

Decarbonization of Manufacturing

Gabriel Emilio Pineda Ulloa

Climate Change Law and Policy

## Introduction

The manufacturing industry has had some significant changes in the last couple of decades, starting with incorporating new technologies oriented to mark a recent tendency towards mitigating the effects of climate change on general populations health and natural resources and everything related to the environment; emphasizing what carbon emissions have caused a previous couple of years. Several actions have been taken to provide some advantages and benefits to the industry and, at the same time, make sure there is full enforcement of the regulation set forward to reduce carbon emissions and reduce the amount of pollution that is caused by this economic sector. There are concessions made to big corporations in this industry to ensure sustainable development; the economic activities can keep working as usual. The profits earned can be projected positively for the next decades considering the adapted improvements nowadays. The best modern-day solution on this topic came in the last two decades by having the first precedent of fully operational facilities on renewable energies, demonstrating on an international basis that the dependency on fossil fuels we've had since a while ago can be changed and carbon emissions can be lowered or even stopped on a long term. Decarbonization of manufacturing is the best modern-day solution to reduce the emission of greenhouse gases and improve the industry on several levels. Most of the renewable energies used in this industry are based on taking advantage of natural resources with a good percentage of efficiency, availability, and restoration capacity. There are even some power generation resources that entirely operate based on biological wastes; most of the time, they look forward to taking advantage of the trash from agricultural activities, granting a wider variety of options for power generation, and allowing the manufacturing industry to make a diversification on the power generation resources.

## How the decarbonization of Manufacturing reduces climate change's effects and improves public health.

The increase in manufacturing operations and its development with new technologies and significant advances have been some of the most determining factors in the rise of climate change and its effects. Toxic waste and greenhouse gas emissions by industry are the primary pollutants that must be addressed today for the manufacturing industry to begin significant differences in sustainable development and mitigate the adverse effects they can have on the population in general, especially on the overall health of the people and the environment. These situations are strictly related to the emergence of natural disasters continuously arising more than usual. They are even advocated as the principal cause of irregularity between people and the environment. Although several pollutants are generated by the manufacturing industry, today, greenhouse gas emissions must be our most significant concern to improve this economic sector decisively and thus begin to demonstrate significant changes.

The emissions of toxic gases are known to increase the risk within the society of developing cardiorespiratory diseases and other illnesses that were not as common as maybe 20 or 30 years ago, even if there are other diseases caused by this same emission that is worth mentioning due to the high mortality rate and the high rate of infection on the population, still these tend to be the most common. Once these diseases begin to become more common within society due to the high levels of carbon in the atmosphere, we can thank specific indicators such as the increase in the rate of mortality, a low expectative of life, and even the increase of chronic diseases within the population that these are issues that are strictly related.

One of the most critical objectives of making manufacturing an eco-friendlier industry is to mitigate the damage caused to people due to the emissions caused by manufacturing. To achieve these goals, some actions must be taken. New technologies and better practices must be implemented as viable solutions for a sector that reduces pollution and the dependency on non-renewable resources to a more acceptable basis for the environment. While it is true that manufacturing in recent years has reached its highest levels of production and technological development, it has also reached its highest peaks of pollution if we are based on specific indicators that today show us the background of some contaminants in different natural resources and especially the hands of increased pollution in the atmosphere. Although some pollutants do not usually stay in the environment for long to be considered “active pollutants” for the same amount of time as others today, there is a particular pollutant that is produced mainly by manufacturing that is regarded as one of the most dangerous if we evaluate it according to impact level it has generated in the two significant interests on why carbon emissions should be reduced, public health in general and the environment.

These are the ‘invisible gases’ as they are called today; an example of these is carbon monoxide, known to be an odorless gas that is produced in manufacturing by creating plastic in industrial quantities that in the environment can generate irritation in the skin, diseases in the lungs such as cancer and can even arrive some organ problems that are not part of the respiratory system.

In addition to the conventional contaminants that we find today due to the high levels of carbon we see in the atmosphere over the years, other non-secondary contaminants have emerged that are the effects of the pollution we can already find today.

