ISOMETRIC

Wastewater Alkalinity Enhancement 1.0 Protocol

Public Consultation Summary

Published on 07/02/2025

Context

Isometric held a public consultation on its Wastewater Alkalinity Enhancement 1.0 Protocol to receive stakeholder input on this Protocol.

The public consultation was announced on the 15th of November, 2024. The period of consultation lasted 30 days, with the final day as the 15th of December, 2024.

After the initial public consultation, the feedback received was considered for incorporation into the Protocol. All stakeholders have received responses to the submitted feedback.

This document summarizes the feedback received during the public consultation and the revisions included as a result of the comments. Content in italics and brackets are excerpts from the public consultation version of the protocol to give the reader necessary context behind the comment.

We thank all participants for their time.

Summary of feedback received

Wastewater Alkalinity Enhancement 1.0			
Theme	Resolution	Comments	Section
The definition of initial mixing zone is unclear	Thank you for the feedback. We have renamed "Initial mixing zone of discharge site" to "mixing zone of discharge site" in Table 4, to make it clearer that this is not referring to the mixing that occurs upon dosing into the WWTP, but rather the mixing upon discharge into the natural environment. We have also clarified throughout the protocol when "initial mixing" is used that is referring specifically to the mixing of discharge with receiving waters.	*[rock or mineral feedstock is added into the secondary treatment process]* this is confusing. Later in the protocol you describe losses as occurring in four zones, the first of which is called the initial mixing zone. The initial mixing zone is described as taking place during the initial discharge of water from the plant, whereas this suggests it is added during the secondary treatment process	1
Flexibility to allow for storage of < 1000 years.	Thank you for the comments. We acknowledge that there is value in CDR approaches with shorter duration durability, however this protocol specifies 1000+ year durability because the long term storage for this approach is dissolved inorganic carbon (DIC) storage in oceans, which is described in more detail in this storage module: https://registry.isometric.com/module/dic-storage-in-oceans/1.0). That module provides justification for why we consider DIC in oceans	Do we really want every method to lock CO2 for over 1000 yrs (in deep ocean and sediments)? Will a temporary storage of upper to a few hundred years also count? I think that flexibility should've been allowed.	1

	to have well over 1000 years durability, based on the residence time of DIC in the oceans of 10,000+ years. As long as the discharge ends up in the oceans, and any potential losses of CO2 back to the atmosphere are accounted for and deducted upfront, the practitioner does not need to further prove 1000 year durability.	*[long duration storage (>1000 yr) of CO_2 in seawater]* Not clear. Do you imply as long as it is discharged to seawater it is long duration storage or do want the practitioner to prove his/her practice leads to long duration storage? I assume CO2 in most wwtp effluent (@BAU) will be released back to the atmosphere in coastal ocean. So with ALK enhancement, the CO2 can stay longer in seawater with the possibility to be moved to deep water. But whether it is over 1000 years to hard for the practitioner to prove.	4
Is it necessary to restrict the protocol to "retrofits"?	Thank you for the comments. We use "retrofit" to mean the introduction of new materials, products or technologies to an existing process or facility. This can include adding new alkalinity dosing to WWTPs that did not previously add alkalinity, increasing dosing in plants that already add alkalinity, adding additional monitoring to the WWTP to quantify CDR, etc. We have defined more clearly what "retrofit" means in the protocol. The purpose of the retrofit requirement is to allow for a system boundary that excludes the emissions from the construction and normal operations of a WWTP. The scenario of new construction WWTPs specifically designed with WAE in mind may be explored in a future version of this protocol. As per the applicability criteria, WWTPs that are already adding alkalinity as part of their normal operations are eligible under this protocol.	*[For the purposes of this Protocol, a Wastewater Alkalinity Enhancement process must be retrofitted into existing WWTP operations]* Not entirely clear that this restriction is necessary, provided that a clear counterfactual, without alk addition aimed at CDR, can still be established.	1
		[Projects must operate as retrofits to existing WWTP facilities.] See comment above.	4
		[Under this Protocol, a Project must be a retrofit to an existing WWTP facility (see Section 4).] Does section 4 not also include WWTP that currently add alkalinity?	7.3

