COMMENTS TO TRUSSEL REPORT
William Bourcier
February 15, 2017.

I have reviewed the assessment of carbon dioxide releases from subsurface desalination feeds provided by Trussel Technologies (Appendix G2 – Trussel Technologies Inc. Technical Memorandum, Response to CalAm MPWSP DEIR) and compared their results with the estimates that I provided as comments to the DEIR and California Ocean Plan.

Our results differ in that I predict larger carbon dioxide releases than estimated by Trussel. In my opinion the values I quoted are more accurate estimates than those reported by Trussel. I believe the following observations and comparisons explain the differences.

1. *The Trussel report ignores all carbon dioxide released from the reverse osmosis permeate*

The Trussel report correctly assumes that the location at which the carbon dioxide release will take place will be affected by the reverse osmosis process. Once the feed fluid is brought to the surface from the well and contacts the atmosphere, it will begin to equilibrate with the atmosphere and release carbon dioxide. Depending on the type of pre-treatment and feed storage methods, much of the degassing may not happen until after the fluid has been subjected to the reverse osmosis (RO) process. In typical sea water RO processing, much of the contained dissolved carbon dioxide will end up in the permeate (vs. the concentrate) as can be seen in Appendix A of the Trussel report. The carbon dioxide in the permeate stream will be released to the atmosphere upon exiting from the RO system.

However, in the Trussel report it is asserted that this carbon dioxide will **not** be released because prior to distribution of the RO permeate, the permeate will be chemically treated to avoid release of carbon dioxide. Although no more detail is given in the Trussel report, this could be done by adding caustic (NaOH) to the permeate to increase the pH and convert the dissolved carbon dioxide gas into bicarbonate ion. Adding caustic lowers the effective partial pressure of carbon dioxide in the fluid and if added in the right amount (added molal amount of caustic = molal amount of carbon dioxide that would have been released) no carbon dioxide release to the atmosphere will take place. In normal seawater desalination systems a small amount of caustic is commonly added to the permeate in order to avoid corrosion of the distribution system. The caustic is usually added after carbon dioxide degassing in order to reduce the mass of caustic needed. I assert here that caustic addition is the chemical treatment referred to but not specifically identified in the Trussel report.

The error in this analysis is that no account is taken of the carbon dioxide release ("carbon footprint") which takes place during the production of caustic used to treat the permeate. Caustic is commonly produced using the chloralkali process. The carbon footprint (the amount of carbon dioxide generated and released as a result of production of the caustic) is substantially larger than one mole of carbon dioxide per mole of caustic. In other words, to make enough caustic to

neutralize some mass of carbon dioxide in the permeate requires that a much larger amount of carbon dioxide be generated during the production of the caustic. This ratio is about 2 for most production facilities (i.e. two moles of carbon dioxide are produced per mole of NaOH) but numbers as low as 1.7 are reported for the most modern chloralkai plants [1].

So it is clearly not valid to ignore the carbon dioxide released from the reverse osmosis permeate. Chemical treatment to suppress carbon dioxide release makes the total release of carbon dioxide associated with desalination even greater. In order to minimize total release of carbon dioxide the best approach is to simply allow the carbon dioxide to degas. Other options imply larger CHC releases.

The carbon dioxide that would be released from the permeate and is ignored in the Trussel report needs to be added back to the estimated carbon dioxide release in order to report an accurate and complete carbon dioxide release rate.

2. *In the Trussel report the well fluid composition used to compute the "worst-case" carbon dioxide release is not representative of fluids sampled to date and in fact is nearly the "best-case" scenario*

The well fluid composition used in the Trussel report to compute carbon dioxide release is not representative of the carbon dioxide gas contents of the 15 wells sampled to date in the Marina area as part of the CalAm project. Figure 1 below shows my estimated carbon dioxide release rates along with the fluid studied in the Trussel report (in red). As can be seen, the well fluid

