Review comments to Life Cycle Assessment of Ammonia as an Alternative Marine Fuel (28 May 2022)

Note: The review is done as pro bono work and does not qualify as a third-party review according to the ISO 14044 standard.

	Reviewer A	Reviewer B	Reviewer C	Reviewer D
Reviewer	*Anonymous*	*Anonymous*	*Anonymous*	*Anonymous*
Introductory comments				
Introductory comments	**Comment no. A.1** I find the theme interesting and well timed, and the execution of the LCA more than as competent as required for a Master's Thesis presumably well supervised by Prof. Hauschild and BIMCO expert. I especially appreciate the work that went into section 5.2.		**Comment no. C.1** Overall, this is an exceptionally thorough, detailed and well-presented study into an extremely complex subject. It is also a very timely, and most notedly, early paper. It is timely because the industry needs to have this information before decisions are made, and it is early because very few similar studies exist; indeed, as illustrated by this study, some fundamental values of marine fuels are still not widely available or accepted.	

			This paper therefore succeeds in its most important aim – of providing well thought out, explicit and repeatable calculations on the most important elements regarding ammonia vs fuel oils. This has, of necessity, meant that the original scope provided by BIMCO be proportionately limited, and the work done by the authors be properly bounded. This is in common with all similar LCA analyses at this time of technology. **Comment no. C.2** Some quick calculations indicate that the hydrogen market is more valuable than the oxygen market. If this and other such considerations can be demonstrated early on as justification for the oxygen substitution	

			methodology, then this may be a useful further explanation. However, the relative values of hydrogen from fossil fuel processes vs hydrolysis would still be outstanding. **Comment no. C.3** We find the study broadly compliant with the methodologies of ISO 14044 but, since the authors do not intend ISO compliance, we will not make further comment.	
Comments to specific chapters and sections				
Executive summary – General comments		**Comment no. B.1** This section contains some key findings recommend re-writing or using an illustration to describe the findings: "*The characterised midpoint results showed that, in 9 of the 18 impact categories, MGO had the lowest impact, while Green Ammonia*	**Comment no. C.4** It appears that the headline output will be table 11 (reproduced in the Executive Summary as table 2). However, this table only represents the base scenario including 'oxygen substitution'. The text that proceeds it does not fully explain benefit given to green ammonia from this and	

		had the lowest impact in 8 out of the 18 impact categories – including 'Global warming'. Furthermore, Green Ammonia had negative impact scores in the categories where it had the lowest impact, which means that the crediting of the production of secondary functions is higher than the impacts. Brown Ammonia had the highest impact score in 13 out of the 18 impact categories." (Page IV) **Comment no. B.2** This text is a bit difficult to understand. Recommend rewriting it for more clarity: "*When compared to only the fossil marine fuels, Green Ammonia has the lowest impacts in 9 out of 18 midpoint impact categories including 'Global warming'.*" (Page V)	the later impact of the resulting sensitivities on the results in this table and elsewhere. Many of our comments below appear to be caused by this reliance on a single scenario, whereas the results of the other scenarios are presented (thoroughly) towards the end. We think in fairness this balance needs to be addressed somewhat. We do not feel that this will dramatically reduce the result of the paper but may lead to it being able to be read more fairly in real time. **Comment no. C.5** The executive summary uses the base scenario and relevant details. The impact of this is discussed at length later.	

Executive summary – Comments on limitations		**Comment no. B.3** This limitation impacts on the one of the key findings and creates a high level of uncertainty in the findings: “*Data could not be located for the production of VLSFO and MGO. Modelling VLSFO as HFO with the addition of a desulfurizing process was deemed as a reasonable approximation. An underestimation of impacts is expected seeing as the Claus Process, a part of the desulfurizing process, could not be modelled due to data not being located. Modelling MGO as diesel was also deemed as a reasonable approximation as only a slight overestimation of impacts occur. Neither of these points are expected to impact the*	**Comment no. C.6** We support the various modelling of VLSFO and MGO. It is surprising that proper numbers have not been calculated for these fuels and this seems a valuable area to research further: “*Data could not be located for the production of VLSFO and MGO. Modelling VLSFO as HFO with the addition of a desulfurizing process was deemed as a reasonable approximation. An underestimation of impacts is expected seeing as the Claus Process, a part of the desulfurizing process, could not be modelled due to data not being located. Modelling MGO as diesel was also deemed as a reasonable approximation as only a slight overestimation of impacts occur. Neither of*	