Comments on the description of the wastewater treatment process.	Thank you for the feedback, we have amended the description of the wastewater treatment process in the introduction accordingly. We also reframed the description of secondary treatment to be focused on the source of the biogenic emissions, as that is the focus of this protocol.	Disinfection is normally considered part of secondary treatment as it is required for all plants under the original CWA. Tertiary is more commonly reserved for adding processes to meet more stringent discharge limits, like plants with low BOD, TSS, or TP limits.	1
		[solid and dissolved organic carbon is transformed into CO_2 through biological processes, which results in emission of biogenic CO_2] This is a bit simplistic. There is more happening here that probably should be acknowledged. Of course not all influent TOC is converted to CO2.	1
		Screening is generally considered part of preliminary, not primary treatment.	1
The documentation of partnership with the WWTP should show that the WWTP is okay with dosing AND will continue to provide access to the project proponent for any continual monitoring that is required.	Thank you for the feedback. We have included a clause of providing access to the project proponent for continual monitoring.	This documentation should show that the WWTP is okay with dosing AND will continue to provide access to the project proponent for any continual monitoring that is required.	4
Add estuaries as a discharge option.	Thank you for the comment. We accepted the change.	change to "rivers and estuaries"	4

Expanding alkalinity addition beyond biological treatment.	Thank you for the comment. We consider adding alkalinity to the effluent discharge point as ocean alkalinity enhancement (OAE), as the carbon removal happens in the ocean and would need a very different quantification approach. More details are described in our OAE from coastal outfalls protocol: https://registry.isometric.com/protocol/ocean-alkalinity-enhancement/1.0. The WAE protocol is limited to quantifying the reduction of biogenic CO2 outgassing within the boundaries of the WWTPs, which is why it specifies alkalinity addition in the biological treatment portion of the facility. It's possible for a project to use both the WAE and OAE protocol at the same time if they meet the requirements of both protocols. We've added some language clarifying that the combination of using the WAE & OAE protocols can be explored in consultation with Isometric, as there will be a number of considerations to work out for the first time, such as setting clear boundaries between the two projects, emissions allocation between the two projects, safeguards to ensure no double counting, etc.	*[Alkalinity addition occurs in the biological treatment portion of the facility]* I think this limitation is unreasonable. As far as mCDR is concerned adding ALK to the effluent discharge point is more efficient. But adding to the biological treatment portion is more efficient for the overall CDR (=mCDR + emission reduction within WWTPs). I do not think you should set up artificial boundaries.	4
Accounting of upstream feedstock emissions in the business-as-usual (BAU) scenario.	We appreciate all the comments and engagement on this topic - this is an area of debate, and getting comments on this topic is crucial to inform our decision making. We have carefully considered all of this feedback and have had numerous followup conversations around this topic. The Isometric Standard dictates that credits should only be issued for carbon removal, not emissions avoidance or reductions, and it is very important to clearly distinguish between the two.	*[Increase the alkaline feedstock dosing rate above the BAU operations in a WWTP that does currently add alkalinity (e.g. in the form of lime, NaOH, $MgOH_2$, etc.) for process control. See Section 8.3 for details on calculating the counterfactual in this case.]* Is there a third option that could apply. Decrease the Product Carbon Footprint of the feedstock below BAU operations in a WWTP that does currently add alkalinity. An example would be a WWTP currently using Brucite with a product Carbon footprint of 750kgCo2e/t being replaced by a low	4

	We define carbon removal activities as those that can generate net-negative emissions in a net-zero world. Emissions reduction activities, on the other hand, will never reach below zero emissions. With that definition, we amended the protocol to consider the case of a WWTP using a carbon intensive alkalinity source such as NaOH in their BAU with more nuance. If the BAU feedstock emissions exceed its CO_2 sequestration potential upon dissolution in wastewater, then this is a net-emitting activity. In this case, the "CO_2 sequestration potential" of the feedstock is compensating for the emissions of producing the carbon intensive feedstock, and we do not consider there to be any carbon removal in the BAU scenario. Projects operating in this case may be able to set the counterfactual term to 0, provided it's evaluated on a case by case basis in consultation with Isometric. Please see Appendix 3 in the Protocol for further explanation. Furthermore, it is required Project Proponents to account for feedstock production and transport emissions and deduct this in the net carbon removal calculation. We amended the protocol to make it more clear how BAU feedstock emissions should be accounted for in the scenario of WWTPs that already add alkalinity as part of their existing practices: 1. If the WAE project is using the same feedstock as the WWTP BAU operations and just increasing the dosage, then feedstock emissions only need to be accounted for the portion that is above BAU. This is considered the continuation of an existing practice where only the	carbon synthetic magnesium hydroxide with a PCF of 250kg/t.	
		The production of NaOH is highly carbon-intensive, requiring significant energy input ranging from 2,000–2,500 kWh per ton of NaOH produced (see Fig. 2). This energy demand results in emissions of approximately 0.85–1.200 kg CO2e per ton of NaOH, assuming a grid emissions factor of 0.4 kg CO2e per kWh in the U.S. These emission estimates exclude transport and embodied emissions, which would further increase the carbon intensity when considering the broader chlor-alkali process (e.g., electrode production and replacement). In comparison, the production of CaCO3 involves mining and milling, leading to a lower carbon footprint of 0.03–0.1 tons of CO2e per ton of limestone. As such, the case for counterfactual should not just be simply that any amount of NaOH usage must count against the CDR achieved when using CaCO3 – remembering that 1 ton of limestone can sequester ~0.4 ton of CO2 whereas with NaOH we are sequestering some of the emissions from NaOH production and may be net carbon positive. The protocol as is (section 8.3) appears to oversimplify the counterfactual not accounting for the energy intensiveness of caustic for pH control. Instead, it should allow for the recognition that some forms of alkalinity, such as NaOH from conventional production, are significantly carbon positive and it's use in wastewater is not carbon removal but some carbon emissions savings. CaCO3 use, on the other hand, is entirely carbon removal.	4
		The concepts presented appear too binary in that the carbon-intensity associated with the production and transport of those baseline alkaline inputs should inherently be factored into their use (and subsequent carbonate alkalinity generation). As such, WWTPs with existing NaOH or lime use should be considered with nuance when establishing a baseline or counterfactual	4