Getting into more detail is the ozone generated by manufacturing that accumulates in the different layers of the atmosphere, the leading cause of this phenomenon. The mixture of these other gases can be highly irritable and harmful to health. Burning coal, fossil fuels, and energy generation plants based on oil and gas will soon be the main activities that give origin to this phenomenon. Even though these are not the only reasons why we find all these harmful gases in the atmosphere, they can be considered the main contributors to this phenomenon.

Some of the most common examples of secondary pollutants caused by the high level of toxic gases in the atmosphere are acid rain, which consists of precipitation that contains high levels of polluting gases that then fall back into the layers of the earth in the form of rain<sup>1</sup>. This rain can be highly contaminated in the ecosystems where this phenomenon is happening and have severe implications for people if they are exposed to it for long periods.

### Significant reasons for Decarbonizing Manufacturing

The production of carbon within the industry does not always have to be strictly related to the economic activity or the sector in which the industry is specialized; it has a lot to do with the resources used for a power source. Manufacturing can produce an endless number of pollutants that lead to other situations that can harm the environment. Still, fossil fuels can make the most significant impact on the environment. In the last couple of decades, there has been a campaign to remove fossil fuels and incorporate more clean

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<sup>1</sup> Hanks Gerald, Types of Industrial Pollutants, Sciencing, January 22, 2019, <https://tinyurl.com/8nkvvpsw>.

energy sources. In the long term, it can even represent a benefit from a certain point of view to include energy sources that work based on renewable resources since these do not require the same maintenance and are not as pollutant as the conventional methods that have been used for a while, in addition to the fact that the process for the use of natural resources is economically speaking more viable than the process that is necessary to refine oil and gas, without mentioning how harmful is to the environment the process to acquire this type of fuels. While it is true that we are in the “advanced stages” in the development of manufacturing, it has not been possible to reach an optimal level in the implementation of clean energies that work based on natural resources, even though they are more helpful to the environment, this is a significant change to the industry that cannot be achieved in the short term.

Even if it has its long-term benefits today, the installation of this power generation based on renewable resources can have an initial cost for building up and starting operating that can go twice as high if compared to the prices that are required for generation systems that work based on fossil fuels, not to mention the cost of maintenance needed for clean energy power generation systems such as biomass or a system of solar panels.

Even considering these costs, a factor plays in favor of renewable energies: the lifetime or duration of both power generation systems. Natural resource-based energy sources tend to have a longer life expectancy than conventional methods, with industries continuing to invest in machinery at longer intervals. This factor gives renewable energies an upper hand over the traditional techniques if we consider all the economic aspects of both systems.

By having a longer lifetime, big corporations and industrial companies won't find themselves with the financial task of replacing machinery for their operations in the short term. Even if it doesn't seem like a significant advantage for renewable energies or there will probably be some experts that won't consider this as a significant substantial benefit that can be sold to uprising corporations that seek to change the resources of their power generation investment. Maintenance costs play more prominent roles than people expect in the industrial sector's economy; in the end, that's the primary reason the economic sector developed, increased profits, and reduced costs. Economically speaking, implementing renewable energies manufacturing can be underestimated sometimes.

On the other hand, most of the pollutants caused by manufacturing can negatively affect the environment and population besides contamination and health problems. Water and soil pollution have influenced other economic sectors in the last decades. It has become more difficult for humankind to find ideal places for agricultural activities based on crops and livestock in the previous decades. It has become even more apparent in some cities and towns across the U.S, with extensive manufacturing operations, deficient urbanization, and a low-density population. The proximities of these manufacturing compounds tend to be highly contaminated by the solid and liquid wastes they dump.

They are increasing the toxicity levels in rivers, lakes, and even the sub-soil of the local area. Growing crops or raising livestock in the regions that this can slightly influence, the significant wastes generated by manufacturing pollution can cause major considerable health problems for the population that depends on these agricultural activities. Crops and seeds have obvious indicators of growing in contaminated places, lousy products, and minor deformation of crops can give us clear signs of toxicity in the land.

Or, in some cases, crops won't grow at all with land that has been adequately prepared for these activities. On the other hand, rivers and lakes are more susceptible to the pollutants generated by manufacturing movements. The most immediate effect of these pollutants is first seen in fishing activities. These water sources, over time, can get to a point where they are no longer capable of sustaining life, considering the significant effects they have on the population in general that are exposed to consuming this contaminated water. And these are just some of the considerable impacts that carbon emissions can have on the environment, directly affecting human life and valuable resources.

