Real-World Issue Annotated Bibliography

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How Do We Reduce the Carbon Footprint of Manufacturing?

As a world economic leader, the US has a booming manufacturing sector. Between 1870 and 2014, manufacturing increased twentyfold, going up an average of 8% each year (Egilmez et al. 860). Nearly a third of all greenhouse gas emissions are caused by manufacturing, so as the amount of manufacturing increases, so do emissions (Egilmez et al. 854). These are a problem since they contribute to global warming and severely impact the ecosystem. As Earth's population increases and demand for goods goes up, manufacturing is not likely to decrease. Therefore, it is necessary for manufacturers to examine their carbon footprint and take steps to reduce it. Currently, scientists are developing ways of doing this by optimizing manufacturing processes (Edgar and Davis). In addition, more and more businesses are examining environmental impact when developing new products (Miranda et al. 13065). Despite these improvements, manufacturing sectors with some of the highest emissions, such as petroleum refinement, livestock processing, and alloy production, need to take further steps (Egilmez et al. 853). To reduce emissions in these sectors, scientists are developing new technologies and methods for manufacturing. Engineers are tackling the problem of greenhouse gas emissions through both general and targeted solutions.

Bošnjak, Roko, et al. "Possibilities for Mitigating the Environmental Footprint of Dairy Ruminants." *Mljekarstvo*, vol. 68, no. 3, 2018, pp. 153–168. *Food Science Source*, doi: 10.15567/mljekarstvo.2018.0301.

This peer reviewed journal article explains the harm to the environment of raising ruminant livestock. This is one specific sector of manufacturing that can reduce its carbon footprint through targeted solutions. The article describes how ruminant livestock, such as cattle and sheep, emit large quantities of methane when digesting food. In order to process forage, their digestive systems ferment food. This releases hydrogen which triggers a methane-producing reaction to get rid of it. Methane then seeps out through the animals' mouth and nose and is released into the environment. The article then goes on to explain solutions to this problem. One solution for reducing methane production that relates to engineering is changing the livestock's diet. A diet engineered to have an ideal blend of dietary staples can reduce the carbon footprint

of livestock manufacturing. The article goes into detail, explaining that diets with more forage and fiber produce more methane. Grain heavy diets work to reduce methane production; however, these diets are unhealthy for the animals. The article provides a working solution to this problem: distiller's grains. These are an engineered grain with fermented starch that will not harm livestock. The article also mentions this is a costly solution. This lets me know that more work needs to be done to find a methane-reducing feed that can be implemented globally. The article also mentions other more experimental solutions to the carbon footprint of livestock manufacturing. These include genetic selection and gas capture. These examples show solutions that engineers could implement to improve the greenhouse gas emissions of ruminant livestock production.

Edgar, Thomas and James Davis. "Smart Process Manufacturing – A Vision of the Future." *ACS Publications,* I&EC Research, https://pubs.acs.org/page/iecred/anniversary/100/smart-processing.html.

This article is not a peer reviewed source, so its credibility comes from its authors who are work at at UT Austin and UCLA, respectively. The article gives an overview of smart process manufacturing. This uses connected smart devices to automate processes and optimize performance in manufacturing plants. These devices can make measurements, send and receive data, make decisions, and implement changes. The article then explains that this allows plants to quickly adjust to changes in the environment, reducing downtime and increasing efficiency. According to the authors, smart process manufacturing promotes environmental sustainability. Increasing efficiency with smart process manufacturing can reduce the environmental impact of manufacturing. Smart process manufacturing is a solution that can be utilized in many areas of manufacturing.

Egilmez, Gokhan, et al. "Carbon Footprint Stock Analysis of US Manufacturing: A Time Series Input-Output LCA." *Industrial Management & Data Systems,* vol. 117, no. 5, 2017, pp. 853–872. *Emrald Insight,* doi: 10.1108/IMDS-06-2016-0253.

This peer reviewed journal article gives an overview of the impact of greenhouse gas emissions due to manufacturing. It explores in depth which sectors of manufacturing are the greatest contributors to these emissions. It also analyzes overall emissions over time in relation to the size of the US' manufacturing sector. Although industries have worked to lower their emissions, the growth of manufacturing has left net emission the same. This shows the urgency of this problem. This source gives plenty of background information on the current carbon footprint of manufacturing.

Miranda, J., et al. "Integrated Product, Process and Manufacturing System Development Reference Model to Develop Cyber-Physical Production Systems - The Sensing, Smart and Sustainable Microfactory Case Study." *IFAC-PapersOnLine,* vol. 50, no. 1, 2017, pp. 13065–13071. *ScienceDirect,* doi: 10.1016/j.ifacol.2017.08.2006.

This is a peer reviewed journal article that discusses using good product design to improve efficiency, cost, environmental impact, and other factors. It describes a case study where the overall design of a manufactory is changed, and smart features are added. It then goes on to

analyze the improvement of this model over the previous one. This article is proof of the benefits of smart process manufacturing, a general solution to the problem of greenhouse gas emissions. It uses life cycle assessment analysis to show that the manufactory's carbon dioxide emissions were reduced. It also points out other benefits to efficiency that smart process manufacturing provides. Because manufacturing plants can digitally monitor themselves, they can react to breakdowns faster than humans.

van Dijk, H. A. J., et al. "STEPWISE Project: Sorption-Enhanced Water-Gas Shift Technology to Reduce Carbon Footprint in the Iron and Steel Industry." *Johnson Matthey Technology Review*, vol. 62, no. 4, 2018, pp. 395–402. *Ingenta*, doi: 10.1595/205651318X15268923666410.

This peer reviewed journal article discusses research done on a carbon capture method for steel and iron manufacturing. Through a process called sorption enhanced water-gas shift, waste carbon dioxide can be captured. The article explains how they have improved on this technology, increasing the amount of carbon captured and increasing efficiency. This shows not only a solution to carbon emissions but also an area for further improvement. The article also mentions some other approaches for reducing emissions for steel and iron manufacturing. These include using bio coal, hydrogen, or electrolysis to reduce the iron ore. These solutions could greatly decrease the amount of carbon dioxide released into the environment by steel and iron manufacturing. Their further development will help reduce this sector's carbon footprint.

Greenhouse gas emissions are a detrimental product of manufacturing that need to be reduced. Whether with general solutions or targeted ones, there is much room for improvement on the technology we currently have. If I choose to go into research, I can be a part of this improvement effort. I could contribute to the current and pressing issue of greenhouse gas emissions. On the other hand, if I don't go into research, this problem will still involve me. When developing new products, I must consider how my decisions will affect the products' manufacture and emissions output. As an engineer, I have a responsibility to develop sustainable products with low environmental impact. The carbon footprint of manufacturing is a problem that engineers continuously need to work to reduce.