	portion of emissions above BAU is considered. This is consistent with “Approach 3” in the following article mentioned in the comments: https://carbonplan.org/research/cdr-counterfactual-accounting. 2. If the WAE project switches to using a different feedstock from the WWTP BAU, then this is considered a new process and emissions must be accounted for for all of the feedstock used. This would be “Approach 4” in the aforementioned article. We have additionally clarified that the calculation of CO2e_counterfactual is only focused on the counterfactual CO2e_stored, i.e. the conversion of biogenic CO2 to bicarbonate in the WWTP in the absence of a WAE project. CO2e_counterfactual does not include BAU GHG emissions. The calculation of CO2e_emissions considers all the emissions relative to BAU, and we have clarified that CO2e_emissions must be positive to ensure that emissions reductions are not credited.	state with comparison to using less carbon intensive sources of alkalinity.	
		Could feedstock manufacturing below BAU be included in the diagram. With a low carbon alkalinity it would be possible to increase alkalinity and decrease feedstock manufacturing below BAU.	7.2, Figure 1
		We’re concerned that the framing of the Wastewater Alkalinity Enhancement (WAE) system boundary decisions implies that avoided BAU emissions can increase the carbon dioxide removal (CDR) credits earned. The introduction, section 8.1, figure 1, and table 1 all appear to indicate that only the project emissions that exceed the Business As Usual (BAU) emissions are considered. If a WAE project replaces a BAU approach to managing wastewater pH, using this boundary could result in some of the credited CDR representing avoided BAU emissions rather than additional removals. As a purely illustrative example, imagine a BAU wastewater treatment plant that applies 15 tons of alkalinity, resulting in 15 tons of CO2 emissions to source the alkalinity. A CDR project proponent takes over the alkalinity treatment and they apply 20 tons of alkalinity — 15 tons to replace the existing practice, and 5 tons extra to optimize for CDR. The rule that emissions below the BAU are ignored should apply to the 15 tons of alkalinity that replaces the BAU. It should not apply to the 5 extra tons that would not have been applied in the BAU. However, the current rules appear to allow a CDR project to ignore all of the emissions that fall below the BAU, whether those emissions are associated with the BAU replacement or not. This is a problem because it means that avoided emissions achieved by making the BAU practice more efficient could effectively be used to offset the emissions of the new CDR activity (e.g., adding the 5 extra tons). This outcome is inconsistent with Isometric’s v1.0 Enhanced Weathering protocol, which conservatively guarantees	7.2, Figure 1

		that avoided BAU emissions are not counted as CDR by requiring project proponents to account for all CDR project emissions, whether they replace the BAU scenario or not. We recommend aligning the WAE protocol with the v1.0 Enhanced Weathering protocol outcomes by either (1) requiring that all project emissions be counted whether they replace the BAU scenario or not or (2) requiring that the emissions associated with the “extra” alkalinity are fully considered no matter how overall project emissions compare to overall BAU emissions. The second option would also guarantee no avoided BAU emissions are counted as CDR, but would require clear rules to define the “replacement” and “extra” alkalinity applied by the project. We recognize that Section 7.2 paragraph 3 could offer an alternative interpretation of what the WAE protocol requires: “Any emissions from sub-process or process changes that would not have taken place without the … CDR process must be fully considered”. This could be interpreted to mean that the embodied emissions of the 5 extra tons of alkalinity, which would not have taken place in the BAU scenario, must be “fully considered.” If that interpretation is correct, we would suggest adding clarifying language in the text, table 1, and figure 1. It would also be helpful to formulate how the BAU is compared to the project in the emissions equations. For further context, we recently wrote about why this counterfactual accounting problem is so challenging (https://carbonplan.org/research/cdr-counterfactual-accounting). Many parts of the current WAE v1.0 protocol appear similar to what we call “Approach 2: Ignore obvious avoided emissions”, which we show can still embed avoided emissions in CDR credits when the “replacement” and “extra” parts of a CDR project are not considered independently. What we call “Approach 3” addresses this problem by comparing only the "replacement" portion of the CDR project to BAU emissions. Our “Approach	