Even if decarbonizing manufacturing doesn't eradicate the impact of several decades of pollution, it can be an initial point that leads to significant steps in mitigating the effects we are trying to handle nowadays. Instead of using non-renewable power sources, which can lead to all the previously described situations, renewable energies can allow us to properly use the resources and decrease pollution to a more acceptable standard. Taking into account that a cleaner power source should be enforced with good practices on waste management and the handling of natural resources.

The main focuses that are majorly discussed on decarbonizing the manufacturing industry and how to mitigate or reduce the effects caused by industry in the last years. Everything has been narrowed into two simple approaches that were started at the beginning of this century. The first important point to be addressed is to reduce the oil and gas consumption in the industry; there is no way we can achieve a complete standardization of renewable power sources in the industry shortly but decreasing the emissions of greenhouse gases can be accomplished gradually by lowering the use of fossil fuels.

Several types of research and studies have determined that carbon emissions and other elements in the atmosphere have significantly impacted the effects of climate, especially in the last years. Even though that climate is known to be caused by several factors that are reduced to the increase of manufacturing operations, it is also known to be one of the primary sources that have caused climate change and its effects. Climate change can't be diminished in the short term but by implementing renewable energies, changing. The way this industry handles all types of waste and even lowers the amount of pollution caused by this industry can be significant steps toward making a big difference in the environment and revolutionizing the industry.

#### Regulations we find today that benefit manufacturing in its decarbonization

The energy production sector and manufacturing have generated a significant change in the index of emissions; is thanks to the regulation that has been implemented with a particular emphasis on reducing greenhouse gas emissions and the effective enforcement that has been achieved. That has let us achieve better measurement levels in the last couple of decades if we compare them to twenty or thirty years ago before some kind of regulation was enacted and significant control over manufacturing pollution was addressed.

Despite the improvements made in the last couple of years, there is still a tremendous dependence on fossil fuels in manufacturing, power generation, and several economic activities that are related, representing more than sixty percent of the total energy generation in the U.S. is one of the most critical assets within the American economy.

Through the Clean Air Act, several governmental entities, mainly the Environmental Protection Agency, were given the power to control greenhouse gas emissions in several economic sectors, including manufacturing<sup>2</sup>. This law has had two critical approaches that have allowed good results in the last decades.

First, by establishing specific standards that corporations must comply with to reduce greenhouse gas emissions. Although these emissions cannot be eradicated from the beginning, they give a critical starting point to establish a cap on the gases that can be launched into the atmosphere—making the task of technological advances much more accessible than gradually reducing the percentages of pollution<sup>3</sup>. The second is to force the different groups and consortia within the manufacturing industry to implement as many as possible solutions to reduce GHG emissions into the atmosphere<sup>4</sup>. A clear, obvious example is to leave aside fossil fuels and depend more on renewable energies. These two significant objectives set for manufacturing had led them to several benefits for the industry itself, the population in general, and the environment. A substantial reduction in air pollution has been achieved in the last two decades by lowering the consumption of fossil fuels and boosting renewable energies in manufacturing. The primary source of air pollution is the greenhouse gas emissions and the carbon that is usually emitted into the atmosphere generating significant effects on climate change. Several environments have been affected by this kind of pollution; the gases thrown into the atmosphere can negatively impact beyond the atmosphere.

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<sup>2</sup> Durkay Jocelyn, States Reactions to EPA Greenhouse Gas Emissions Standards, National Conference of States Legislatures, April, 24, 2017, <https://tinyurl.com/4fepk9cd>.

<sup>3</sup> Center for Climate and Energy Solutions, Regulating Power Sector Carbon Emissions, 2019, <https://tinyurl.com/556x8dpj>.

<sup>4</sup> United States Environmental Protection Agency, Progress Cleaning the Air and Improving Peoples Health, 2012, <https://www.epa.gov/clean-air-act-overview/progress-cleaning-air-and-improving-peoples-health>.