		outcome of the study." (Page V)	*these points are expected to impact the outcome of the study."* (Page V) **Comment no. C.7** LCI inventories are always predicated to the researcher's best endeavours and no single holistic library exists. Furthermore, until the relative impacts of the parameters are known (as well as other external parameters such as child slavery), such an agreed global, unitised inventory cannot exist. Studies like this are what such a library must eventually be built on. As the study says, at this stage, the important thing is to compare like to like within compatible data as much as possible, which is what this achieves:	

			“Using life cycle inventory (LCI) data from other LCA studies is not ideal as it can potentially lead to mistakes/problems being replicated. However, it should be noted, that the LCA studies used were all deemed as being credible. Thus, using these LCA studies is not expected to impact the results compared to using data with higher specificity. Complete LCI’s were not provided (in these LCA studies) and as a result different sources were often used to model a process - also not ideal as different sources can present different values for the same inputs and outputs in addition to using different methods to produce LCI data. It should be noted that prior to selecting sources to model a specific process, these sources	

			were compared in order to ensure that values and modelling methods are comparable. Consequently, the outcome of this study is not expected to be impacted." (Page V) **Comment no. C.8** The approach with DESMO and relative energy seems sensible, logical and consistent: "*The DESMO Calculation Tool is geared towards fossil marine fuels and is thus not made to be used for alternative marine fuels such as Ammonia. However, looking into how DESMO calculates the energy demand per nm, the fuel's energy density and total system efficiency are believed to be the only input parameters. Thus, it was deemed as a fair estimation to input Ammonia's energy*	

			density and total system efficiency and then use the estimated energy demand per nm. Based on the current knowledge level regarding DESMO, using this estimate of the energy demand per nm is not expected to impact the outcome of the study. This limitation is further explained in Section E.7 in Appendix E." (Page V) **Comment no. C.9** Summary on Limitations – these are known and expected and since the data is compatible, these limitations should not affect the outcome of the comparison.	
Executive summary – Comments on recommendations for further work			**Comment no. C.10** The fact that the ammonia fuel does not comply, as calculated, with NOx abatement technology is, in the first instance, a serious limitation to the study. It	

			is given as a mandatory goal and not achieved. It is not reasonable, at first sight, to compare a compliant fuel with a non-compliant fuel. However, again, this is a comparative study, not an absolute study, and so although we do not know the final impact of NOx compliance, we can be confident that the fuel has a considerable advantage to allow for the impacts of the required compliance. The prioritisation of this recommendation should be seen in this light; we need to compare compliant fuels: "*Include a NO_X abatement technology as otherwise the Ammonia-fuelled two-stroke engine is not allowed to operate in international waters. This is due to NOx regulations (IMO Tier II).*" (Page VI)	

			Comment no. C.11 Port operations – we agree that these, and other processes, should have further study: "*Include port operations, e.g. berthing and manoeuvring, in order to increase knowledge regarding the well-to-wake environmental impacts of the three investigated fuels.*" (Page VI) **Comment no. C.12** Fuel storage onboard – as above, we agree that this requires further study. However, as this and the previous point illustrate, there are a large number of simplifications in this study (operations, capex, ship design, regulations, supply chain (existing vs new and novel), existing technology vs future, etc.) and therefore we	