		4” is consistent with Isometric’s v1.0 Enhanced Weathering protocol.	
		We recommend explicitly stating that CO2e_counterfactual must always be positive. This would ensure that projects would not earn CDR credits for avoiding emissions associated with the BAU alkalinity practice.	8.3
		[Equation 1] How would a change to allow carbon alkalinity be treated with this equation. For example, if Counterfactual CO2e is calculated on the basis of a magnesium hydroxide feedstock (Brucite) with a PCF of 750kg co2e/t but the alkalinity enhancement uses a synthetic magnesium hydroxide with a PCF of 250kgCO2e/t.	8.1
Monitoring data related to regulatory requirements can't be redacted	Thank you for the comment. We have included this change.	Now that monitoring is part of the platform, it may be worth stating that monitoring data related to regulatory requirements can't be redacted.	5.6
Ecological impacts requirements	Thank you for the comment. Yes the requirement is described in the first sentence of 6.3.1, which is to conduct an environmental risk assessment. The risk assessment should at a minimum consider the factors listed in this section. No change made.	It is not clear from this writing what do you expect the practitioners to do. Is it covered under the first sentence of 6.3.1?	6.3.1
Other significant risks of elevated WWTP effluent pH	Thank you for the feedback, we have incorporated these into Section 6.3.1. We added the risk of the WWTP not being able to meet its discharge permit as a factor that needs to be assessed and mitigated, and we included the additional context of how increased effluent pH may impact aquatic life through increased free ammonia fraction.	Perhaps the most significant risk of elevated WWTP effluent pH is increased free ammonia fraction and effluent NH3 toxicity for treatment plants without significant dilution at the outfall or effluent dominated receiving streams.	6.3.1
		A significant risk might also be impacts on the WWTP not meeting its discharge permit, e.g. for pH<9.0 as an example.	6.3.1

Leakage emissions	Thank you for the feedback. We decided to keep this language here for consistency with other protocols, and for clarification of how leakage emissions are defined as it is sometimes not clear to readers that this is referring to market leakage.	*[as a result of induced market changes]* suggest to delete highlighted text - unnecessary qualification?	7.1
Leakage emissions	Thank you for the suggestion. We decided to keep the phrasing as is for now, for consistency across our other protocols. But we have noted this as a small update to make across protocols the next time we do a broad update on GHG accounting sections.	I think it is better to say "likely" leakage as it depends on the areas outside the system.	7.1
Terminology is confusing between CO2 and CO2e	Thank you for the feedback. To clarify, we only consider gross CO2 removal, but the "e" is there when referring to the "net removal" because net involves subtracting emissions, and we account for non-CO2 GHG emissions as well which need to be converted to a CO2 equivalent. Table 1 clarifies the scope of which greenhouse gasses are included for each source, sink, or reservoir considered in the system boundary. We have now clarified earlier in 7.1 when net CO2e is first introduced that only gross CO2 removal is considered.	*[The total net CO_2e removal is calculated using a series of measurements for a specified Reporting Period, and is written hereafter as CO2eRemoval,RPCO2e{Removal,RP}CO2e Removal,RP.]* while it is a good thing you emphasize CO2e removal, at the current stage the community's focus is on CO2 removal. Your emphasis on CO2e may slow down the CDR effort.	7.1
		[For CO_2 capture and CO_2 leakage, only CO_2 is expected to be included as part of the quantification.] you need to make this point clear earlier. Otherwise, it would slow down the overall CDR effort.	7.2
System boundary	Thank you for the feedback. The system boundary sets out the GHG Sources, Sinks, and Reservoirs associated with the project that need to be considered in the GHG Statement. Figure 1 and Table 1 establish the system boundary, but they are not referring to the actual flow of water itself.	I feel quite uncomfortable reading this section. Coastal and ocean water flows and cannot strictly put within a box with a clear boundary. Many of the ideas come from terrestrial CDR practice and may not strictly applicable to the coastal ocean.	7.2