## Economic and Environmental benefits from Decarbonization

Manufacturing can generate many pollutants, some being more dangerous than others. Considering the indicators of pollution and various studies on the general condition of the environment, it has been ruled that it is the emission of greenhouse gases, the pollutant which we must put more effort into today to improve climate change conditions. It is not that the other types of pollution shouldn't be addressed on the same basis. Still, in recent years a global campaign has emerged that guides us to redirect the resources we have to look for feasible solutions that can be implemented as soon as possible in all the types of pollution that have been generated by manufacturing in recent years. And especially when we started talking about manufacturing, which has increased carbon levels in the atmosphere by a considerable amount in recent years.

It is necessary to recognize that these efforts are accompanied by strong economic incentives for the manufacturing industry to implement the provisions imposed mainly by local governments and often driven by international treaties or conventions to improve the enclosed standards today. The most discussed subject in this topic that has emerged into a more significant issue is to estimate how many groups or consortia would adopt all these measures to reduce carbon levels in the atmosphere without counting on the benefits granted by many governments today. It is fair to say that in recent years economic benefits have been the biggest drivers of the decarbonization of manufacturing; we must always consider that there is still some motivation on corporations' behalf to mitigate the effects caused by themselves, but we will always have that undeniable truth that this has not been the main reason in recent years.

Both economic and environmental benefits that are granted nowadays must be put on the same ground and should be considered on an equal basis; both types of benefits must be taken with equal importance when the industry begins to revolutionize for the use of all. In the same way, it can be said that both are strictly related to each other; among the basic principles of environmental law is the future of sustainable development. It argues that a complete story of economic activities can be reached without sacrificing significant steps de the environment. We are far from producing zero pollution levels but reducing carbon emissions into the atmosphere considerably mitigates the impact already caused in previous years. And at the same time, action plans or measures are implemented that specialize in repairing the damage already caused, not just trying to reduce the effects.

The economic benefits that large corporations can receive within this industry are not limited to incentives and bonuses that they can receive from local governments; the implementation of renewable energies can represent, in the long term, be more viable from an economic point of view than fossil fuels. Tax exemptions, recognition on the international basis and even a better stand off on the global market can be some of the advantages that big corporations can encounter by implementing renewable energies and following up the tendencies that will mark the bigger changes in the future.

How the decarbonization of manufacturing is achieved with the implementation of  
renewable energies

There are two critical approaches when introducing renewable energy in the manufacturing industry. The first approach is to try to phase out the fossil fuels that today are still used in many industry sectors.

The second is to achieve the greatest possible technological advances in manufacturing. Today many renewable energy sources can serve as viable options for manufacturing; some can become more expensive and compatible than others. Everything depends on the sector and the economic activity that manufacturing has been developed. Replacing fossil fuels seeks to reduce carbon emissions in the atmosphere and set aside non-renewable resources. In addition to their use, the refinement and adequation of these resources can be very expensive, not to mention the pollution they entail.

This is without considering the breakdown they generate once they are used. As far as technological advances are concerned, not only does the fact of looking for alternative sources of energy generate technological advancements, but many sectors in this industry also require machinery that today mainly operates based on oil and gas. However, it does not represent the highest percentage of pollution generated by manufacturing; it has a certain level of influence on fossil fuels consumption. And this is how the two most important problems that must be addressed as soon as possible to achieve the decarbonization of the industry more effectively are emphasized.

The main point is to replace the energy sources that operate based on fossil fuels with renewable energies; this is not an easy task. But today, you can see clear examples worldwide of a clear preference for renewable energies over conventional methods. In addition to reducing carbon emissions into the atmosphere, many governments have implemented incentives within this economic sector to encourage energy generating plants and other manufacturing sectors to depend more and more on renewable energies and even diversify energy suppliers to have different power sources.

The main objective of decarbonizing manufacturing activities is not to reduce emissions of greenhouse gases that go into the atmosphere but to eradicate them with alternative energy methods. This increasingly seeks to reduce the dependence we have today on fossil fuels and promote renewable energies as primary sources of power source. Although there are no other methods of obtaining energy other than fossil fuels, such as nuclear energy, which depends entirely on the reaction of certain radioactive materials in contact with water and other components, it has the downside of producing many carbon emissions and other elements that are harmful in the different layers of the atmosphere. Today, there are many options to make fossil fuels obsolete, but this does not mean that all the other available choices are more convenient, making it clear that renewable energies are the best option. Many natural resource-based energies today are incorporated throughout different U.S. industries.