			feel that the level of granularity in this study is correct at the time: “*Include fuel storage on-board the Panamax bulk carrier in the LCI model, as different storage conditions are expected between the fossil marine fuels and Ammonia - thus relevant to include as this is a comparative LCA study.*” (Page VI)	
Executive summary – Comments on recommendations for improved data points			**Comment no. C.12** Oxygen substitution benefit – given both the size of this benefit and its relative economic / market insecurity (i.e., its unknown), we feel this is the single most important part for further work. Further it is a triple effect of Oxygen, Nitrogen and Hydrogen. This may not need to be an in depth LCA, but more a top-down market viewpoint justifying the allowances given. We	

			feel more justification needs to be given to oxygen substitution in terms, maybe of relative productions of Nitrogen, Oxygen and Hydrogen at present and the resulting economic markets (i.e., Nitrogen is the secondary priority now, and potentially more a waste of oxygen production. How much oxygen may be replaced by hydrolysis, and will it be economical)? "*Investigate oxygen substitution in more details, including predictions for the future oxygen market's supply and demand.*" (Page VI) **Comment no. C.13** Ammonia combustion emissions – we have also found these surprisingly difficult to discover. Whilst the expected benefit of the GHG performance of	

			ammonia is known and is properly used as the base comparison for this study, we will in future need to know all the relative effects and potential ‘unintended consequences’ before the shipping market commits to any future fuel. This includes understanding the relative merits of the impact categories. We agree that this is a secondary recommendation for this study, but as an external area, it needs more research: “*Ammonia combustion emissions were not available, and are thus modelled as best estimates. MAN Energy Solutions expects to run its first tests with an Ammonia-fuelled engine in the summer of 2022. Thus, contacting them after this is*	

			recommended." (Page VI) **Comment no. C.14** We concur that more data is needed from fuel producers. It is in surprisingly small supply: "*It is recommended to contact VLSFO, MGO and Ammonia producers in order to get primary production data from representative sites, if possible.*" (Page VI)	
General comments to chapter 1				
Section 1.1		**Comment no. B.4** Given the high degree of uncertainty in the data there is a risk this goal is outside the scope of the study: "*The results are intended to be used by BIMCO to assist shipowners (members of BIMCO) with tools on which to base future capital and operational expenditure*		

		(CAPEX/OPEX) decisions." (Page 2)		
Section 1.2				
Section 1.3				
Section 1.4				
Section 1.5				
Section 1.6				
General comments to chapter 2				
Section 2.1				
Section 2.2			**Comment no. C.15** Reference Flows – the required amount of pilot oil is 5%. This is thought to be at the very low end of estimates, with many estimates giving 20-30%: "*In this LCA study, the chosen pilot oil is VLSFO with SPOC/SFC = 5% - meaning that 5% of the amount of energy injected into the cylinders at full load and at a given speed is VLSFO.*" (Page 4)	
Section 2.3	**Comment no. A.2** One could discuss the use of system expansion and crediting, which gives green ammonia	**Comment no. B.5** This reads as a hybrid approach, if this is the case then this should be further highlighted. From	**Comment no. C.16** Production processes – we have accepted green, brown and blue methods of producing hydrogen.	

	negative values for some impact categories. "*System expansion (through crediting) is applied with regard to the production of oxygen, argon and sulphur - as there are alternative production pathways for these products.*" (Page 5) While this is not wrong, I would expect a consideration of the fact that crediting will depend on if there is a market for the products, e.g. for all oxygen generated in the electrolysis process, further than the scenario analysis in section 5.2.2. since this is absolutely pivotal.	a regulatory perspective the approach is mostly attributional so for comparison this is important to achieve the goal: "*The consequential approach entails using a mix of long-term marginal processes/technologies for processes structurally changed while using average processes in all other cases.*" (Page 5)	Presumably in the future we can also produce oxygen (and nitrogen?) in a green manner. If oxygen production is to follow the world in decarbonising, presumably we will reach a stage of 'green oxygen' in which case the previously discussed position of oxygen substitution presumably becomes less valuable? This is outside the scope but reinforces the difficulty in oxygen substitution benefits. Similar comments could be made about future technology for oil production – may be even 'pink' oil production (i.e., all power for oil production comes from nuclear, for example). We agree at this stage that this is beyond the scope of the study, but it reinforces the issue of possibly	

