influential clout. The idea of soft governance can be linked to the self-inflicted constraints that are prevalent in the UNFCCC and the IPCC's guidelines of stabilising GHG emissions while still sustaining economic development. In essence, the UNFCCC "does express multiple objectives and constraints, ambiguous and often incompatible, reflecting the plurality of interests represented in the regime" (Brunner, 2001, p. 8). This plurality of interests can arguably amass to be a stronger force of power than one that would be pushed forward by an individual nation state.

The following sections focus upon the interplay and contrasts apparent in this collection of discourses.

4.2 The incumbent model of governance

4.2.1 Green Governmentality

For the purpose of this study, the paper uses the following characterisation of green governmentality (Luke, 1999) to act as part of the theoretical discursive framework. Green governmentality can be considered as a complex system of geo-power, eco-knowledges and enviro-disciplines. Luke's (1999) definition of these terms bear particular relevance to contextually framing the discussion around the use of BECCS as part of a global climate mitigation technology portfolio. Eco-knowledges for example can be perceived as being constructed under techno-scientific management to maintain the planet's ecosystem services and natural resources as items of global capital. A responsible stewardship of nature is advocated by the green governmentality discourse, however, the methods that can be deemed as responsible can be open to interpretation. This framing of responsibility plays an important role in the production of IAMs and how BECCS is perceived within that context.

The green governmentality discourse possesses a set of 'eco-knowledges' (Bäckstrand & Lövbrand, 2006). These so-called eco-knowledges are made up of numerous scientific experts and advisors that are tackling issues of environmental risk management under the umbrella of sustainable development. The stewardship of nature has now become a requirement that necessitates effective and efficient global climate governance. The administrative duties of this governance include organising and ultimately legitimatising 'the right disposition of things' (Bäckstrand & Lövbrand, 2006; Foucault, 1986) between humans and nature. This 'disposition' is subjective and the principal stakeholders in the discourse have a responsibility to make sound decisions based on near irrefutable climate science. In the absence of inarguable facts, this creates a grey area (Howlett, 2014; Geden, 2016) that is difficult to govern and produce policies for. Bäckstrand & Lövbrand (2006) deem climate modelling and policy making to be part of the green governmentality discourse that can be described as being technocratic. Green governmentality can be defined as a discourse that stems from Foucault's concept of governmentality in relation to our social interaction with the natural world.

The technocratic nature of the green governmentality discourse can involve taking a broad overview of the various inputs that influence the global climate, there is a recognised risk of this leading to the discourse's protagonists becoming detached from the natural world and marginalising sections of the

world from their elitist perspectives (Bäckstrand & Lövbrand, 2006). This poses the question, “who does [this] discourse serve?” (Foucault, 1986 pp. 57). By employing a more reflexive perspective on the green governmentality discourse, international institutions and their frameworks, such as the UNFCCC, attempt to re-embed their understanding of planetary issues in a more localised context by inviting local actors to participate. These local actors possess valuable knowledge about relevant complexities on the local level (Bäckstrand & Lövbrand, 2006) and their inclusion helps to boost the democratic ideals that the UN is founded upon.

Despite this invitation to representatives from more localised contexts, there is still a long way to go to break down the well-established hierarchy that is firmly in place in climate governance and the production of climate science and knowledge. There has been a strengthening of an ideology or an agenda through a self-gratifying network of actors (Jasanoff, 2004; Latour, 2005) that frequently reference each other’s academic papers (Minx et al, 2017; Minx et al, 2018) that continue to perpetually legitimise the role of BECCS in climate mitigation discussions through shared vocabularies, theories and explanations (Lövbrand & Stripple, 2011). This construction of eco-knowledges (Luke, 1999) through the use of shared vocabularies and theories within a relatively small network of actors can serve as an example of geo-power (Luke, 1999) being established within the green governmentality discourse as these academics share a common perception on the role of climate governance and how issues of climate mitigation should be addressed.

The green governmentality discourse implies that much of the world’s natural resources, ecosystems and resilience can be assessed, measured and quantified in a quest for manageability (Rutherford, 2007). Under this discourse, large-scale scientific and institutional bodies such as the IPCC and the UNFCCC have required a continuous chain of research into climate science. This has arguably resulted in the methods of standardisation and simplification that has created a setting where the unknowable becomes knowable (Rutherford, 2007) and scientific findings that reinforce the concept that every aspect of nature can now be imagined and quantified to a degree that it ultimately becomes governable (Rutherford, 2007). It can be said that these large-scale methods of standardisation and simplification are also in-line with the ideals that are commonplace in conventional forms of science and engineering.

The green governmentality discourse lays out the discursive framework at international climate negotiations with a portrayal of the world’s ecosystems and their services as governable components that can be subject to management and control (Bäckstrand & Lövbrand, 2006). This framing of nature’s intricate make-up, combined with the simplification and standardisation of climate data, has permitted the creation of a climate governance framework that possesses a ‘global gaze’ (Bäckstrand & Lövbrand, 2006). This framework perceives technological fixes such as BECCS to be in-keeping with the win-win rhetoric that is prevalent in climate mitigation parlance (Pettenger, 2007). This win-win framing is more dominant within the ecological modernisation discourse (Pettenger, 2007), which is described in the following section.

The technocratic nature of green governmentality can also be seen within the ecological modernisation discourse. This related discourse is apparent in literature related to climate governance and the production of climate science as well as being prevalent in international multi-lateral institutions such as the UNFCCC. Ecological modernisation is defined in the following section.

4.2.2 Ecological Modernisation

The ecological modernisation discourse can act as a bridge between the green governmentality discourse and the neoliberal narrative. A ‘weak’ interpretation of the ecological modernisation discourse (Dryzek, 2013) sees a free market setting and deregulation pushing forward technological innovations that can be classed as clean development mechanisms (Okereke et al, 2009). These mechanisms are widely considered as both environmentally friendly and cost-effective. With overlapping characteristics and traits between the green governmentality and ecological modernisation discourses, there are environmental markets created such as ‘cap and trade’ and the ‘polluter pays principle’. This thesis study uses this understanding of the ecological modernisation discourse to help conceptualise the relationship between a neoliberal economic paradigm and forms of environmental

governance. The influences of neoliberalism can implicitly narrow the policy options available to climate policy makers as discursive parameters that are adhered to within discussions on climate governance and the production of climate science. Therefore, the issue of climate change can be framed less as a moral hazard and more as an opportunity to introduce cost-benefit market-based solutions to remedy past failures of the state.

As mentioned in the previous section, the ecological modernisation discourse drives the win-win narrative of green growth strategies (Bäckstrand & Lövbrand, 2016) that look to embed market environmentalism (Bäckstrand & Lövbrand, 2016) into multi-lateral levels of climate governance such as the UNFCCC. The political rationality that aligns with the ecological modernisation discourse can prove popular as the techno-optimist nature of the discourse promises opportunities for green jobs driven by innovative low-carbon technologies (Bäckstrand & Lövbrand). This green-growth agenda, spread by the ecological modernisation discourse, is a technological adaptive approach to tackling climate change through normative sociotechnical transitions that do not seek to directly mitigate or abate the causes of climate change (Gillard et al, 2016).

The ecological modernisation discourse aligns with the concept of green capitalism that seeks continuous and incremental reform to the existing political and economic system rather than rethinking and transforming the hegemonic structures that have led to anthropogenic climate change (Gillard et al, 2016). Post-development approaches have rejected the reformist narrative set forward by the ecological modernisation discourse with alternative economic paradigms such as degrowth (ibid) being discussed as method for achieving necessary levels of emissions reduction. The civic environmentalism discourse possesses a number of these post-development characteristics and is detailed in section 3.3.

4.2.3 Resilience

The resilience discourse seeks to challenge the entrenched neoliberal governmentality (Welsh, 2014) that promotes the ideologies of the incumbent neoliberal economy. This is related to the world of climate science, IAMs and BECCS as the resilience discourse questions the ‘risk society’ (Storm, 2009; Welsh, 2014) that a large portion of the world has grown accustomed to. This society that is built upon risk and uncertainties can produce vulnerabilities and crises both on societal and environmental levels. Despite this, the majority of the world currently subscribes to this neoliberal paradigm (Klein, 2007; Cerny, 2008) that has an inherent reliance on risk. Undoubtedly this has an influence on the institutions of governance and frameworks of climate science (Okereke et al, 2009).

“Resilience discourses mark a break with the modernism of the ‘risk society’ by introducing novelty, adaptation, unpredictability, transformation, vulnerability and systems into a governmental discourse that now makes the governance of uncertainty and unpredictability a hallmark of rule. In this ‘period of crisis’ versions of resilience are being mobilised to facilitate archetypal governmental technologies of neoliberalism; government at a distance, technologies of responsabilisation, and practices of subjectification that produce suitably prudent autonomous and entrepreneurial subjects in a world of naturalised uncertainty and crisis.” (Welsh, 2014 pp.16)

The resilience discourse advocates a responsible management of uncertainty and risk (Welsh, 2014). Uncertainty is a prevalent factor in the production of IAMs and consequently risk is a ubiquitous feature of climate governance and policy making. As can be seen from recent releases of information that cover a range of IAMs, accurate predictability is hard to come by (Hausfather, 2018), especially when calculating a yardstick carbon budget. There is a large degree of uncertainty, and consequently risk, involved in attempting to decide upon an emissions benchmark. The ‘budgetary’ science is arguably still in its embryonic phase and can therefore not make concrete predictions due to the sheer amount of variables involved. Some of these variables and points of controversy are implicitly and explicitly assessed and challenged within the texts chosen for analysis in this thesis study.