One of the best examples of implementing renewable energy in manufacturing today is that of Tesla Motors. It is currently known that they are developing a couple of factories that will depend entirely on solar panels, wind farms, and a geothermal plant in the vicinity of the compound. This is an excellent example of using these energies today; it also shows us the variety of options that this industry has and the importance of diversifying the energy sources for a compound.

By developing and implementing these technologies that reduce the burning of fossil fuels, the industry is increasingly gaining achievements and innovation. These alternative power sources generate many benefits for the factories in the long term.

## How biomass as an energy source reduces greenhouse gas emissions

Biomass is one of the most influential power resources in both environmental and economic aspects that have had the most significant uprising in recent years, which consists of burning agro-industrial waste to generate liquids or gases that function as fuel for manufacturing facilities<sup>5</sup>. Biomass is one of the most convenient solutions to be used as a renewable power source; having a good number of agronomical activities in the U.S. makes this resource accessible with low costs<sup>6</sup>.

The biomass's direct combustion most regularly produces heat by converting solid, gaseous, and liquid products. Agriculture activities leave many residues from wood; using it as an example of a biomass product, they are exposed to high temperatures. The gases released are then processed to become energy<sup>7</sup>. When some wastes are not compatible with the conventional method of decomposing natural mass, such as animal waste that usually carries a high degree of humidity, first they are exposed to certain gases that generate an oxidation process that releases certain gases and components used for energy purposes. Biomass offers excellent accessibility to these products must be achieved. Both animal and vegetable mass from wastes can be effectively used to produce energy where pollution caused by gases can be significantly mitigated<sup>8</sup>.

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<sup>5</sup> Kay Peter, How Manufacturers are developing and using renewable energy, SmartCities Dive, 2017, <https://tinyurl.com/2jzcb3sk>.

<sup>6</sup> Environmental and Energy Study Institute, Biofuels and Biomass, Ideas, Insights and Sustainable Solutions, 2018, <https://www.eesi.org/topics/bioenergy-biofuels-biomass/description>.

<sup>7</sup> U.S. Department of Energy Federal Energy Management Program, Whole Building Design Guide, September 15, 2016, <https://www.wbdg.org/resources/biomass-electricity-generation>.

<sup>8</sup> U.S. Energy Information Administration, Biomass explained, Independent Statistics & Analysis, June 8, 2021, <https://tinyurl.com/4k8rfw7y>.

Despite being exposed to different processes, they are still valuable assets to generate power; in the U.S., considerable amounts of garbage are used as energy on a significant scale, considering how much energy would be needed for the manufacturing industry. At the same time, this would not be a renewable resource that would replace conventional energy methods and would not always become the first option when other renewable sources of energy are considered. But it is undoubtedly an option that must be regarded in the industry. The costs of the heaters that must be used can be very high and would even generate an economic detriment if we believe the level of productivity.

These operating plants to process biomass require meticulous care and become very complex in the machinery's composition. The facilities already need to store enough fuel for their operation without considering the different boilers, pumps, fans, and generators. Some facilities have even come to an end where the control systems have automated the process. Although this is a viable alternative to push renewable energies to be used within manufacturing, they have the significant problem of the fuel that must be handled to operate this system at its best capacity. Manufacturing facilities have adopted the practice of drying as much as possible the biomass that will be used to increase the level of efficiency as much as possible. However, it is not always the friendliest solution speaking from an economic point of view. More and more companies in Europe and the United States are developing these engines based on biomass.

Most of these systems can be found in the U.S. The method he uses most in the United States is the direct combustion of biomass. In recent years, incentives have been implemented in manufacturing to implement this renewable energy within its compounds.

Although they can vary, considering the Federal legislation and its applicability in each state.

### Benefits obtained by implementing renewable energies

There are two significant benefits that we can obtain from renewable energies and their implementation in the manufacturing industry: economic and environmental. If we look at things with an economic perspective, renewable energies can directly influence the manufacturing industry. Still, the power generation sector has also been developed where fossil fuels are not the only power source we see nowadays. There is still a clear dominance of fossil fuels in this market, but it will be time before fossil fuels become obsolete. Local governments and significant enterprises and corporations have marked a tendency worldwide to start implementing renewable energies over the high-pollutant energy methods. Even if there is still a high demand for fossil fuels, it has become a more familiar example for facilities to diversify their energy supplies and increment the possibilities in the market to get several energy providers.