			providing too much benefit from oxygen substitution where there are other production paths which will have great improvements in their future efficiency: “*Acquisition of nitrogen for Ammonia production consists of atmospheric air separation, usually cryogenic [10]. This results in nitrogen, oxygen and argon, each of which are valuable products. Thus, the co-production of oxygen and argon are secondary functions of this process. Hydrogen acquisition for Ammonia production can be done in several ways, of which Green Ammonia is through electrolysis. Electrolysis is a multifunctional process, as oxygen is also co-produced in addition to hydrogen [10].*” (Page 5)	
Section 2.4			**Comment no. C.17**	

			Completeness requirements – At some point we need to discuss the difference between an established process and a disruptive process. Implementing ammonia as a fuel may be expected to have a more disruptive effect on shipping than this study presents. This paragraph is probably the most relevant illustration of this, and the easiest place to make some minor changes to recognise both the upheaval required for ammonia as a fuel, but also the associated logic in excluding it in this study. For example: Production, maintenance and operation of ammonia and fuel oil two stroke engines are vastly different if you take into account design, build, safety, training, regulations, standards, supply chain, etc.	

			We agree that these elements can realistically be put aside, since they present far too much of an issue for such a study, but that this needs more transparency. We feel the readers will understand and be sympathetic to this if it is spelled out in a little more detail that is more directly related to a shipowner's concerns. We therefore recommend that BIMCO, who are very familiar with these concepts as directly understood by shipowners, work briefly with the report writers to expand this paragraph and make it more directly understandable for shipowners: "*As this is a comparative LCA study, processes that are assumed to be the same for all three marine fuels have been excluded from the system*	

			boundaries: (I) Production and maintenance of the two-stroke engine. (II) Functional necessities such as lubricating oil. In addition, other processes/aspects have been excluded from the system boundaries: (I) Capital equipment such as machines and transportation vehicles. This is common practice in a process-based LCA. Additionally, BIMCO and shipowners have no control over the production of such equipment and it is thus not important to include especially with regard to the motivation of this LCA study. (II) Storage both during transport from fuel producer to Rotterdam and on-board the Panamax bulk carrier. Different storage conditions are expected between fossil marine fuels (VLSFO and MGO)	

			and Ammonia. However, as this aspect is viewed as capital equipment it has been excluded from the system boundaries. (III) Transport from fuel producer to Rotterdam - determining the marginal long-term producers of these three marine fuels could not be done. In addition, it is expected that shipowners buy fuel from producers that are relatively close in proximity to where the fuel will be utilised (in order to minimise costs). Thus, excluding this transport distance from the system boundaries is not expected to impact the results greatly. (IV) Auxiliary engines, as requested by the study commissioner (BIMCO). (V) Berthing, manoeuvring and other port operations, also as requested by the study commissioner.” (Page 6)	

Section 2.5				
Section 2.6				
Section 2.7				
General comments to chapter 3				
Section 3.1			**Comment no. C.18** There is an inherent contradiction that we are considering future technology with present technology. This is unavoidable but its consequences could be discussed more, for example oil distillation may reduce its use of fossil fuel as energy supply, other processes will switch electricity supply from fossil based to renewable, and therefore benefits of using ammonia may reduce over time.	
Section 3.2				
Section 3.3		**Comment no. B.6** The lack of actual data causes a huge uncertainty for the well-to-tank emissions for these fuels which could impact the result:	**Comment no. C.19** It seems that air is separated more for oxygen than for nitrogen. In any case, oxygen is produced in much smaller quantities	