Crediting the avoidance of non-CO_2 GHG is beyond the scope of this protocol, and thus is not considered.	Thank you for the comments. Emissions of non-CO2 GHGs from the WWTP are not included in the systems boundary (see Table 1), so there would not be the potential for implicitly crediting their reductions. Furthermore, CO_2e Counterfactual only considers CO_2 that would have been stored in the absence of the project. In the introduction, we do mention that WWTPs are significant sources of N2O and CH4 for completeness to acknowledge that CO2 is not the only GHG that is emitted at a WWTP. Reduction of other GHG gasses, while not credited for under this protocol, could be considered co-benefits of WAE. We added an additional clarification sentence in the introduction to make it clear that only the removal of CO2 is credited under this protocol to avoid any potential confusion.	Surely any project related change in non-CO2 GHGs emissions must be reflected in the LCA, and thus there would be an implicit crediting for any reduction?	7.2.1
		[Crediting the avoidance of non-CO_2 GHG is beyond the scope of this protocol, and thus is not considered.] then why do you even include these earlier? that has a potential to confuse readers.	7.2.1
Counterfactual scenario definition	Thank you for the comment. Counterfactual scenario refers to what would have happened in the absence of the WAE project. So it is not referring to the case of once alkalinity has been added.	Is counterfactual scenario the right word? Once we added ALK, it becomes a reality. Isn't it?	7.3
Confusing notation	Thank you for the comment. We changed it to CaCO3 in the example to make it more clear.	*[MCO3]* this is a little confusing because it looks like you meant Mg. Since you are already just demonstrating an example, not all of the possible feedstock chemistries, it would be more clear to say CaCO3.	8.2
The quantification method doesn't work as written if the feedstock is not a pure mineral.	Thank you for pointing this out. We have added text clarifying that conservative assumptions must be made when non-pure feedstocks are used.	*[Equation 3]* This method doesn't work as written if the feedstock is not a pure mineral. You can't assume that the individual minerals dissolve at the same rate and just take a weighted average. The molar mass for the feedstock doesn't make sense for a feedstock that is not a pure mineral with a single cation	8.2

Quantification section repeats parts of the introduction	Thank you for the comment. We have placed this information in the Introduction, but have kept it as a reminder in Section 8.2.	*[It is important to note that Wastewater Alkalinity Enhancement projects prevent the release of biogenic CO_2 to the atmosphere, which is not counted in standard GHG accounting frameworks. Thus, Wastewater Alkalinity Enhancement qualifies as carbon dioxide removal, rather than emissions avoidance.]* Probably better placed in the Introduction?	8.2
Should CO2 losses be relative to the baseline?	Thank you for the comment. This protocol only considers the CDR that occurs within the confines of the WWTP, so any net uptake (from reduced outgassing or ingassing) that occurs in the estuary or ocean are not included in crediting. The losses only refer to any re-emission of the CO_2 that was captured within the WWTP.	*[CO2eLosses,RP are losses of CO_2 due to riverine and oceanic processes, in tonnes CO_2e. See Section 8.2.3 for calculation of this term.]* shouldn't this be relative to the baseline (BAU)? this could also be a negative value if more CO2 is take up in estuarine and coastal ocean waters. For example, if at BAU ocean releases CO2 to the atm of 5 units and now with ALK enhancement, ocean uptake CO2 of 3 units, then there is net mCDR of 8 units.	8.2
Allow for plant-specific considerations that are not captured by the schematic and equation.	Thank you for your comment. A paragraph has been added below the schematic to clarify that there may be site-specific variations in the treatment process that require different considerations, and that these must be documented in the PDD. The examples provided by this comment are given.	There may be important project or plant specific considerations that may not be well captured with this simplified schematic and must be managed in project documentation. Examples: 1. Recycle streams produced within the plant, normally solids handling processes, could bring into the control volume considerable sources or sinks (high NH4 load) of ALK. 2. TF/SC and similar processes that are a combination or hybrid of attached and suspended growth may not fit this exactly. 3. HPO plants that inherently accumulate even larger supersaturation of CO2 compared to traditional or conventional activated sludge may need to be considered a bit differently. 4. Some chemicals may be added into the process at inconsistent doses that depend on season, seasonal permit limits, etc. These chemicals could be sinks of ALK, for example alum and ferric iron salts. They could also result in ALK production, for	8.2.1