This is a significant factor that is beneficial for the market in general by enlarging the market options for manufacturing. More jobs are created, and therefore, a positive activation of the market is achieved through these changes. Besides the economic benefits achieved, like government incentives, diversification of power sources in the market, and a higher job offering, it is fair to emphasize the environmental benefits that renewable energies can grant us.

The significant effect of implementing these power sources is first seen in the decrease of air pollution by reducing the emissions of greenhouse gases. Reducing air pollution means a substantial improvement in the population's overall health; common diseases caused by this pollution have been decreased to acceptable levels. Several ecosystems have also reached the impact of reducing air pollution; the pollution caused by greenhouse gases can be so strong. It has reached a point where there has been a negative effect on food chains and other matters related to agronomical, environmental, and food-related topics.

#### Thermal solar systems as a source of renewable energy in manufacturing

The implementation of Solar Thermal Systems in manufacturing processes has represented a considerable advance in the use of renewable energies. This system has been implemented most of the time in manufacturing facilities that require low-temperature applications<sup>9</sup>. It is commonly used in small-scale plants and industries with low energy consumption, as in the textile and agricultural industries. Although this system is benign for the environment, it tends to have certain limitations since it requires a high initial investment, and the costs for its operation can be costly in some cases. Fossil fuels have higher efficiency in terms of costs and process, and significant manufacturing companies tend to keep these power sources over thermal solar systems. From an economic point of view, several sectors in manufacturing are not quite ready to start implementing this system as their primary source of energy. Still, they are known to be

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<sup>9</sup> International Renewable Energy Agency, January 2015, Solar Heat for Industrial Processes, <https://tinyurl.com/bx83ttfe>.

one of the best options for industry to begin a diversification of power sources. This renewable energy has a high-efficiency percentage of resource use/energy produced.

It is known to be easier to take advantage of solar energy than most of the renewable energies that have been enhanced nowadays; despite proper installation and correct operation of the system, there is no further action needed for this power source to be done, so it can start producing energy. Hydroelectric plants, biomass, and other renewable options to produce energy must have a complex system so the natural resource can be appropriately used for energy production; this can raise the cost of the operation besides the maintenance needed to run the operation process correctly.

This system is also highly reliable; this power source lacks any issues that can considerably affect its performance. This power source's biggest problem generally affords the direct impact caused by weather conditions. Most of the time, the energy produced by the thermal solar system is kept in power banks that can store the energy produced during its effective hours. This problem can be addressed from several perspectives since these facilities are chosen mainly in areas that meet the proper qualifications to be installed. And most of the locations that are selected to develop this type of renewable energy do not encounter drastic weather changes that can affect the system performance.

Why should electrification of internal processes should be incorporated into manufacturing, and how does it help to decarbonize the industry

Decarbonizing manufacturing can take much more than just implementing renewable energies, reducing energy consumption, or any other solution that has been implemented in the last couple of years to mitigate the effects produced by the constant emissions of greenhouse gases. Most of the internal processes used in manufacturing regarding the sector they belong to are powered by fossil fuels, increasing their consumption at alarming rates even though renewable energies have been acquainted in the last couple of years. Sometimes this fossil fuel dependency is not limited to the machinery used in manufacturing compounds; there are some cases where this same energy is being produced to comply with the energy demand some of these facilities require<sup>10</sup>. Energy consumption in manufacturing is not limited to assembly lines or internal processes regarding the activities done in general; most of these facilities must run logistics beyond that.

It is known that the industry with the higher energy consumption based on fossil fuels is manufacturing, taking the lead by far when compared to other economic activities like mining and agriculture, which are known to be the next following two significant pollutants after manufacturing. Implementing electrification can change the perception of a high pollutant industry and grant substantial benefits that will directly impact the pollution rates that have been handled in the last decades.

Besides the conventional power sources used in manufacturing, electrification can help reduce operating costs significantly; machinery with fossil fuel-based energy requires higher maintenance with a shorter lifetime.