Resilience is a discourse that can be found in climate governance and can often draw parallels with the climate justice movement (Paterson & Stripple, 2012). However, the resilience discourse, as its name

would suggest, has ‘resilience’ as its rallying cry instead of ‘revolution’. ‘Revolution’ drawing connotations with the climate justice movement. The resilience discourse is politically neutral (Welsh, 2014) and although it seeks to potentially challenge the incumbent forms of governmentality, it does not focus upon the power and possible injustices that are involved in prevalent forms of governmentality. Resilience can be defined as a system, i.e. the world, having the capacity to absorb and tolerate shocks with an adaptive and resilient approach (Joseph, 2013). Therefore, the resilience discourse can still find its place within a neoliberal economic paradigm, perhaps with just a larger degree of caution than the other incumbent discourses described earlier. Nevertheless, resilience theory can be articulated and put into practice by societal grassroots movements as a basis of achieving a regime shift (Welsh, 2014). One notable example being resilience thinking within the expanding ‘transition town’ movement (Hopkins, 2008).

Although resilience thinking can be found in a number of emerging social and environmental justice movements, it is primarily used for the purpose of building the adaptive capacities (Wise et al, 2014) of societies to withstand the impending effects of climate change. This resilience thinking can be seen in the implementation of plans to achieve sustainable development, such as disaster risk reduction (Wise et al, 2014) and the emergence of the green bond markets (Demary & Neligan, 2018).

When adaptive approaches are taken to tackling issues of climate change, resilience thinking, in this context, does not take into account the emergent properties of socio-ecological systems and the inter-temporal feedbacks that will arise as these systems are reacting to the changing contexts in which they are located (Wise et al, 2014). Positive feedback loops (Meadows et al, 2012) can be delayed and locked-in due to the contingency of historical trends and decision-making. This adaptive nature differs from the transformative nature of the civic environmentalism discourse which is detailed further in a later section. Resilience pathways that stem from adapting to triggers (Wise et al, 2014) (environmental, social, political, and economic) hinder the flexibility of being able to transform industries and societies on an infrastructural level, this limiting of opportunities can enforce a rigidity of the current global system, and its discourses, that are averse to transformational change.

4.2.4 Overview of Incumbent Model

Green governmentality comes under the branch of eco-governmentality (Malette, 2009) that can be said to possess two discourses that can be described as competing and overlapping simultaneously (Malette, 2009). Ecological modernisation and green governmentality can be wrapped up into a discursive bundle, grouped together under the umbrella of eco-governmentality and more recently have merged into what can be described as liberal environmentalism (Bäckstrand & Lövbrand, 2016; Bernstein, 2000). Henceforth, after this section, the green governmentality and ecological modernisation discourses will be collated under the term ‘liberal environmentalism’.

The resilience discourse, although not considered in the same group of discourses that can be labelled as ‘liberal environmentalism’, still plays a part in the maintenance of the incumbent climate discourses and their influence on global climate governance. As described earlier, there are examples of the green governmentality and ecological modernisation discourses becoming merged with so many points of crossover and overlapping (Malette, 2009) that embody numerous aspects of a capitalist and neoliberal economic paradigm. The resilience discourse acts as an accepted voice of reform (Davoudi, 2016) and adaptation in this context that can be considered as legitimising the Promethean (Dryzek, 2013) path that green governmentality and ecological modernisation are taking climate governance along (McGrail, 2011). This legitimisation is achieved via the resilience discourse having minor successes in bridling and curbing the haste at which the liberal environmentalism discourses and status quo operate while resisting radical and systemic change (Davoudi, 2016). Parallels can be drawn in the world of politics with socialist agendas dissuading capitalism from exponentially heading to its own self-demise. The voice of incremental change keeps the whole capitalist behemoth alive (Streck, 2016) and extends its longevity despite still veering towards an arguably unavoidable and inequitable collapse (ibid).

Consequently, the resilience discourse finds itself positioned as a bridging discourse between the dominant and incumbent liberal environmental discourses and the challenging civic environmentalism discourse.

4.3 Counter-discourse – Civic Environmentalism

The civic environmentalism discourse, which is underpinned by a basis of resilience thinking, does not possess the same neutrality as the resilience discourse. The political rationality fuelling the discourse is deeply sceptical of the inequitable power hierarchy (Bäckstrand & Lövbrand, 2016) that the discourse perceives as being ubiquitous within current structures of climate governance. The civic environmentalism discourse would criticise the influences on climate governance and policy making from a hierarchy based upon capitalism, patriarchy, and sovereignty (ibid). Consequently, the civic environmentalism discourse, and the climate justice movement that it inspires, has a commitment to principles stemming from socialism, that look to overhaul the global capitalist system (ibid) with the commonly used mantra ‘system change, not climate change’. In the quest for systemic change, the radical movements stemming from the civic environmentalism discourse look to not simply increase regulation on forms of ‘market governance’ (Larner, 2000) and ‘soft governance’ (Oels, 2005) but to dismantle their discursive stronghold on decision making within climate governance.

There are deep-rooted scepticisms arising from the civic environmentalism discourse and the climate justice movement that perceive the global climate governance framework as being structurally unsound due to its interconnectedness with the “global capitalist order that commodifies nature and endorses neo-colonialism” (Bäckstrand & Lövbrand, 2016 pp.15). This connection to the capitalist liberal paradigm is exemplified by the green governmentality discourse advocating softer forms of governance that allow a ‘market of authorities’ (Uggla & Soneryd, 2017) to shift away from a set of mandatory regulations. This market would be comprised of corporations, NGOs, the state, and various other relevant stakeholders. Here it is possible to see how the persistence of the green governmentality discourse has brought in market-driven conceptualisation of nature and its resources that is practised by the principal agents involved in global climate governance (Uggla & Soneryd, 2017). This market influence on international institutions, such as the UNFCCC, arguably further embeds the capitalist ideology into the politically and socially acceptable transition pathways that are created by climate modellers.

The civic environmentalism discourse is bolstered by NGOs such as Oil Change International and the Corporate Europe Observatory (Leino, 2017) that have been protesting against the decision to permit corporations to attend COPs and other international climate negotiations in their ‘Kick Big Polluters Out’ campaign (Kreitman & Masson, 2017). It requires further research to fully understand the depth of market influence within international climate policy making. NGOs that are proponents of the civic environmentalism discourse are often affiliated with the climate justice movement. The justice movement focuses on tackling the issue of climate change from an ethical perspective that focuses on an equitable transition and radical restructuring of the current system in order to protect the basic rights for humans and other living species (Swaffield, 2016). The civic environmentalism discourse draws attention to decision-making within climate governance and the legitimacy and accountability of these processes (Gregorio et al, 2015). The discourse is sceptical of the win-win rhetoric (ibid) spouted by advocates of the liberal environmentalism and reformist discourses while calling for transformative change that challenges the hegemonic power structures of society.

5. Methodology

The methodology for this thesis study is comprised of two components; the method for analysis and the method for data collection. The method for analysis provides an adequate framework for the discourse analysis; this is informed by the theoretical background. The method for data collection looks at the qualitative methods used to assess previous literature, critical of BECCS’ inclusion in climate models, between a specific timeframe.

5.1 Method for Analysis

The results in this thesis study are derived from a discourse analysis that focuses on the discursive practices found in the text of literature that can be considered critical of BECCS' inclusion in climate models, this is at the meso-level. At the macro-level, the analysis assesses the interdiscursive societal and political rationalities that influence the creation of this aforementioned literature.

The discourse analysis is based on a theoretical framework inspired by Michel Foucault (1986). Foucault's interpretation of governmentality has given rise to varying offshoots of governmentality discourses including the one of green governmentality. This discourse is used alongside the discourses of ecological modernisation, resilience, and civic environmentalism to set the discursive framework for this study. These four discourses can be used as archetypes for analysing the manner in which BECCS is portrayed in the chosen literature that focuses on the construction of climate modelling scenarios. These specific discourses were chosen for this study as they are the primary discourses that can embed rationales into the administrative processes of climate governance and the production of climate science (Welsh, 2014; Bäckstrand & Lövbrand, 2016). Although there have been challenges to the morphing of the green governmentality and ecological modernisation discourses into the discourse that has been labelled as 'liberal environmentalism' (Bäckstrand & Lövbrand, 2016) from a leftist perspective – i.e. from actors engaged in the civic environmentalism discourse, this liberal environmentalism approach has dominated the eco-modernist approach to governing the climate (Bäckstrand & Lövbrand, 2016) in the post-Copenhagen and post-Paris eras. The resilience discourse, as described in the theoretical framework, cannot be described as being part of liberal environmentalism but it does not directly challenge the techno-optimist, growth-centric agenda purported by the other dominant climate discourses.