		"*Data on the production of both VLSFO and MGO could not be located.*" (Page 14)	than nitrogen (due to contents of air). It seems that more discussion is needed on global relative demand and supply for oxygen and nitrogen, both now, and in a more nitrogen dependant society. If, as seems might be the case, nitrogen is excessively produced such that large quantities of it are either very cheap or seen as a waste, then the economies need to reverse in order to achieve oxygen substitution benefits. For green ammonia to receive such large benefits then the present and future supply and demand equation needs better justification: "*Cryogenic air separation for the production of nitrogen was modelled using the unit process "air separation,*	

			cryogenic | oxygen, liquid | Consequential, U" from the consequential ecoinvent database. In this process, the production of nitrogen is a secondary function as the main output is oxygen. According to the process, there is a 1:3.27 ratio between the production of oxygen and nitrogen. Thus, in order to use this process for the production of nitrogen, inputs and outputs are all divided by 3.27. The four different production pathways for hydrogen are modelled using life cycle inventory (LCI) data from four life cycle assessment (LCA) studies: [27], [35], [24], [9], and one literature review study [11] – all regarding hydrogen production. [27] and [11] were used to model coal gasification (Brown Ammonia) while [27] and	

			[35] were used to model methane steam reforming both with and without CCS(Grey and Blue Ammonia respectively). It is assumed that the CCS technology used has an efficiency of 95% [32]. Electrolysis (Green hydrogen) is modelled using [24] and [9]. In addition to these two sources, a stoichiometric calculation is done in order to estimate the amount of oxygen produced. Theoretically, with a 100% efficiency, 10 kg of de-ionized water would produce approximately 1.1 kg of hydrogen and 8.9 kg of oxygen, see the stoichiometric calculation in Section E.4 in Appendix E. However, [24] states that 10 kg of de-ionized water only produces 1 kg of hydrogen. Thus, with this reduced efficiency, it is	

			expected that 8 kg of oxygen is produced (as the molar mass ratio between hydrogen and oxygen in water is 1:8). The remaining 1 kg is assumed to be un-reacted de-ionized water which is consequently modelled as an output." (Page 14) **Comment no. C.21** We are not sure how the numbers for CCS have been achieved or utilised. CCS may be 95% efficient in terms of carbon captured, but its efficiency in terms of overall utilisation is unclear: "*It is assumed that the CCS technology used has an efficiency of 95% [32].*" (Page 14) **Comment no. C.20** It is an accepted problem that the potential main problems with ammonia	

			emissions (such as particulate matter) are not better known. This is not the fault of the study but is clearly an area for urgent research: "*As seen above in Table 7, there are no particulate matter emissions for Ammonia. MAN Energy Solutions does not have an estimate as this emission type can only be quantified through measurements taken during engine tests - MAN Energy Solutions expects to run its first tests with an Ammonia-fuelled engine in the summer of 2022. It should be noted that the Ammonia combustion emissions stated in Table 7 are best current estimates, and not based on actual measurements.*" (Page 15)	

			Comment no. C.22 The exclusion of transportation and the associated new supply chain is clearly a major issue, but honestly excluded due to obvious limitations. A recognised area for further work that does not detract from the study: "*Transport of materials and fuels between processes has not been included in the LCI model.*" (Page 15)	
Section 3.4			**Comment no. C.23** This is a difficult section [section 3.4] we do not wish to dwell on. In essence, it appears that selected values for perturbation and scenario analysis were used rather than the full scope presented in the study. It may be that to analyse all the information used, in toto, was too much for	

			the study. This seems understandable.	
Section 3.5				
General comments to chapter 4				**Comment no. D.1** First observation is that they are far too high on Grey ammonia compared to MGO. If we set MGO to 100%, they are at 250 – 300% for ammonia made from NG (grey), while I am at 140% as shown in the figure bellow their figure. Then for a blue one with CCS they are at 200 – 250%. What we can achieve with CCS is certainly debatable but a figure of 50 -75 % reductions is a conservative estimate, which means 35-70% of MGO if we have 140% for Grey Methanol. **Reply by the authors to comment no. D.1** As we do not know the methodological background of the results that the reviewer