		example the addition of supplemental carbon being added to drive additional denitrification during times of the year when TN permit limits are lower.	
Clarification of sample digestion	Thank you for the comment. Sample digestion refers to measurement of WAS; this has been clarified. For measurement of FS_Effluent, this term refers to feedstock that is suspended in the effluent stream, not dissolved. Thus, samples must be acidified prior to filtration to ensure any undissolved feedstock can be measured.	*[sample digestion, or analysis on ICP-MS or ICP-OES]* If you are trying to measure the undissolved feedstock, wouldn't you need sample digestion? If you are trying to measure dissolved (see previous sentence), then sample digestion isn't needed and you should not acidify samples, because you will re-dissolve any precipitated carbonates, which shouldn't be considered dissolved.	8.2.1.1
Why is Option 1 referring to dissolved weathering products if Option 1 is using the solid phase?	Thank you for catching this. This is a typo -- phrasing has been changed to "cations relevant to the chosen feedstock".	*[relevant dissolved weathering products]* I'm confused - isn't Option 1 using the solid phase, not the dissolved products?	8.2.1.1
What is baseline referring to in Option 1?	Yes, thank you, this should refer to the influent stream; this has been updated.	*[baseline]* Should this be relative to the influent stream? Or what does baseline mean in this context? The concentrations in the effluent and the WAS will still change over time without dosing from the water coming into the WWTP.	8.2.1.1
Does the solid phase quantification approach assume that all dissolution is from carbonic acid?	Thank you for pointing this out. We have reformulated Equation 3 and subsequent sections to fully account for non-carbonic acid dissolution.	*[solid phase]* Does this assume that all dissolution is from carbonic acid?	8.2.1.1
Location of text.	Thank you for the feedback. We have moved this to the introductory paragraph of "Calculation of m_dissolved"	*[All calculations must be submitted for verification.]* Should be in the intro to this section rather than hidden down here!	8.2.1.1

If there are multiple base cations in the feedstock that contribute to CDR, it shouldn't be assumed that they all weather at the same rates.	Thank you for the comment. Because dissolution is being directly measured, rather than modeled based on an assumed dissolution rate, only what has weathered is being accounted for in this framework.	*[conservative dissolved weathering products]* If there are multiple base cations in the feedstock that contribute to CDR, it shouldn't be assumed that they all weather at the same rates. This analysis should happen for each cation. (Maybe this is implied but it would be clearer to say it explicitly.)	8.2.1.2
Upper Limit of CO2e Stored	Thank you for the comments, we have reframed this section to be more clear that it's referring to the total biogenic CO2 outgassing within the WWTP. This protocol only credits for the avoided biogenic CO2 outgassing that occurs within the confines of the WWTP, and not any reduced outgassing that occurs after discharge in rivers, estuaries, or ocean. The purpose of this section is thus to have a check on how much of the biogenic CO2 outgassing is expected to occur within the WWTP as opposed to outside of the plant. Because this is framed as a validation check, we accept a range of options for estimating this upper bound. We've updated the options in this section based on the comments received.	*[CO_2eStored cannot, by definition, exceed the counterfactual biogenic CO_2 emissions.]* why not say the total amount of biogenic CO2 production? again counterfactual is confusing.	8.2.2.3
		in this case, baseline emission is more straightforward.	8.2.2.3
		[Measurement of dissolved CO_2 concentrations prior to aeration and in the outflow from secondary treatment. The difference in these values can be taken as the CO_2 loss during the treatment process.] This may or may not be correct as it depends on the rate of biogenic CO2 production or organic carbon decomposition. If the rate is high enough comparing to the CO2 degassing or emission, then, DIC difference will be smaller than the true CO2 degassing loss. Yes, Comparing to the baseline is the key.	8.2.2.3
		Section 8.2.2.3. It is not clear to me why one has to report an upper limit of CO2eStored if measurements of CO2 uptake are part of the protocol. Furthermore, the two methods suggested both have issues. For the first ("Measurement of dissolved CO_2 concentrations prior…), CO2 is not a conservative entity due to the hydration reactions in the carbonate system. Therefore measurements at two stages of co2 will not constrain biogenic co2	8.2.2.3

		production. For the second method (“Modeling of outgassing in secondary…”), this method would also need an estimate of a transfer velocity (or gas exchange coefficient). Due to bubbling and the non-standard turbulence associated with WWTP, determining the gas transfer velocity will be difficult and probably prone to a wide range of possibilities. A firm understanding of the gas transfer velocity currently is a large source of uncertainty in most aquatic systems. A straightforward method would be to model the potential CO2 production with Biological Oxygen Demand (BOD). BOD is an estimate of potential CO2 production and is already a standard measurement. BOD+CO2 prior to aeration would constrain the amount of CO2 available for reactions.	
More discussion of the impact of WAE on WWTP equipment lifetimes	Thank you for raising this. The emissions associated with more frequent replacement of plant equipment above business as usual frequencies is accounted for. This is covered in Table 1 under the category of "consumables" for membranes, and "Maintenance of project site." Maintenance of project site includes "maintenance, repair, replacement, and refurbishment activities associated with equipment, buildings and infrastructure," and would cover replacing parts such as pumps or pipes. We have expanded upon this part of the table to provide more specific examples of possible increased fouling and wear on equipment.	if alkaline feedstock is added in the secondary treatment zone, as mentioned earlier, then carbonate precipitation can absolutely occur in the aeration / secondary treatment tanks. Calcium carbonate precipitation can lead to membrane fouling, driving up the energy required to supply oxygen to the tanks and to mix the water. This also greatly impedes the lifetime of the membranes which normally have a lifetime of about 20 years depending on the material. This should already be accounted for in the methodology, but adding alkalinity to the secondary treatment will likely foul the membranes and increase losses associated with precipitation, increased energy use, and increased material use above the BAU as a tradeoff for the increased dissolution kinetics associated with introducing alkalinity at this stage. This methodology should more explicitly discuss the lifetimes of the equipment necessary to carry out these treatments, and the impacts that this approach would have on them (membranes are just one example: pipes, pumps, etc. would also have to be replaced at a greater rate). As I see it, the term "materials" in the scope defined above does not obviously include	8.2.3