Types of discourse in climate governance				
Yellow – Dominant Climate Discourses / Green– Challenging Discourse				
Aspects of discourse	Green governmentality	Ecological modernisation	Resilience	Civic environmentalism
General discursive practice (operations of knowledge production)	Shared technocratic vocabularies & examples of eco-managerialism	Shared technocratic vocabularies & examples of process optimisation	Shared technocratic vocabularies but contains alternative methodologies	Moral hazard of BECCS & questions on equity and sustainable longevity
Political rationale(s)	Delay in stringent mitigation	Techno-optimist narrative	Precautionary Principle	Climate Justice
Economic rationale(s)	Cost-effectiveness of BECCS	Cost-effectiveness of BECCS	Mitigating higher future costs of adaptation	“Borrowing from the future”

Fig 1. Table 1 | Summary of characteristics of the discursive archetypes used to identify prevalent discourse(s) in the literature that can be considered critical towards the inclusion of BECCS in climate scenarios.

[Figure one](#) displays a table that has been constructed in order to depict how the methods for analysis will be operationalised within the analysis of discourses that can be found and identified in the chosen

literature in this thesis study. The four archetypal forms of discourse prevalent in climate governance and chosen for this study are; green governmentality, ecological modernisation, resilience, and civic environmentalism. Upon recognition of the discourses apparent in the literature, the study will look at how the discourse(s) manifests itself within the literature. This will be done by interpreting the general discursive practices that are visible, implicitly and explicitly, in the texts, and the political and economic rationales that have influenced the apparent discourse(s). As can be seen in the [table](#), the resilience discourse shares aspects of both dominant and challenging narratives in climate governance. There are more discursive aspects to be found in the analysis of the gathered texts, but this table provides a useful analytical tool-box for reference.

Prior discourse analysis in this field, particularly the work on green governmentality and its interplay with the ecological modernisation discourse and the overarching neoliberal narrative, has shed light on some of the intricacies of climate governance and how discourses can affect the production of climate science, including the production of climate models. This study builds on this substantial body of research and offers new insights on how BECCS' legitimacy as a tool of mitigation is questioned due to its current role as a controversial component of the climate mitigation technological portfolio. This is done by analysing and viewing excerpts of literature on climate models through a theoretical lens.

In their 2013 paper that discusses legitimacy within global climate governance, Karlsson-Vinkhuyzen and McGee analyse three differing types of legitimacy. Source-based legitimacy, process-based legitimacy and outcome-based legitimacy. Source-based legitimacy is based on well-established expertise; legitimacy can also be gained through institutional tradition that cements permanency and respect in the field of science. Process-based legitimacy is unsurprisingly founded in procedure; on the international stage this is primarily based in transparent and interdisciplinary processes that ensure equality through democratic decision making. Outcome-based legitimacy arises from the effectiveness of governance; this is perceivable through witnessing the direct impacts of governance and the extent of their equitability within contributions to problem-solving. (For further information in relation to various forms of legitimacy in climate governance, see Karlsson-Vinkhuyzen and McGee, 2013).

There are indications that there are correlations between legitimacy, within climate governance, and its link to power. "Powerful actors engage in efforts to change what is considered legitimate in international society because legitimacy makes power more effective and its maintenance less costly." (Karlsson-Vinkhuyzen and McGee, 2013 pp.57)

BECCS as a CDR method under the Clean Development Mechanism (CDM) (Lederer, 2011; Lomax et al, 2015a) remit can be described as a policy instrument that offers source-based legitimacy to IAMs and RCPs, but it is important to consider which stakeholders perceive this method of CDR as a legitimate technique (Lederer, 2011).

Theories of legitimacy as an analytical concept can help aid the framing of BECCS' role in climate mitigation as perceived in the chosen literature. Alongside the analysis of the discourses and ideologies present in the chosen literature, the concept of legitimacy, assessed with the above given definitions allow one to analyse BECCS' role in climate mitigation.

Aspects of legitimacy	Forms of legitimacy		
	Source-based	Process-based	Outcome-based
Existing legitimacy challenged	Renowned institutional structures of IPCC & UNFCCC	Democratic processes & outsourcing of IAM construction	International Treaties
New forms of legitimacy	Interdisciplinary Frameworks & Pedigree of Knowledge	Higher-resolution modelling without large amounts of standardised data	-

Fig 2. Table 2 | Summary of characteristics of different forms of legitimacy. The table is used to identify strategies to build legitimacy for the discourse(s) prevalent in the literature that can be considered critical towards the inclusion of BECCS in climate scenarios.

[Figure 2](#), similar to [Figure 1](#) is a table that has been created in order to depict how the methods for analysis is operationalised within the analysis of which forms of legitimacy are apparent in the chosen literature. Once a form(s) of legitimacy has been identified in the text, the analysis ascertains if the form of legitimacy is a pre-existing form of legitimacy that is commonplace in climate governance. The analysis also considers new versions of legitimacy created by the literature via different methods of research. The forms of literature are identified by using Karlsson-Vinkhuyzen and McGee’s (2013) interpretation of how legitimacy used in climate governance can be classified as being source, process or outcome-based. By using the framework displayed in [Figure 2](#), it is possible to see how legitimacy is challenged and formed within the chosen literature. The discussion section takes the findings from the two thematic threads used in the results and raises questions on the dynamic relationships between discursive narratives/practices and how forms of legitimacy are formed, strengthened, and weakened in climate governance in relation to BECCS’ inclusion in IAMs.

A limitation of only employing a Foucauldian inspired approach to critiquing the chosen discourses is that it omits to bring in the work of further theorists that can offer further interpretations of governance and the involved discourses. There are various analytical approaches that can be taken when addressing the theory of governance and governmentality. For example, Neo-Gramscian perspectives on hegemony (Femia, 1987) can help theorists to understand some of the idiosyncrasies of climate governance and how dynamic relations of power can impose on the democratic processes of governance and the production of climate science, i.e. integrated assessment models. This is a recognised limitation of this study; the paper is unable to sufficiently explore the varying theoretical frameworks that are available on the subject of climate governance.

A further limitation of using discourse analysis as the principal analytical tool for this thesis study is that there are a number of pitfalls that are often encountered when undertaking this analytical approach. There are six archetypal features of discourse analysis that can be described as not adequately analysing the chosen data, literature in this context. These features are as follows; “(1) under-analysis through summary; (2) under-analysis through taking sides; (3) under-analysis through over-quotation or through isolated quotation; (4) the circular identification of discourses and mental constructs; (5) false survey; and (6) analysis that consists in simply spotting features.” (Antaki, Billig & Potter, 2003 pp. 3)

“Under-analysis through summarising” (ibid) and “spotting features” (ibid) within the assessed texts were important obstacles to overcome during this thesis study. Instead of cherry-picking aspects of the text that aligned with the discursive framework, it was important to display how and why the chosen texts could be described as fitting in with the narratives of the discourses laid out in the theoretical framework. However, “under-analysis through taking sides” (ibid) can be trickier to recognise when

undertaking a study of this type as an inherent bias may exist in the mind of the author. Therefore, this limitation may only be deduced after the study undergoes peer-review. As the methodology for this thesis study is qualitative in nature, it is important not to summarise quantitative data (text) and consequently lose important information. Instead, an analysis of the discursive effects on the composing of the literature and the style that it takes is much more beneficial for a coherent discourse analysis.

Within the thesis study, there is a point made of identifying shared vocabularies and rhetorical devices that are emblematic of some of the discourses under discussion. There is a chance that the study falls guilty of “the circular identification of discourse and mental constructs” (Antaki, Billig & Potter, 2003) by pinpointing technocratic styles of writing in the chosen literature without a thorough explanation on the discursive practices that have led to the creation of shared vocabularies and the technical characteristics that are embedded in some of the chosen literature. The analysis and discussion sections of the thesis study allow for this necessary explanation but could still be accused of not sufficiently capturing the rationale behind these common repertoires. To offer a full and comprehensive explanation of the discursive practices at play in the creation of literature on IAMs may lie outside the remit of this particular study.

5.2 Method for Data Collection

The method for data collection for this thesis study is centred on the gathering of literature between 2009 and mid-2018 that focuses on BECCS within IAMs. This selection of date parameters has been chosen as it coincides with the post-Copenhagen era (Bäckstrand & Lövbrand, 2016) up until the close of the first negative emissions conference that was held in Gothenburg in mid-2018. The 2009 Conference of the Parties was held in Copenhagen between the 7th and the 18th of December, the conference was widely perceived to be a backwards step for the climate negotiation process (Dimitrov, 2010) as no binding political declaration was made after the conference rejected the proposed accord. However, the failure of Copenhagen could be said to incite a renewed effort to achieve a multi-lateral climate agreement for UN member states to subscribe to (Muller, 2010). The era that followed the underwhelming Copenhagen summit laid the foundation for the Paris Agreement in 2015 and there has been a significant amount of literature published on climate modelling during this period. The closing of this timeframe that this thesis study focuses upon is the close of the first negative emissions conference that was held in Gothenburg from 22nd to the 24th of May 2018. This conference has arguably signalled in a new era of discussion on the use of negative emissions as tools of climate mitigation. BECCS featured heavily in the conference. Although the background section of this thesis study looks at the evolution of BECCS and many of the driving factors from pre-Copenhagen that have amalgamated into the discourse setting that is under review, the literature that is under assessment is only taken from the period between the 18th of December 2009 to the 24th of May 2018.