				is referring to, it is not possible for us to evaluate why the results are different from ours. A possible reason for the differences is that there is a difference in choice of methodology framework, central assumptions, system boundaries, etc. A likely cause of the difference could be that the reviewer has applied an attributional framework, in contrast to us using the consequential framework. As explained in our report, we chose a consequential modelling approach because the decision context is 'Situation B: Macro-Level Decision Support' as pr. the European Commission's ILCD guidelines. This has strong influence on the results, compared to if

				we had adopted an attributional approach. In Figure 11 (page 26), the process contribution to GWP results is depicted, which gives an insight into how our results came about and shows the difference between the fuels. Here it can be seen that electricity use makes up the majority of the impact for Grey and Blue Ammonia, and CCS is not applied to the electricity production, only the emissions from the hydrogen production itself.
Section 4.1		**Comment no. B.7** The findings here are a little puzzling, the difference between grey ammonia and MGO?: Impact Category: Global Warming in table 11. (Page 19)	**Comment no. C.24** It appears that the headline output will be table 11 (reproduced in the Executive Summary as table 2). However, this table only represents the base scenario including 'oxygen substitution'. The text that proceeds it does not fully explain	

			benefit given to green ammonia from this and the later impact of the resulting sensitivities on the results in this table and elsewhere. Many of our comments below appear to be caused by this reliance on a single scenario, whereas the results of the other scenarios are presented (thoroughly) towards the end. We think in fairness this balance needs to be addressed somewhat. We do not feel that this will dramatically reduce the result of the paper but may lead to it being able to be read more fairly in real time.	
Section 4.2			**Comment no. C.25** It is known that it is very difficult to provide normalised results when relative weightings are unknown. The text explains this.	
Section 4.3				

General comments to chapter 5				**Comment no.D.2** The Green ammonia as I have calculated it are 6% of MGO, based on using an E-diesel as the pilot fuel. So, if you use conventional MGO you will be at around 10%. Claiming that you not only make a 100% reduction to zero, but a 200% reduction to -100% does not make sense. **Reply by authors to comment no. D.2** As we have applied a consequential modelling approach, we have used system expansion rather than allocation in the handling of multifunctional processes (in accordance with the ILCD guidelines and also the ISO 14044 standard). The way that we have modelled Green Ammonia results in a large electricity substitution, as the

				electrolysis process has a by-product of oxygen (8:1 molar mass ratio with Hydrogen). As explained in Section 5.1.1, the electrolysis is assumed to substitute cryogenic air separation as the way of producing oxygen for the market, and thus the electricity that would be used in this process is credited to the electrolysis. This led to the credit of 5.74*10^6 CO_2-eq/FU. (The choice of cryogenic air separation as the current way of producing oxygen was informed by the ecoinvent database, and there were no obvious alternatives to this route for oxygen production.) Further explanation of the modelling choices can be found in Section 2.3 "*LCI Modelling Framework*" and in Section 5.1.1. "*Process*

				Contribution". To investigate the sensitivity of this system expansion assumption, we also did the modelling assuming that the oxygen is just released to the atmosphere in which case the substitution is 0 (see scenario results in Section 5.2.2. "*Scenario Analysis*"). In this case there are no negative impact scores, and ammonia performs notably worse, as described in the report. This scenario is however an unrealistic worst-case scenario in terms of the future oxygen demand, and we only did it to estimate an upper bond of the life cycle impacts from green ammonia. When oxygen production crediting is 0%, the carbon footprint is 1.96*10^6 kg CO_2-eq/FU compared to 3.77*10^6 kg CO_2-