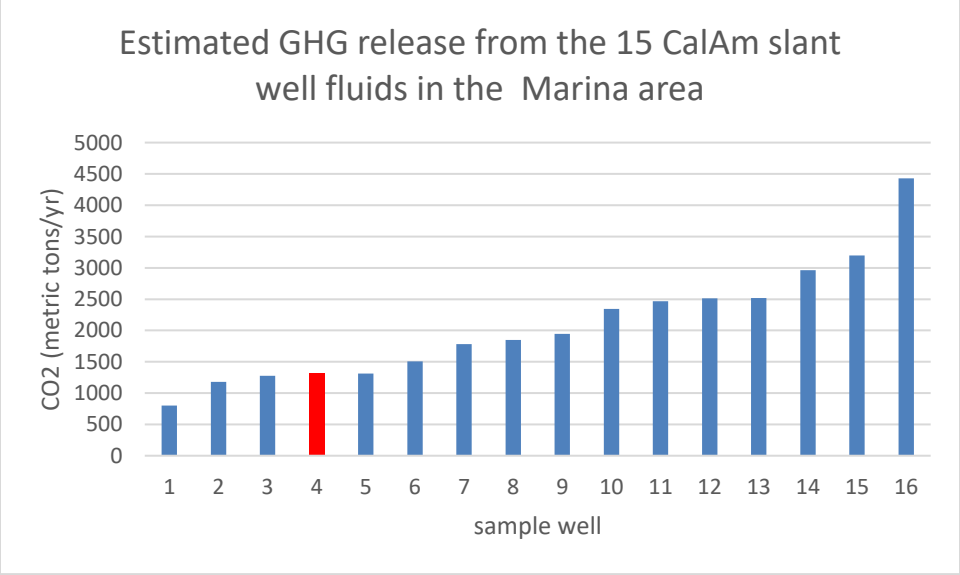

Figure 1. Estimated carbon dioxide release rates (metric tons per year) for the 15 well fluid samples reported in the Draft EIR (Appendix G2) and, in red, the fluid composition used in the Trussel study. Estimates are based on 9.6 MGD plant operating at 41%

[1] http://www.eurochlor.org/media/9385/3-2-the_european_chlor-alkali_industry_-_an_electricity_intensive_sector_exposed_to_carbon_leakage.pdf

recovery. Average release for all wells is about twice the release of the fluid used in the Trussel analysis.

chosen for their study has among the lowest carbon dioxide contents of the 15 wells sampled. In fact it is the fourth lowest in gas content. The Trussel report having referred to this fluid as being a "worst-case scenario" is simply not true. It is closer to being a best-case scenario. Their estimated release rate of 735 tons/year when corrected for loss from the permeate increases to about 1311 tons/year. This is about one half of the average release rate for all wells sampled to date by CalAm in the Marina area and less than 30% of the largest value.

3. *Comparison of methods for estimating carbon dioxide releases*

It should be noted that the method I use to estimate carbon dioxide release and the method described in the Trussel report provide very similar carbon dioxide release rate estimates when compared directly. I estimate about 770 tons/yr for the RO concentrate carbon dioxide release vs. 735 tons/yr of release reported in the Trussel report. The small difference between these two numbers can probably be attributed to slightly different thermodynamic data used in the two methods. Note that I used the same correction methods for salinity, temperature, and other factors described in detail in the Trussel report. This suggests that going forward we have an accurate and verified method for estimating GHG releases. What is needed now is validation of the method from an actual feed source.

Summary

The Technical Memorandum provided by Trussel Technologies provides verification that carbon dioxide release from subsurface intakes is likely to take place. For any given fluid composition, the calculated release tonnages calculated by Trussel are very similar to those Bourcier provided in comments to the DEIR and a later report on the topic. The agreement verifies the method of calculation that both parties (Trussel and Bourcier) used to estimate carbon dioxide release rates.

The fact that the carbon dioxide release tonnage estimates provided by Trussel are smaller than those reported by Bourcier is due to two issues: (1) the Trussel estimates ignore any release from the reverse osmosis permeate – which I have shown above to be a unjustifiable assumption; and (2) the Trussel report uses a fluid input composition that has among the lowest carbon dioxide contents of any of the wells sampled to date by CalAm in the Marina area. These two factors are responsible for the difference in estimated carbon dioxide release rates.

In addition, and potentially of far more importance is methane release from the feed solutions. Methane is often found in co-equal amounts with carbon dioxide in pore waters such as those that host the proposed desalination feed sites along the California coast. Because of the much greater greenhouse potency of methane vs. carbon dioxide, methane is of far more concern. Future work to address the issue of GHG release from subsurface feed intakes should include actual measurements of both carbon dioxide and methane in potential desalination feeds.