Data for this thesis study are derived from sources that are available with a university accredited login, searches of keywords and phrases were firstly put into the search engine offered by Google Scholar, however this returned a set of 493 articles² that were considered too vast in order to appropriately investigate and assess for the purpose of a Master’s thesis study. For that reason, the study elected to search in Scopus’ range of academic journals. This was done via a keyword search of “BECCS” and “Integrated Assessment Models” between the date parameters of 2009-2018. This search returns 21 results³, these 21 papers predominately focus on the inclusion of BECCS in IAMs. The papers that this search returned that were rejected for various reasons can be found listed in the [Appendix](#) with explanations of why they were not selected for the textual analysis. The predominant reasons behind rejecting a paper for analysis were down to the papers being 1) too narrowly focused on a particular region or industry sector and 2) the integrated assessment models under analysis were not used in the construction of RCP2.6.

Each of the 21 articles were read as part of the collating data process. One of the 21 articles was written by my supervisor Mathias Fridahl, “Socio-political prioritization of bioenergy with carbon capture and

² As of last [search](#) dated 22/08/18

storage” (Fridahl, 2017). To avoid any conflict of interest and to ensure full transparency in the study, this article was not assessed as part of the literature review.

Within climate science, there are numerous terms that can be abbreviated into acronyms such as ‘BECCS’ and ‘IAMs’, sometimes they are referred to in academic papers as whole words, but they are often abbreviated into these terms that are part of the common parlance within climate science and climate governance. As the keyword search for this study consisted of solely ‘BECCS’ and ‘Integrated Assessment Models’, there is a chance that some relevant texts will have slipped through the net during the data collation. This is a limitation of using this method of data collection.

As the methodology for this study only requires a climate modelling literature review for data collation, there were no issues of transparency or ethical considerations to address, with the exception of the aforementioned example authored by my supervisor. This qualitative approach was chosen to give an overall view of the literature that is directly or indirectly critical of BECCS’ inclusion in IAMs used in the construction of RCP2.6.

6. Results

6.1 Discourse and Legitimacy Review in Literature

The results comprise of eleven articles that were found with the keyword search as detailed in the method for data collection section. The articles were then individually selected from a larger body of literature as they are the peer-reviewed papers that can be considered directly or indirectly critical of the inclusion of BECCS in the integrated assessment models that were used in the construction of RCP2.6.

Instead of having a paper-by-paper layout in chronological order, the results have been divided up into two thematic threads. The first thematic thread will focus on the discourses that are prevalent in the chosen literature, as per [Figure 1](#). The second thematic thread looks at the forms of legitimacy that are drawn upon, implicitly and explicitly, to criticise and delegitimise BECCS’ inclusion in IAMs for the purpose of achieving RCP2.6. These forms of legitimacy are depicted in [Figure 2](#).

The eleven articles and journals that have been chosen for this thesis study as per the methods for data collection are as follows:

- I. Economic and ecological views on climate change mitigation with bioenergy and negative emissions (Creutzig, 26th October 2014)
- II. Expert assessment concludes negative emissions scenarios may not deliver (Vaughan & Gough, 31st August 2016)
- III. The role of bio-energy with carbon capture and storage in meeting the climate mitigation challenge: A whole system perspective (Mander et al, November 2016)
- IV. Climate Dreaming: Negative Emissions, Risk Transfer, and Irreversibility (Shue, 24th March 2017)
- V. A sustainable pathway of bioenergy with carbon capture and storage deployment (Kato et al, July 2017)
- VI. Assessment of mitigation strategies as tools for risk management under future uncertainties: a multi-model approach (Mori et al, 8th January 2018)
- VII. Opportunities and Trade-offs among BECCS and the Food, Water, Energy, Biodiversity, and Social Systems Nexus at Regional Scales (Stoy et al February 2018)
- VIII. The energy return on investment of BECCS: is BECCS a threat to energy security? (Fajardy & Mac Dowell, 20th March 2018)
- IX. Evaluating the use of biomass energy with carbon capture and storage in low emission scenarios (Vaughan et al, 29th March 2018)

- X. Constraints on biomass energy deployment in mitigation pathways: the case of water scarcity (Séférián et al, 27th April 2018)
- XI. Unprecedented rates of land-use transformation in modelled climate change mitigation pathways (Turner et al, 15th May 2018)

6.2 Climate Discourses

In the eleven analysed texts, it has been possible to identify examples of discursive practices and rhetoric by using the table displayed in [Figure 1](#). Some of the chosen texts display the familiar discursive practices that would be commonplace in other literature that focuses on climate governance, mitigation and the use of the NETs. For example, Kato et al’s 2017 paper ([V](#)), although it explicitly states that the assumptions in IAMs over future yield capacity are not possible, it cannot not be labelled as a literary example of the civic environmentalism discourse. This is because the language used is in-keeping with the technocratic linguistic approach which is commonplace in the liberal environmentalism discourses where data and information are only rendered legible to the well-established academic and scientific elites of the discourse (Lövbrand & Stripple, 2011). It also contains a thread of process optimisation, emblematic of the ecological modernisation discourse. The methods of knowledge production visible in Kato et al’s article ([V](#)) are arguably situated with the necessary condition of aiding policy advancement and shaping political discussions (Bäckstrand & Lövbrand, 2007). The article was supported by the Environmental Research and Development Fund from the Ministry of Environment of Japan, that have a number of publications relating to Climate Risk Management, Mitigating and Adapting to the effects of climate change (Env.go.jp, 2018).

“Bioenergy with Carbon Capture and Storage (BECCS) is a key component of mitigation strategies in future socioeconomic scenarios that aim to keep mean global temperature rise below 2°C above pre-industrial, which would require net negative carbon emissions in the end of the 21st century.” (Kato et al, 2017) ([V](#))

This explicit acceptance of BECCS being part of the technological mitigation portfolio (as shown in above quote) is representative of the narratives involved in the liberal environmentalism discourses. The paper contains characteristics that are emblematic of the resilience discourse as it draws attention to the biophysical and technological limitations to achieving sustainable crop production via an economically viable strategy. However, the paper does not build upon the potential importance of these limitations and instead focuses on strategy changes that would facilitate the implementation of BECCS. The paper questions technological improvement assumptions on the CCS process and the discrepancy of estimations on crop potential and yield development between a top-down IAM perspective and a ‘bottom-up’ set of estimates. Although the paper offers up a new form of process-based legitimacy (discussed in the next section) that could be utilised by actors in the civic environmentalism discourse to counter the legitimacy established by dominant climate discourses, the paper is still primarily based in the liberal environmentalism discourses.

While Kato et al ([V](#)) question the specific assumptions found in IAMs in relation to future yield capacity in relation to BECCS feedstocks, Stoy et al ([VII](#)), 2018, question the overall validity of IAMs that can be used to help guide climate policy. This question of validity is based on the failure to consider the environmental and socioeconomic trade-offs that will be involved in the large-scale implementation of BECCS. Through the utilisation of an interdisciplinary framework, the authors are able to assess these trade-offs related to food, water, energy, biodiversity, and social systems. They highlight the importance of using interdisciplinary processes to develop scenarios that are, as they see it, more robust than the BECCS dependent IAMs. In Stoy et al’s publication ([VII](#)), there is a simultaneous representation of the discursive agendas put forward by the transformation demanding civic environmentalism discourse, and also, market-incentivising opportunities to bolster the ‘green growth paradigm’ (Wanner, 2015), an integral component of the liberal environmentalism approach to climate governance. Stoy et al represent

the discursive narrative of liberal environmentalism within the paper with the wording of the below quote.

“The integrated assessment models used to develop climate policy acknowledge the need to implement net negative carbon emission strategies, including bioenergy with carbon capture and storage (BECCS), to meet global climate imperatives.” (Stoy et al, 2018 pp.100)

By using the term ‘acknowledge the need’, the article opens with a seemingly unavoidable acceptance that the implementation of NETs such as BECCS is imperative to meet climate policy objectives. This stance could be strongly contested by advocates of the transformative civic environmentalism discourse that would argue that the widespread rollout of NETs can be avoided with an overhaul of consumerist behavioural patterns and the capitalist ideology (Proedrou, 2018).

Stoy et al (VII) do not categorically dismiss BECCS’ inclusion in IAMs as wholly unacceptable, instead it advocates a new range of IAMs that can include a smaller-scale deployment of BECCS with a greater comprehension of dynamic feedback loops and less embedded assumptions, this is more in-line with the resilience discourse agenda. Therefore, this article by Stoy et al recognises the perspectives stemming from the multiplicity of discourses without portraying an allegiance to any; as stated in the theoretical framework – it is not common for an individual discourse, within this dynamic interwoven set of discourses, to possess a loyal followership (Oels, 2005).