		the emissions associated with replacing capital equipment more frequently. I also think that, given the impacts on plant's infrastructure, these credits should be analyzed on a 20-year project lifetime https://www.nature.com/articles/s41598-020-61814-5 here is just one source for calcium carbonate precipitation in secondary treatment. This problem is not insignificant	
Discussion of additional CO2 uptake in estuary & ocean	Thank you for the feedback. Indeed, there is potential for more CO2 uptake in the estuary and coastal waters. The quantification for open-water CDR is described in the OAE protocol. Please see the above comment response.	depending on the amount of ALK addition (or liming), instead of loss, estuarine & coastal waters can also take up more CO2 as mCDR, again relative to the baseline.	8.2.3
		[The effluent exiting the WWTP is enriched in TA and DIC compared to the receiving waters. After discharge into the receiving waters, losses may reduce the efficiency of CO_2 stored as a result of Wastewater Alkalinity Enhancement. If it cannot be justified that these losses are negligible, it is expected that these losses are quantified and subtracted in the calculation of CO2eStored,RPCO2e{Stored, RP}CO2eStored,RP.] I agree. But depending on the amount of ALK addition (or liming), instead of loss, estuarine & coastal waters can also take up more CO2 as mCDR.	8.2.3
		[The aims of monitoring in receiving waters are to demonstrate permit compliance, monitor environmental conditions, conduct ongoing monitoring for quantification of downstream losses, and establish processes for adaptive management to ensure that Project activities are stopped if negative impacts are identified.] Another aim is to assess the additional mCDR, that is CO2 uptake by estuarine and coastal waters because of the ALK addition in the WWTPs.	11.3

Near field losses quantification approach	Thank you for the feedback. The two endmember mixing model you described is indeed the method we expect practitioners to use to determine the outgassing loss (or ingassing tendency). We will update the language in the protocol to clarify this.	*[The recommended quantification approach for outgassing upon initial mixing is to estimate the difference between the measured DIC at the WWTP effluent and the theoretical equilibrium DIC of the effluent and ambient water mixture calculated at ambient environmental conditions (temperature, salinity, pH, and pCO_2).]* I don't think this approach is correct. I do not see how you calculate the theoretical equilibrium DIC at ambient conditions (T,S, pH and pCO2). Do you assume a known pCO2 to calculate the DIC? The correct approach is to use the two endmember mixing model. You can predict the DIC(m) and TA(m) of the mixture from the two endmembers S(1), TA(1) and DIC(1) and S(2), TA(2) and DIC(2). Then the difference between DIC(m) and the observed DIC is the outgassing loss DIC. This is also the correct way to calculate the theoretical pH and pCO2 of the mixture before the outgassing loss.	8.2.3.1
Framing of ocean outgassing	Thank you for the comments. This sentence is referring to the efficiency of how much DIC can be stored per unit alkalinity in the ocean, or delta DIC/delta Alk. So for an example of NaOH dissolution, delta DIC/delta Alk = 1 initially upon dissolution in the WWTP. But upon entering the ocean which has a higher pH, the carbonate system is shifted more towards carbonate ions so some of the carbon is now stored as CO32- instead of HCO3-, and delta DIC/delta Alk might decrease to be 0.9.	*[Typically, the ocean has a higher pH than rivers and the increased presence of CO32- in oceans can reduce the total storage of terrestrially exported DIC.]* I don't understand this statement. In the context of outgassing, why raised pH and CO32- would reduce the total storage of terrestrial exported DIC.	8.2.3.2.2
		Yes, estuarine and coastal degassing of CO2 driven by high CO2 from river and wetland waters can reduce storage of DIC, but that is not because of the higher pH and CO32- in the ocean.	8.2.3.2.2

