Title: Circular economy in the meat processing sector – using life cycle assessment as a screening tool

Authors: Tracey Colley, Morten Birkved, Michael Z Hauschild

Life cycle assessment (LCA) is an rigorous, comprehensive analytical method which has been used to assess the environmental impacts of food supply chains in many geographic areas, most notably Europe and North America (Aronsson et al., 2014). There have been carbon, water and land use footprints (CF, WF, LUF) and LCA studies on meat supply chains for beef, sheep, pork and chicken in Australia (Ridoutt, Page, Opie, Huang, & Bellotti, 2014; Ridoutt, Sanguansri, & Harper, 2011; S. G. Wiedemann, Mcgahan, & Murphy, 2017; S. G. Wiedemann, Yan, & Murphy, 2016; S. Wiedemann, McGahan, Grist, & Grant, 2010; Stephen Wiedemann et al., 2015), most of which have confirmed results of similar studies from overseas, namely that most of the environmental impacts are associated with the on-farm emissions. Studies on improving the sustainability of food supply chains have mostly focused on identifying opportunities within individual life cycle stages, then aggregating the opportunities from each stage to propose a whole of supply chain solution. Only more recently have LCA studies taken a whole of supply chain approach (Hessle, Bertilsson, Stenberg, Kumm, & Sonesson, 2017; Sonesson et al., 2016), identifying synergies within and between life cycle stages, to identify an optimised supply chain which is consistent of the objective of the circular economy, namely to maximise the value and utility of all supply chain components at all times (Stahel, 2016).

A recent study had identified potential improvements in post-farm meat processing and product distribution as reducing waste and energy use, changing from fossil fuels to bioenergy and optimising packaging use and transport (Sonesson et al., 2016). As part of the analysis, the opportunity for incorporating a diversity of energy sources and a mix of renewable and bioenergy were included.

This study proposes a decision support framework for assessing the opportunities for the circular economy in agribusiness sectors. The first step involved a gate-to-gate LCA of a meat plant which processes beef, sheep, pigs and goats, with the requisite collection of a detailed site inventory from primary and secondary data sources. The functional unit was one tonnes of hot standard carcase weight (t HSCW), which is the weight of the animal carcases as they leave the kill floor and enter the chiller. All treated wastewater is currently used onsite and biogas generated from the anaerobic pond treatment systems is not captured, but is emitted to atmosphere. Byproducts are processed onsite to produce tallow and meal and tallow is currently exported while meal is sold in the local market. The plant supplies the domestic meat market and has a transport fleet for distributing chilled product. The site is connected to the electricity supply grid and does not have any backup power generation, and the boiler fuels are coal and LPG, as the site is not near a natural gas pipeline. The current operation was used as the base case and the results were verified against existing published data.

The second step involved comparing site consumption data from the life cycle inventory to current industry benchmarks. A number of efficiency projects were identified and this reduced consumption was used for all the scenarios.

The third step involved identifying resources and opportunities in the supply chains. Data from the life cycle inventory was used to identify potential streams, with a focus on maximising the value of each stream. Published CF, WF, LUF and LCA studies from Australian upstream supply chains were analysed to identify supply chains characteristics. Opportunity for energy supply diversification were included at this stage, with a particular focus on renewable and bioenergy integration opportunities. For the case of biomass production, assumptions were made about annual growth rates of biomass and this was converted to an area of land area required.

The fourth step involved identifying physical, chemical, biological, geographical and technological constraints (or risks) relevant to the supply chain and the geographic location of the site using a qualitative approach. This was used to eliminate infeasible scenarios and scenarios which increased risks in areas such as public health, cost or liability for the company.

The fifth and final step involved modelling a number of scenarios using openLCA software using the Ecoinvent database for background processes and using the Life Cycle Impact Assessment methods as recommended by the Australian Life Cycle Association Society (Renouf et al., 2016). These scenarios included utilising tallow, biogas from the anaerobic treatment pond, solar photovoltaics, wind turbines and biomass in different combinations for transport, thermal and electrical energy supply.

Although the results are location specific to a certain extent, this study provides a method which could be used to support agribusiness supply chains in the transition to a circular economy, to enable them to reap the benefits while minimising the risk.

References:

Aronsson, A. K. S., Landquist, B., Esturo, A., Olafsdottir, G., Ramos, S., Pardo, G., … Mjöll Ingolfsdottir, Gyda1 Yngvadottir, E. (2014). The applicability of LCA to evaluate the key environmental challenges in food supply chains. In *Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-food Sector* (pp. 55–63). ACLCA.

Hessle, A., Bertilsson, J., Stenberg, B., Kumm, K.-I., & Sonesson, U. (2017). Combining environmentally and economically sustainable dairy and beef production in Sweden. *Agircultural Systems*, *156*, 105–114. http://doi.org/10.1016/j.agsy.2017.06.004

Renouf, M. A., Grant, T., Sevenster, M., Logie, J., Ridoutt, B., Ximenes, F., … Lane, J. (2016). *Best Practice Guide for Life Cycle Impact Assessment in Australia* (Vol. 2). Retrieved from http://www.alcas.asn.au/sites/default/files/Best Practice Guide (V2 15_2_16) (Final)_0.pdf

Ridoutt, B. G., Page, G., Opie, K., Huang, J., & Bellotti, W. (2014). Carbon, water and land use footprints of beef cattle production systems in southern Australia. *Journal of Cleaner Production*, *73*, 24–30. http://doi.org/10.1016/j.jclepro.2013.08.012

Ridoutt, B. G., Sanguansri, P., & Harper, G. S. (2011). Comparing Carbon and Water Footprints for Beef Cattle Production in Southern Australia. *Sustainability*, *3*(12), 2443–2455. http://doi.org/10.3390/su3122443

Sonesson, U. G., Lorentzon, K., Andersson, A., Barr, U.-K., Bertilsson, J., Borch, E., … Wall, H. (2016). Paths to a sustainable food sector: integrated design and LCA of future food supply chains: the case of port production in Sweden. *Int J Life Cycle Assess*, *21*, 664–676. http://doi.org/10.1007/s11367-015-0969-5

Stahel, W. R. (2016). Circular economy. *Nature*, *531*(24 March 2016), 435–438. Retrieved from http://www.nature.com.proxy.findit.dtu.dk/polopoly_fs/1.19594!/menu/main/topColumns/to pLeftColumn/pdf/531435a.pdf

Wiedemann, S. G., Mcgahan, E. J., & Murphy, C. M. (2017). Resource use and environmental impacts from Australian chicken meat production. *Journal of Cleaner Production*, *140*, 675–684. http://doi.org/10.1016/j.jclepro.2016.06.086

Wiedemann, S. G., Yan, M.-J., & Murphy, C. M. (2016). Resource use and environmental impacts from Australian export lamb production: a life cycle assessment. *Animal Production Science*, *56*(7), 1070. http://doi.org/10.1071/AN14647

Wiedemann, S., McGahan, E., Grist, S., & Grant, T. (2010). Environmental Assessment of Two Pork Supply Chains Using Life Cycle Assessment, (9), 134. Retrieved from http://www.fsaconsulting.net/fsa/docs/RIRDC_Pork_LCA.pdf

Wiedemann, S., McGahan, E., Murphy, C., Yan, M.-J., Henry, B., Thoma, G., & Ledgard, S. (2015). Environmental impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment. *Journal of Cleaner Production*, *94*, 67–75. http://doi.org/10.1016/j.jclepro.2015.01.073