Two of the selected articles chosen for the thesis study address shortcomings in BECCS related assumptions in IAMs in a similar fashion but from differing sectors. Séférian et al, 2018 (X) focus on BECCS from a perspective of water security while Fajardy & Mac Dowell, 2018 (VIII) undertake an approach from the viewpoint of energy security. Séférian et al (X) focus on the water scarcity constraint that could severely hinder the likelihood of sustainable large-scale BECCS deployment and therefore restrict the achievement of mitigation pathways based on BECCS. By highlighting one of the projected feedbacks on large-scale BECCS deployment, this paper implicitly challenges the techno-optimist paradigm that is inherent in the liberal environmentalism discourses (Heshmati, 2018). This techno-optimist setting and the need for standardisation for the purposes of governance has necessitated the requirement for global-scale IAMs that possess a ‘global-gaze’ (Backstrand & Lövbrand, 2006) and a black-box nature (Besel, 2011; Pindyck, 2017) that makes it difficult to identify and contrast what quantity of the results are down to assumptions or empirical scientific data. Séférian et al’s (X) findings counter the BECCS optimism in regards to projected water availability/scarcity and therefore play a part in delegitimising BECCS inclusion in IAMs that are used for achieving RCP2.6. The resilience discourse can gain credibility through process-based legitimacy methods that allows the discourse to challenge existing discourses through a medium that is potentially considered more credible than the activist-oriented climate justice movement under the discourse of civic environmentalism. However, with resilience thinking at its heart, the civic environmentalism discourse can use these types of studies in its goal of overhauling and displacing the incumbent model of climate governance that has protected neoliberal interests through the green governmentality and ecological modernisation discourses. Despite Séférian et al’s article (X) displaying examples of process-based legitimacy that could be claimed by the resilience discourse, their paper does not explicitly challenge the construction of IAMs and their inclusion of BECCS but instead advices on reconfiguring the estimations for peak CO₂ emissions. The methods used for questioning BECCS’ legitimacy are drawn upon in the following section.

Fajardy and Mac Dowell (VIII) enter the BECCS debate with a similar style but by focusing on the feasibility of BECCS power plants having a net positive energy output. If BECCS is expected to make a significant contribution to the world’s future energy supply, it is imperative that it offers a degree of energy efficiency in its processes and must remain net energy positive at a bare minimum. Fajardy and Mac Dowell (VIII) find that the energy intensity of the supply chain of biomasses can represent a notable challenge to the assumption that BECCS will achieve the purported level of efficiency. Much like Séférian et al (X), Fajardy and Mac Dowell (VIII) use smaller-scale models and frameworks to

consider how BECCS implementation would manifest on a more localised level than is considered by the IAMs used for achieving RCP2.6. By using this methodology Fajardy and Mac Dowell (VIII) highlight the uncertainty of widespread BECCS deployment and the possible range of what it can achieve as a large-scale CDM; as this quote exemplifies; "... BECCS can be both carbon positive and negative and both energy positive and negative, the scope for unintended consequences is vast." Fajardy and Mac Dowell, 2018 pp. 1592 VIII.

This type of methodology is characteristic of the resilience discourse that advocates the introduction of precaution-based risk management when dealing with climate change (Klinke & Renn, 2002). The concept of risk-society (Storm, 2009) is an intrinsic factor of the market-centric liberal environmentalism discourses so even a reformist approach advocating stronger, but not transformative, forms of regulation, as the resilience discourse dictates (Welsh, 2014), is an implicit but weak challenge to the discourses dominating climate governance. Although the articles authored by Séférian et al (X) and Fajardy & Mac Dowell (VIII) both implicitly raise questions of the incumbent climate discourses, they do not show any explicit examples of siding with any particular discursive narrative or agenda.

Mori et al's 2018 (VI) paper resides in a similar discursive setting as the papers offered by Séférian et al (X) and Fajardy & Mac Dowell (VIII) but does not share the same method that implicitly critiques the way that BECCS is incorporated into differing IAMs. Mori et al's (VI) publication uses a meta-analysis approach to assessing various IAMs in order to make comparisons on correlating and diverging findings. This meta-analysis allows the authors to find which model assumptions are consistent throughout the findings. Mori et al (VI) consider BECCS to be an essential part of making the stringent climate target feasible across the multiplicity of models, despite many documented variabilities on how the NET will be deployed across the world. This thesis contends that this is not due to an increased amount of accuracy found by measuring a diverse range of IAM projections but instead; is emblematic of the constraining parameters that are enforced at the stage of construction of each respective model. The pursuit of a more diverse set of information, as used by Mori et al (VI), is implicitly at odds with the liberal environmentalism discourses that tacitly advocate the reliance upon aggregated and standardised data in climate science. Regardless of the methods used in Mori et al's (VI) publication, that wouldn't be out-of-place within the resilience discourse, the article remains rooted in the linguistic framework that is shared in the liberal environmentalism discourses.

There is an emergent pattern perceivable in the articles authored by Creutzig, 2014 (I) and Vaughan et al, 2018 (IX). Both of these publications are certainly critical to BECCS dependent IAMs but do not necessarily belong to either the reformist advocating resilience discourse or the transformative touting civic environmentalism discourse, despite displaying aspects of their narratives. Vaughan et al's paper (IX) recognises the perceived advantage of BECCS being a cost-effective approach to achieving negative emissions with the added advantage of having further purposes other than negative emissions, such as electricity generations and biofuel production. If negative emissions are to be commodified, i.e. through carbon credits – this is in-keeping with the discursive narrative of liberal environmentalism that incorporates the merging ideologies of green governmentality and ecological modernisation.

"The purpose of IAMs is to explore possible futures and uncertainties associated with those futures. They do so by providing information on alternative low-cost emission scenarios subject to various model assumptions, such as physical constraints on energy systems and timing of international climate policy; they are not intended to provide predictions of the future." (Vaughan et al, 2018 pp. 1-2 IX)

This above quote raises an often-unquestioned aspect of climate modelling. The scenarios seek-out low-cost options for achieving emission targets, this is to facilitate a 'soft-landing' (Lövbrand, 2011) for infrastructure that is heavily reliant on high-emitting industries currently. A high-cost but rapid transition is purported to be socially and politically unacceptable (Azar & Schneider, 2002) and is arguably not included in the models because of the underlying rationale embedded in the incumbent liberal environmentalism discourses despite this being counter to the expected level of global economic growth and the projected costs of climate adaptation in the future (Azar & Schneider, 2002).

The paper from Vaughan et al (IX) also makes reference to the assumption included in the model for global participation on climate change to be achieved by as early as 2030 despite concerns over a lack of action in the wake of the 2015 Paris Agreement. The study uses this explicit assumption as an example to display the stark contrast of an embedded model assumption and the challenges encountered with real-world implementation. The assumption of global participation on climate change to be achieved in just over a decade could be perceived to be part of the pervasive ‘risk society’ narrative (Welsh, 2014). This narrative is implicitly questioned by the authors of this article by highlighting the real-life challenges of shifting geo-political relations in the near-term to reach a unanimous agreement on the approach to climate governance. Vaughan et al (IX) consider IAMs to be useful but heuristic tools that cannot be considered as a replacement for detailed analysis on the underlying concepts and assumptions involved. This consideration stems from the narrative of the resilience discourse and it implicitly challenges the individual silos responsible for operations of knowledge production (Feldman & Ingram, 2009) that occur under the remit of the liberal environmentalism discourses. However, the style and language of Vaughan et al’s (IX) paper does not denounce the conventional rhetoric prevalent in climate governance and the literature on it.

Similar to Vaughan et al (IX), Creutzig’s (I) (2014) article doesn’t position itself within a resilience nor civic environmentalism discourse but it does advise caution to the way that climate science is produced. However, this is done without questioning the power and hierarchy involved in climate governance. Creutzig’s paper (I) still fits into the linguistic framework that is commonplace in the liberal environmentalism discourses and therefore does not clearly represent a discursive shift in the landscape of climate governance. Creutzig’s paper (I) plays a role in the increasing amounts of research on how embedded model assumptions will play out in a real-world scenario with biophysical constraints and inertia in social and political acceptability of transformative climate action. Therefore, it can be said that Creutzig’s (I) article shares characteristics of the liberal environmentalism discourses as well as fulfilling the narrative of considering a precautionary approach to climate science production as advocated by the resilience discourse.

Creutzig’s (I) paper is similar in this respect to Turner et al’s (XI) 2018 paper on land-use transformation related to the implementation of BECCS. The authors of the article indirectly refer to the necessity of employing the precautionary principle when it comes to large-scale land-use transformation as there is no historical precedent or patterns that can be studied in this context. These patterns do exist in other areas that are incorporated into the creation of IAMs, such as population and economics trends but the potential constraints of biomass-based CDR, i.e. BECCS, are not obvious or easy to predict with a large degree of accuracy. The article (XI) is certainly embedded within the resilience discourse as it possesses various points referring to the uncertainties raised in the discussion around large-scale BECCS implementation, ranging from capital costs and volatile markets to concerns about soil sustainability and competing with food production in certain regions. Turner et al’s (XI) discussion of the article calls for a tempering of our expectations in biomass-based CDR and recommends exploring options in the rapid decarbonisation of high-emitting sectors. If undue faith is placed in the potential of BECCS as an effective methods of CDR, the authors pay heed to locking global society into a world with substantial climate change impacts with little wiggle-room for chances of mitigation in the latter part of the century. The analysis and resulting discussion of this land-use article (XI) partly act as a counter-discursive example as the article indirectly questions the inherent assumptions that are part of the make-up of the studied IAMs, this somewhat challenges the aforementioned incumbent set of climate discourses but the authors do not sway from their neutral stance on the inclusion of BECCS in the IAMs and do not discuss how BECCS can be characterised as a moral hazard. By using words such as “unprecedented” and using tangible comparisons, to display the grandiose scales that will be required to supply BECCS’ bio-feedstock needs, places this article (XI) predominately within the remit of the resilience discourse.