Is it possible to use the OAE protocol at the same time for the indissolved feedstock rather than decanter/filter the solids washout?	Thank you for the comment. Yes it's possible for a project to use both the WAE and OAE protocol at the same time if they meet the requirements of both protocols. The release of undissolved solids in the final effluent of the WWTP will have to first adhere to the allowable limits in the WWTP discharge permits, which is why there may be some solids removal may still be necessary. We've added some language clarifying that the combination of using the WAE & OAE protocols can be explored in consultation with Isometric, as there will be a number of considerations to work out for the first time, such as setting clear boundaries between the two projects, emissions allocation between the two projects, safeguards to ensure no double counting, etc.	*[Projects which aim to discharge undissolved feedstock into the ocean and quantify open ocean CDR must refer to the Ocean Alkalinity Enhancement from Coastal Outfalls Protocol.]* Is it possible to use the OAE protocol at the same time for the indissolved feedstock rather than decanter/filter the solids washout?	8.2.4
More information on calculating the counterfactual	Thank you for the feedback. We have expanded this section and provide more guidance on calculating the counterfactual for different scenarios.	Surely there's a lot more to calculating the counterfactual emissions/storage than this? 8.3 probably needs to be expanded.	8.3
Why would limestone ever be present in any significant quantity in raw influent or primary effluent?	Thank you for the comment. This is mentioned for completeness, since we assume this is negligible to justify a value of 0 for the counterfactual scenario of a WWTP that does not add any alkalinity.	Why would limestone ever be present in any significant quantity in raw influent or primary effluent?	8.3
Add discussion of case where WAE decreases energy consumption	Thank you for pointing this out. We have included increasing energy efficiency as an example in the protocol under "Secondary Impacts on GHG Emissions." We clarify that crediting emissions reductions is beyond the scope of the protocol though.	WAE could also dramatically decrease energy consumption. For example, alk addition and operating at non-inhibitory pH and ALK could allow operation of aeration tanks/aerobic zones at considerably lower dissolved oxygen concentrations while continuing to meet all treatment objectives (because now ALK is not limiting).	8.4.5

Energy accounting materiality	Thank you for pointing this out. This was part of a list of examples and is not meant to be prescriptive for every project. We are also working on releasing a new GHG accounting module this year which will include materiality guidelines for all projects, so that very minor contributions can be ignored.	*[measurement instruments]* minor contribution	8.4.5
Should allow for a wide variety of WWTPs.	Thank you for the feedback. It is our intention to be inclusive of many different types of secondary treatment processes, and we focused on providing more detailed guidance for activated sludge processes in version 1.0 of this protocol as that is the most common. However we plan to develop more detailed guidance for other types of biological treatment in the future. For now, the protocol allows for flexibility for non-activated sludge plants on a case by case basis. We've modified the applicability section to say: "This protocol quantification framework is developed for WWTP treating biogenic waste with activated sludge reactors and variations on activated sludge processes, which is the most common form of biological treatment. Alternative types of biological treatment require modifications to the protocol, particularly Section 8 and Section 11, and they may be allowed on a case-by-case basis in consultation with Isometric. More guidelines for other types of WWTPs, such as membrane bioreactors, will be explored for future versions of this protocol." We've also added a note in Section 11 to clarify that the exact monitoring locations may differ depending on plant-specific processes (such as Garrett wasting) to make it clear that these	This implies an activated sludge process with a secondary clarifier. The protocol should also be relevant for MBR plants....	11.1
		And in addition, plants that do hydraulic or Garrett wasting from the aeration tank should not be excluded.	11.1
		Similarly, SBR plants should not be excluded	11.1

	are not excluded from the protocol. Exact monitoring locations for each plant just need to be described in the Project Design Document.		
Typos, formatting, & small wording suggestions	All typos have been addressed. Thank you for raising these to us.	emissions in stead of emission?	1.0
		emissions instead of emissio	1.0
		and permits	1.0
		and dissolved	1.0
		rivers and estuaries	4.0
		better to say "one to three months"	4.0
		Inconsistent line spacing makes this table look a bit messy	7.2
		I think the first "separate" is a typo?	7.2
Are all the pre-deployment requirements actually necessary?	Thank you for the feedback. The intention of this section is to compile a list of the data that are used in other parts of the protocol (such as establishing BAU operations), as well as to characterize the natural variability of relevant parameters during normal WWTP operations. We have carefully re-evaluated each pre-deployment requirement and further streamlined it, keeping only the criteria that are explicitly used or referred to in other sections of the protocol.	Are all the pre-deployment requirements actually necessary? The quantification doesn't rely on the baseline carbonate chemistry parameters, and some of this historical plant data may be difficult to obtain.	10
Loss terms are cumulative and dependent on upstream losses.	Thank you for the comment. A loss discount has been reformulated as multiplicative factors of each process which may result in losses. This more accurately reflects how increased upstream outgassing may result in downstream outgassing, due to the reduced availability of DIC from upstream	These losses are not independent of upstream losses; higher levels of river outgassing would tend to reduce losses once bicarbonate reaches the ocean.	8.2.3.2.2

	outgassing. The quantification approach for individual loss factors remains unchanged.		