				eq/FU for MGO and in this case, the Green Ammonia has roughly half the climate change impact of MGO.
Section 5.1	**Comment no. A.3** I note appendix D.4.1 but I am a bit surprised not to see a bit more emphasis or discussion on the N_2O GWP issue in Tank-to-Wake when it compared to CH_4 GWP in W-to-Tank by and large are of the same order of magnitude, and N_2O slip management onboard may be quite challenging. **Comment no. A.4** As key parameters one could discuss the emission factors used especially regarding ammonia, i.e. NOx., exceeding Tier II. Most engine manufacturer also discuss the need to use some abatement system for the NOx emissions from ammonia	**Comment no. B.8** Why is there a credit for CH_4 in green ammonia production? "*VLSFO and MGO also have CH_4 contributions to 'Global warming' though difficult to view in Figure 12 due to these contributions being small in magnitude. In addition, large crediting values for CO_2 and CH_4 can be seen in Figure 12 for Green Ammonia. These constitute the negative impact score for 'Global warming', seen in Table 11*." (Page 25)	**Comment no. C.26** We find the explanation of relative impacts from different processes of well to tank and tank to wake to be well and elegantly expressed. These are important concepts. We find several of our concerns about the oxygen substitution concept explained here but feel that the justification for this should be in the earlier text, rather than in Interpretation. Despite repeated readings of the paper, we don't find our earlier fears allayed by Interpretation. The reasons given here for electricity substitution in the oxygen substitution equation do not recognise that air	

	engines regardless of SECA status and while I acknowledge the discussion found in the thesis, this is a crucial aspect where more analysis and discussion would be appreciated.		separation is presumably used above electrolysis (or other method) due to overall economic efficiency; therefore, despite the 8:1 ratio of oxygen to hydrogen, we still need more evidence of the future potential (environmental or otherwise) for green hydrolysis to provide by-product oxygen whilst a (more?) efficient process (which coincidentally provides oxygen) will provide by-product nitrogen. It appears that if green hydrolysis oxygen is going to disrupt the economies of cryogenic production (as it must in order to substitute), the future balances need further exploration.	
Section 5.2	**Comment no. A.5** System expansion and crediting, and emission factors are chosen to be part of a sensitivity assessment rightly so,		**Comment no. C.27** This section to a certain extent answers a lot of our earlier questions, however on reflection, we have left our text the	

	since there are decisive assumptions made around these.		way it is, since that is how the paper will be read. The point stands that our issues are not addressed in the earlier text or summaries. **Comment no. C.28** It appears from the text that table 15 is derived by simply applying the emission control output benefits to the LCIA without considering any of the costs. Since we do not know the impact or sensitivity of this change, we cannot judge the value of the results in this table. The study recognises this, and we agree it is important for future iterations.	
Section 5.3			**Comment no. C.29** Similar to the above, this section confirms earlier issues, with figure 15 illustrating them nicely. We still believe that this is disproportionately late and would benefit from	

			earlier representation in the text.	
General comments to chapter 6			**Comment no. C.30** Our concerns about representing the calculation issues primarily in section 5 are reinforced here, where the conclusions appear to be predicated on the base scenario with little reference to the other scenarios or sensitivities.	
Section 6.1				
Section 6.2				
Section 6.3				
References			**Comment no. C.31** We understand that reference no. 24 should be to a master's thesis, not a PhD.	
Other general comments				
Other general comments	**Comment no. A.6** I am not an expert on Occupational Health and Safety issues. I can only note that these are not part of Positioning Properties or Impact Categories. In some cases, the Human Health part of LCA may miss		**Comment no. C.32** It should be noted that we have not been able to thoroughly examine the appendices. We assume that all essential text is provided in the main body. We assume that nothing in the appendices is essential	

	important effects for a system assessed if a compound is not acutely or chronically toxic. Examples on the ecological side may be avoidance behaviour in fish, tainting of fish and shellfish leading to decreased commercial value, and more relevant here the low olfactory thresholds for NH_3 in humans, exceeding of which may cause workplaces to be evacuated. Again, I am certain that the LCA methodology has been followed meticulously, I am only advocating that this may be an important consideration when choosing a future fuel.		to understand the paper. If there is something in the appendices that we have not seen that explains some of our comments, then we feel this should be inserted, concisely or in summary form into the main text.	