The remaining three articles by Vaughan & Gough, 2016 (II); Mander et al, 2016 (III) and Shue, 2017 (IV) are all more explicit in their critique of the IAMs used for achieving RCP2.6 and the extent of the role that they permit BECCS to play as a tool for abating emissions.

Mander et al's article (III) investigates the assumptions underpinning BECCS feasibility. It sought to investigate the assumptions included in IAMs relating to BECCS' inclusion; and also, how integral BECCS is for achieving climate sensitivity targets within said models. Out of the chosen literature for this thesis study, this paper is perhaps one of the most outspoken in critiquing the inclusion of BECCS in the IAMs that are used in RCP2.6. Via a thorough dismantling of the embedded assumptions related to BECCS in the IAMs, the authors assess some of system implications that would arise from large-scale BECCS deployment. They describe the IAMs as having a "global and top-down framing of mitigation" (Mander et al, 2016 pp. 6041) (III), with an assumption of the "Marshall style construction programme ... across the entire energy system" (ibid, pp. 6042) included in the IAMs used in RCP2.6.

Mander et al (III) state that the assumption of a mass roll-out delivery of BECCS requires much greater scrutiny given the myriad of uncertainties across industry sectors, geophysical capacities and technological limitations. This article's contribution to the wider body of climate modelling literature marks a stark contrast from the dominant techno-optimist narrative that has prevailed throughout a lot of climate modelling literature under the influence of the liberal environmentalism discourses. It could be considered that Mander et al's (III) article could find itself situated as a literary example of the resilience discourse, with its findings potentially fuelling the more radical civic environmentalism counter-discourse.

Vaughan & Gough's (II) methodology consisted of an expert elicitation process to analyse a key set of assumptions extrapolated from an extensive literature review. These experts from academia, business, policy, and NGOs were able to investigate the credibility of the given assumptions and come to the conclusion that the large-scale deployment of BECCS is unrealistic due to biophysical, technical, and societal constraints. The article (II) comments on policy discourses (i.e. liberal environmentalism) that assume that BECCS' deployment will be driven by market incentives and a globally agreed upon price of carbon. This will require a continent-spanning regulatory framework in order to sufficiently manage and monitor this, this implicit and ambitious assumption is prevalent in the IAMs used for RCP2.6. The liberal environmentalism discourses are challenged in the findings of this article that implicitly advocate the rise of the civic environmentalism discourse that challenges the capitalist ideology (Watts, 2002; Newell & Paterson, 2010) inherent in the neoliberal narrative that runs through the liberal environmentalism discourses. This is achieved via the chosen experts' combined pedigree of knowledge in their respective fields of expertise. This strengthens their overall credibility to question the IAM assumptions that underpin the feasibility of projected BECCS implementation.

Henry Shue (IV) states that most NETs, such as BECCS, are simply hypothetical solutions and to rely upon them is a gamble. Upon assessing BECCS' impact on land-use and freshwater supplies as well as other externalities, Shue (IV) sees their inclusion as an example of 'moral corruption' as the proposed NETs deployment is to 'avoid causing expense or inconvenience' to those that can afford more ambitious methods of mitigation in the near-term. Shue (IV) states that their inclusion in a large degree of IAMs is illegitimate as policy makers 'lazily indulge in patently unfair policies' (2017 pp. 19). This choice of challenging, almost combative, language is an example of the rhetoric put forward by the civic environmentalism discourse that looks to displace the entrenched liberal environmentalism discourses that have had a strong influence on climate governance and the production of climate science over recent decades.

Shue's (IV) concluding remarks read as a call-to-arms for urgent climate mitigation in the near-term opposed to hedging our bets and rely upon the projected successes of NETs in the future. Shue's paper (IV) can therefore be firmly placed within the civic environmentalism discourse that exists as a contrasting counter-discourse to the liberal environmentalism discourses. It is too early to speculate on whether this counter-discourse will displace the incumbent discursive narrative. This shift will not become apparent until the discursive landscape has transformed to the extent that there are tangible outcomes of action on climate policy and climate mitigation.

6.3 Legitimacy

As per the table displayed in [Figure 2](#), the analysis looks at forms of legitimacy that are drawn upon in these texts that are directly or indirectly critical to the inclusion of BECCS in IAMs. There were multiple examples found of pre-existing legitimacy, found in the production of climate science/knowledge and in the realm of climate governance, being implicitly and explicitly challenged by the methodologies, findings, and rhetoric that were identified in the analysed texts.

The research methodologies used in some of the chosen literature could be an indicator that the resilience discourse is beginning to obtain process-based legitimacy through peer-reviewed scientific publications that question the inherent assumptions and ‘global gaze’ (Backstrand & Lövbrand, 2006) that have been part of BECCS dependent IAMs. However, it is important to note that the construction of this new form of process-based legitimacy is not an endorsement of the resilience discourse by the authors of said publications. The examples of resilience favouring legitimacy are apparent in the publications from Kato et al ([V](#)), Fajardy & Mac Dowell ([VIII](#)), and Séférian et al ([X](#)). For example, Kato et al ([V](#)) use a method of bottom-up, smaller-scale, and more accurate set of biophysical assessments. This has made it possible for this paper to implicitly and indirectly delegitimise the inclusion of BECCS in IAMs due to a number of explicit examples of uncertainties in technological capacity and yield capacity to improve in a sustainable fashion. Kato et al’s ([V](#)) scientific paper offers up a new form of process-based legitimacy that could be utilised by the resilience discourse. Further examples of smaller-scale modelling can be seen in Fajardy & Mac Dowell’s article ([VIII](#)). It is possible for their recent publication to implicitly challenge the source and process-based legitimacy of global IAMs that use heavy quantities of standardised global data and include many questionable assumptions. One example of this is where Fajardy and Mac Dowell ([VIII](#)) find that the energy intensity of the supply chain of biomasses can represent a notable challenge to the assumption that BECCS will achieve the purported level of efficiency. The following quote stands as an example of the difficulties involved when attempting to achieve net positive energy contribution from a BECCS facility.

“Power generation efficiency, transport fuel efficiency, moisture content and yield are therefore key parameters to be optimised when maximising BECCS net electricity balance. In terms of management of these levers, yield, moisture, and transport fuel efficiency are highly dependent on the feedstock and region of import and can therefore be complex to predict and control.” (Fajardy & Mac Dowell, 2018 pp.1589)

The above excerpt exemplifies the complexities involved in optimising BECCS’ potential in the future, Fajardy & Mac Dowell ([VIII](#)) draw attention to the difficulty of predicting the dynamic parameters for the purpose of creating IAMs. This implicitly questions the process-based legitimacy possessed by the IAMs used to achieve the level of radiative forcing of RCP2.6.

Mori et al’s paper ([VI](#)) takes a diverse approach to questioning the embedded assumptions in IAMs used for achieving the targets of RCP2.6. By having a diversified collation method for obtaining model data, the publication can arguably boast a higher level of process-based legitimacy that can potentially undercut the discursive constraints set by the aforementioned discourses. However, this doesn’t indicate that the construction of the IAMs are being criticised or delegitimised by this publication. The same can be said of Turner et al’s publication ([XI](#)) despite drawing their data from the same IAMs used in the construction of RCP2.6; their article indirectly challenges the legitimacy of including BECCS in the IAMs by bringing up issues of uncertainty and infrastructural challenges that will be encountered as a result of implementing BECCS as an integral aspect of the global mitigation portfolio, as detailed in their studied IAMs. Therefore Turner et al ([XI](#)), by using the same IAMs, have contributed to challenging the process-based legitimacy involved in their construction via the recognition of the vast global infrastructural challenges that would be required to facilitate the widespread rollout of BECCS over the century and the uncertainty that has been linked to its potential impacts.

Stoy et al (VII), Creutzig (I), and Vaughan et al (IX) undermine the perceived legitimacy of the production of climate science that is provided to the UNFCCC by the IPCC accredited IAMs. As Vaughan et al (IX) assess some of the IAM's assumptions related to BECCS and its implementation, they note that inherent assumptions will be challenging to achieve in the real-world due to geological differentiations. This is a challenge to both the source-based and process-based legitimacy that exude from climate science and the construction of climate models (Karlsson-Vinkhuyzen and McGee, 2013). Vaughan et al (IX) reiterate the main challenges to the assumptions included in the IMAGE model throughout their paper; one example being that preventing bioenergy crops being cultivated on forest or agricultural land will require a strong and robust regulatory framework. The inherent assumption that this framework will exist will be hard to achieve in a real-world situation.

Creutzig's paper (I) implicitly challenges the source-based legitimacy of the climate science involved in climate modelling by addressing the questionable credibility of the sustainable longevity of BECCS. Outcome-based legitimacy has been hard to achieve in the realm of climate governance and climate mitigation as there are a number of positive and delayed feedbacks, (Meadows & Wright, 2012) involved in the complex and dynamic climate system. In the absence of scientific legitimacy based on concrete results of existing and proposed methods of mitigation, policy makers must rely upon the source and process-based legitimacy offered by the IPCC, the UNFCCC, (Karlsson-Vinkhuyzen & McGee, 2013) and climate modellers. The credibility of the process-based legitimacy remains in question until tangible outcome-based results can be measured, regardless of the degree of transparency and interdisciplinarity included in the construction of the models. Stoy et al (VII) utilise an interdisciplinary framework to critique some of the inherent assumptions that are prevalent in the BECCS dependent IAMs.

Shue (IV), Mander et al (III), and Vaughan & Gough (II) primarily target the source-based legitimacy behind the construction of the IAMs and their heavy dependency on the widespread deployment of BECCS. Mander et al (III) provide legitimacy to the civic environmentalism discourse through a method of delegitimising BECCS' inclusion in IAMs through an exposé of the radical transformative changes that will be required in global infrastructure to facilitate the large-scale deployment of BECCS as projected in the models used for RCP2.6. Vaughan & Gough (II) bring together eighteen relevant experts with a broad and varied knowledge of BECCS and the systems that its implementation will affect. Their article plays a part in delegitimising the IAMs dependency on a widespread roll-out of BECCS facilities, through an alternative method of source-based legitimacy. This source-based legitimacy arises from the respective positions and backgrounds of the eighteen participants that took part in the work-group. Their combined pedigree of knowledge in their respective fields of expertise strengthen their overall credibility to question the IAM assumptions that underpin the feasibility of projected BECCS implementation. Finally, Shue's (IV) scathing comments pay no credence to the source and procedure-based legitimacy that is normally a precursor to the construction of IAMs. Throughout the text, Shue (IV) attempts to delegitimise the inclusion of NETs, such as BECCS, in IAMs by correlating their inclusion with concepts such as 'risk transfer' where rich members of the current generation bestow a large degree of risk onto poorer members of future generations, poetically summarised by Shue as 'generational buck-passing'.

7. Discussion

To address the first research question of this thesis; the findings of this study see discursive narratives of the resilience and civic environmentalism discourses appearing within literature that criticises the inclusion of BECCS in the IAMs used to model RCP2.6 scenarios. However, despite the resilience discourse and the more emergent civic environmentalism discourse having more of a prevalence in climate modelling literature in recent years, much of the eco-knowledge production involved in climate science is still firmly rooted in the setting created by the strong influences of the incumbent climate discourses of liberal environmentalism. Therefore, although there are clear trends of resilience and (less prevalent) civic environmentalism entering the field of climate governance, they don't look set to displace the dominant set of liberal environmentalism discourses that are propped up by an entrenched

capitalist ideology and neoliberal economic paradigm. The power found in decentralised non-sovereign sections of power and knowledge (Foucault, 1986), as is prevalent in climate governance, can be influenced by the ubiquitous presence of vested interests in climate governance and consequently in the production of climate science. The power that has been flowing and circulating through the networks (Foucault, 1980) involved in global climate governance has arguably had a demonstrable influence on the supranational bodies that are involved in the climate mitigation discourse such as the UNFCCC, IPCC, and the academic and scientific institutions that they welcome work from. The eco-knowledges (Luke, 1999) that are deeply instilled into these bodies are a tightly-woven network that possess a shared vocabulary (Luke, 1999), their catalogue of scientific interactions via the publications of academic journals and contributions to scientific findings act as a method of legitimising each other's work. Consequently, the external influences that these actors are exposed to, at international conferences and negotiations, can embed a certain mentality that can become included in peer-reviewed science that is then used as a foundation for policy makers to base climate-related decisions on. The private business interests that are present at these conferences and climate negotiations (Andrade et al, 2015; Greens/EFA, 2018) are emblematic of the ubiquitous nature of the liberal environmentalism discourses that push the green growth narrative until it becomes a constraining framework for climate mitigation to be discussed. By using the tables outlined in the method for analysis, it has been possible to identify the prevalence of these liberal environmentalism discourses in literature related to climate governance, even in examples that are outright critical to their inclusion of BECCS.

The intricate connections between the liberal environmentalism discourses and the neoliberal economic paradigm have manifested a scenario that have allowed the precautionary principle (Heck et al, 2018), as advocated by the resilience discourse, to take a back-seat in climate policy making and has pushed technofixes such as BECCS to the forefront of climate mitigation discussions (Heck et al, 2018) under a soft governance (Oels, 2005) approach. There are dynamic flows between the discourses and this has shrouded the legitimacy of NETs such as BECCS as much of it happens inadvertently as part of a myriad of influential factors.

As can be identified from the analysed literature, there is a narrative of resilience building within academia that can implicitly challenge the merger of the ecological modernisation and green governmentality discourses that have relied upon a market-based model of soft governance to tackle the existential issue of climate change. The strength and influence of this resilience discourse, and whether it leans more to the incumbent liberal environmentalism discourses or sides with the emergent and transformative civic environmentalism discourse, will be easier to assess once the upcoming sixth assessment report (AR6) has been published by the IPCC, this is due in 2021.

The eco-rationalities involved in the liberal environmentalism discourses can be seen as extensions of Foucault's work on bio-politics, drawing upon aspects of environment and sustainability that can be considered as 'things' that are required to be effectively managed and governed.

To address the second research question of this thesis study; the analysis of the chosen literature in the results section has identified that the key forms of legitimacy that are drawn upon to criticise the inclusion of BECCS in IAMs are source-based and process-based legitimacy. There are examples of these pre-existing forms of legitimacy being implicitly and explicitly challenged and undermined by the methodologies, findings and discursive practices found in the analysed literature. There are also new forms of both source-based and process-based legitimacy that arise in the literature in the favour of the discourses of resilience and civic environmentalism. This thesis makes the contention that despite the chosen literature weakening the credibility given to BECCS' inclusion in IAMs used to model RCP2.6, it does not delegitimise it to the extent that would discredit the influential network of geo-power situated at the UNFCCC and the IPCC. This hierarchical set of institutional structures have maintained a strong degree of source-based and process-based legitimacy for a number of decades (Karlsson-Vinkhuyzen & McGee, 2013) and the burgeoning set of counter-discourses do not appear to have a sufficient amount of influential clout to be able to displace the incumbent merged discourses of green governmentality and ecological modernisation.

The inherent assumptions of the IAMs are questioned and challenged throughout the texts analysed for the purpose of this thesis study. Some of these implicit and explicit challenges are emblematic of the narrative being put forward by the advocates of the resilience and, less so, the civic environmentalism discourses. These counter-discourses look to challenge what they perceive as the global managerialism purported by the green governmentality discourse and the techno-optimist paradigm stemming from the ecological modernisation discourse. Ultimately, the civic environmentalism discourse looks to challenge the commodification of climate change (Bäckstrand & Lövbrand, 2016) which the discourse would perceive as being a result of an overarching neoliberal economic paradigm and capitalist ideology that has been pushed onto climate governance via the discursive influences of liberal environmentalism and soft governance. The resilience discourse is not as radical nor as transformative as the civic environmentalism discourse, its call for more precautionary approaches and identifying possible constraints in the future does little to directly challenge the narratives and agendas put forward by the more dominant liberal environmentalism discourses. As mentioned in the theoretical framework of this study, the influence of the resilience discourse can potentially slow the pace that the liberal environmentalism discourses operate but without directly challenging or advocating an overhaul of the current system of climate governance, they can extend its longevity before drastic transformative measures are required.

With BECCS' having a heavy inclusion in the IAMs, some of the critical to BECCS literature has the shared concern that its prevalence in IAMs has normalised its stature as a key tool for carbon dioxide removal. This could potentially add to the mainstreaming of the discussions on NETs as viable tools for mitigation to buttress conventional methods of mitigation as well as, perhaps alarmingly, act as a political tool to delay stringent emissions reductions in the near-term under a soft governance mandate. The papers assessed in this study are predominately, yet not explicitly, going against the grain of the incumbent and dominant narratives involved in climate governance and the production of climate science, in particular reference to global IAMs. They do this by dismantling certain technological, biophysical, and societal/political assumptions via bottom-up models using more spatially disaggregated data and including perspectives from leading experts from the relevant fields of academia and science.

There are fears, uncertainties and objections to proposed large-scale implementation of BECCS, despite this, it is continually considered to be most cost-effective option for carbon dioxide removal (Van Vuuren et al, 2017b) and consequently it has taken the perceived form of a technological insurance policy that can rationalise the delay of stringent climate mitigation policies in the near-term (Lomax et al, 2015b). These arguably necessary stringent policies would be impactful in the short-term but are not in-keeping with the incumbent liberal environmentalism discourses that support the neoliberal economic paradigm that is rooted in the protection of the 'risk society' (Adam et al, 2000; Storm, 2009; Welsh, 2014) and the Promethean worldview (Dryzek, 2013; Meyer, 2016).

In the broader context of sustainable development, this study can be used as part of a litany of neoliberal climate policies and decisions that potentially threaten to undermine (Keohane, 2015; Reynolds, 2015; Cipler & Roberts, 2017) the goal of sustainable development as defined by the Brundtland report "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland et al, 1987 pp. 54). The precedence given to ensuring steady global economic development in the near-term is hindering the ability of future generations to adequately meet their own needs (Keohane, 2015) due to the future biophysical circumstances that they will be locked into at the hands of present-day leaders and policy makers.

8. Conclusion

The significance of this thesis study is that it has identified the counter-discourse narratives prevalent in literature that is critical to the inclusion of BECCS in the integrated assessment models used in the construction of RCP2.6. Through a qualitative review of the analysed peer-reviewed literature, it has been possible to see that, at times, this literature aligns with the resilience (often) and civic environmentalism (less so) discourses to challenge the dominant and incumbent climate governance discourses, under the umbrella of liberal environmentalism. These challenges, of both the legitimacy of BECCS' inclusion in IAMs, and the discursive setting where the source and process-based legitimacy has manifested, firstly occur implicitly through research that focuses on individual sectors and disaggregated areas. This allows for a questioning of the assumptions that are rife in the global-scale IAMs, this questioning is in-line with the narrative stemming from the resilience discourse. Secondly, the challenges materialise through more explicit examples in the literature that make reference to the moral hazard of having IAMs, that are heavily dependent on NETs, being included in the emissions pathways. This narrative is in-keeping with the agenda of the civic environmentalism discourse that looks to overhaul the bodies that impose political and economic rationales (Honegger & Reiner, 2018) on the construction of climate science and knowledge, especially when the produced models and pathways are utilised by climate policy makers when attempting to make robust decisions on mitigation roadmaps.

The results of this thesis study have shown how literature that is critical to BECCS has implicitly and explicitly confronted the legitimacy that have offered credibility to the construction of IAMs used for RCP2.6. This research, in turn, offers a fresh form of mostly process-based legitimacy that is arguably more credible than the processes used in the dominant discourses in climate governance. This is partly due to some of the methods used in the scientific article that approach the subject matter with bottom-up, smaller-scale models that do not have to deal with large amounts of standardised data as per the 'global gaze' inspired IAMs (Bäckstrand & Lövbrand, 2006; Bäckstrand & Lövbrand, 2007) used for RCP2.6. However, some may contest the validity and credibility of a bottom-up approach, further research is required here in order to establish how to appropriately evaluate the credibility of climate modelling. IAMs primarily work with explorative projections of future societies based on a set of plausible assumptions. These projections are heuristic in nature and contain varying degrees of uncertainty and are therefore very difficult to assess and verify. Given the gravitas of climate change, a form of modelling that errs on the side of caution and plausibility when selecting assumptive ranges would be advisable. Especially when these pathways will be the principal sets of data made available to relevant policy makers in order to provide them with the most accurate and salient information to base their decisions upon.

This thesis study adds to the body of research on BECCS and makes the unique contribution of assessing how BECCS, as a controversial component of the technological mitigation portfolio, is perceived by emergent counter-discourses within the realm of climate governance and the production of climate science. This study would recommend further research on the prevalent discourses involved in climate governance and what political and economic rationales underpin their respective narratives. This research is especially relevant given the urgency of the diminishing carbon budget.

“The errors of a theory are rarely found in what it asserts explicitly; they hide in what it ignores or tacitly assumes” (Kahneman & Egan, 2011)

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10. Bibliography

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11. Glossary

AR – IPCC Assessment Report
BECCS – Bioenergy with Carbon Capture Storage
BINGO – Business and Industry Non-Governmental Organisations
CCS – Carbon Capture and Storage
COP – Conference of the Parties
CO₂ – Carbon Dioxide
CO₂eq – Carbon Dioxide Equivalent
EROI – Electricity/Energy Returned on Invested
GHG – Greenhouse Gases
Gt – Gigatons
IAM – Integrated Assessment Model
IMAGE - Integrated Model to Assess the Global Environment
IPCC – Intergovernmental Panel on Climate Change
MONET - Modelling and Optimisation of Negative Emissions Technologies
MW – Megawatt
NET – Negative Emission Technology
Ppm – Parts per million
RCP – Representative Concentration Pathway
SSP – Shared Socioeconomic Pathway
TIMER - Targets Image Energy Regional simulation model
UN – United Nations
UNFCCC – United Nations Framework Convention on Climate Change

12. Appendix

The below texts were part of the 21 articles found when carrying out the keyword search as mentioned in the methods for data collection. These 10 articles were not included in the thesis study for the following reasons:

- i. Fridahl, M., 2017, "Socio-political prioritization of bioenergy with carbon capture and storage", *Energy Policy*, vol. 104, pp. 89-99. – Not part of the literature review as author was one of the supervisors for the thesis study and therefore the analysis of this article could have jeopardised the transparency of the study process.
- ii. Selosse, S. & Ricci, O. 2014, "Achieving negative emissions with BECCS (bioenergy with carbon capture and storage) in the power sector: New insights from the TIAM-FR (TIMES Integrated Assessment Model France) model", *Energy*, vol. 76, pp. 967-975. – Not chosen as it doesn't look at the IAMs that are used in the construction of RCP2.6, it solely focuses on the TIMES Integrated Assessment Model France (TIAM FR).
- iii. Sanchez, D.L., Nelson, J.H., Johnston, J., Mileva, A. and Kammen, D.M., 2015. *Biomass enables the transition to a carbon-negative power system across western North America. Nature Climate Change*, 5(3), p.230. – Not chosen as only focuses on the locality of North America and it does not discuss the inclusion of BECCS in the IAMs used to construct RCP2.6. Its analysis stems from using the SWITCH optimisation model.
- iv. Muratori, M., Calvin, K., Wise, M., Kyle, P. & Edmonds, J. 2016, "Global economic consequences of deploying bioenergy with carbon capture and storage (BECCS)", *Environmental Research Letters*, vol. 11, no. 9, pp. 95004. – Not chosen as their analysis is based on projections from the GCAM integrated assessment model that uses similar assumptive forecasting as the IMAGE model which is the IAM used for the construction of RCP2.6. These assumptions, including a global homogenous price on carbon and perfect international cooperation, allow the authors to take a non-critical stance on the widespread implementation of BECCS.
- v. Bauer, N., Rose, S.K., Fujimori, S., van Vuuren, D.P., Weyant, J., Wise, M., Cui, Y., Daioglou, V., Gidden, M.J., Kato, E., Kitous, A., Leblanc, F., Sands, R., Sano, F., Strefler, J., Tsutsui, J., Bibas, R., Fricko, O., Hasegawa, T., Klein, D., Kurosawa, A., Mima, S. & Muratori, M. 2018, "Global energy sector emission reductions and bioenergy use: overview of the bioenergy demand phase of the EMF-33 model comparison", *Climatic Change*, , pp. 1-16. – results derived from 11 integrated assessment models (IAMs) that participated in the 33rd study of the Stanford Energy Modeling Forum (EMF-33) for a modelling comparison. Therefore not relevant for this thesis study.
- vi. Johnson, N., Parker, N. & Ogden, J. 2014, "How negative can biofuels with CCS take us and at what cost? Refining the economic potential of biofuel production with CCS using spatially-explicit modeling", *Energy Procedia*, vol. 63, pp. 6770-6791. – Not chosen as the article is employing spatially-explicit optimisation models that focus on the United States and were not part of the construction of RCP2.6.
- vii. Nemet, G.F., Callaghan, M.W., Creutzig, F., Fuss, S., Hartmann, J., Hilaire, J., Lamb, W.F., Minx, J.C., Rogers, S. & Smith, P. 2018, "Negative emissions—Part 3: Innovation and upscaling", *Environmental Research Letters*, vol. 13, no. 6, pp. 63003. – Was not chosen since the article is a literature review in its own right and therefore assesses a broad range of literature that discuss varying forms of negative emissions. The article does not offer its own analysis of BECCS and its inclusion in the IAMs used for the purpose of constructing RCP2.6.
- viii. Woolf, D., Lehmann, J. & Lee, D.R. 2016, "Optimal bioenergy power generation for climate change mitigation with or without carbon sequestration", *Nature communications*, vol. 7, no. 1, pp. 13160. – Not chosen as it focuses on Bioenergy-biochar systems (BEBCS) instead of the inclusion of BECCS in IAMs used for RCP2.6.

- ix. *Marcucci, A., Kypreos, S. & Panos, E. 2017, "The road to achieving the long-term Paris targets: energy transition and the role of direct air capture", Climatic Change, vol. 144, no. 2, pp. 181-193.* – Not chosen as it focuses on Direct Air Capture (DAC) as an alternative to using BECCS as the principal negative emission technology in mitigation pathways.
- x. *Favero, A. & Massetti, E. 2014, "Trade of woody biomass for electricity generation under climate mitigation policy", Resource and Energy Economics, vol. 36, no. 1, pp. 166-190.* – Not chosen as the article looks at scenarios created by the WITCH integrated assessment model which is not used in the construction of RCP2.6. The article also mostly concentrates on the economic incentives of biomass trading schemes.