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<sup>10</sup> Occo Roelofsen, Ken Somers, Eveline Speelman, and Maaïke Witteveen, Plugging in: What electrification can do for industry, McKinsey & Company, May 20, 2018, <https://tinyurl.com/22d5mpp3>.

Needing to change machinery periodically and higher-priced care is not viable on a long way inversion. Meanwhile, besides being costly on an initial inversion, electrified machinery doesn't require as much care as it had to be given to machinery using conventional methods of power source. Electrified machinery can sometimes last twice the productive duration of fossil fuel-based; electrical energy is better priced nowadays than oil and gas. Electrical assembly lines can even be friendlier to workers exposed to this harsh environment in facilities, especially when the internal processes in the compound require a high heat consumption that can lead to sickness or diseases, or professional injuries caused by it. That's probably one of the major reasons the manufacturing industry has been desperately changing the power source for their internal processes, reducing the liability or responsibilities that can derive from the employer to the employee so they can run business with less precautions, reducing costs in a considerable way.

#### The economic benefits of implementing electrification in the industry

The manufacturing industry is considered the economic sector with the highest energy consumption nowadays. Most of the energy consumption in this industry derives from the machinery and the internal production and assembly lines used to perform the tasks and activities developed in these facilities; some may vary depending on the sector of each manufacturer. The machinery used in this industry represents a high energy consumption, in general. Still, it also carries on a prominent fossil fuel consumption due to the high dependence on oil and gas for their function.

Even though some solutions have been implemented to decrease the consumption of fossil fuels to reduce the impact that has been generated in the atmosphere for a while now, this power source still represents more than sixty percent of the energy sources used in manufacturing worldwide.

Some industries have adopted hybrid or dual systems where they split the energy usage of this machinery between renewable energies and fossil fuels. Despite still using the conventional methods and not eradicating their use on a total basis, some precedent of relevance on the use of renewable energies has been set. To incorporate better environmental and economical options on the machinery used nowadays, most processes in some manufacturing areas are being electrified. This means that the machinery used during assembly lines and other activities is being powered by electricity produced most of the time with renewable energies—reducing the emissions of greenhouse gases produced by burning fossil fuels and granting a significant advantage to the implementation of these energies. Electrification of machinery used in manufacturing to leave aside fossil fuels as a power source has brought significant technological improvements that can be achieved shortly.

Electrifying machinery in this industry is not always more convenient than conventional methods regarding fuel consumption and power generation efficiency. Still, it helps reduce operations costs in a big way, most of the time in the long term. Even the initial investment necessary to incorporate the electrification method makes these processes economically viable. In addition, they reduce the emission of greenhouse gases significantly by reducing the consumption of fossil fuels within site operations.

Changing machinery's power sources is not a big step toward decarbonizing manufacturing; it won't mitigate as much as other solutions already incorporated in manufacturing. But it will undoubtedly start changing internal processes and methods that several sectors are run by in manufacturing; by lower fossil fuels consumption, the impact generated will significantly be lowered to more acceptable standards and may even mark a trend for facilities operations to decrease the dependency on the conventional methods that had brought us to the urge of changing how things are done in these days. Even if the manufacturing activity by itself can still produce some pollution level, it can be considerably lowered. Decarbonization is not just about reducing emissions or leaving fossil fuels aside; it takes more than creating and developing renewable energies for power generation to make a significant change; creating an eco-friendly culture around this economic activity may take a lot of time and resources to reinvent the industry.

#### How electrifying assembly processes reduces fossil fuel consumption

Depending on the activity or sector to which each manufacturer is dedicated, the energy and heat measurements they require tend to change; most of the time, they vary case by case. It is currently estimated that at least fifty percent of the processes and machinery used within this industry can be successfully electrified, implementing numerous benefits for this industry on its way to depending on electrification rather than fossil fuels.

The fuel consumption costs of the machinery used today within the manufacturing industry turn out to be so high that the value of the energy they consume can be up to five or six times greater than the value of the machinery itself that is being used.

This is the most significant advantage of the electrification of processes in this industry, reducing costs in the energy consumption of machinery used today. And even lower in the long term, the costs necessary to substitute machinery that has complied with their estimated lifetime. Even though making the change to renewable energies can result in a difficult task, in the beginning, most of the time, this kind of investment is meant to be economically viable in the longer term. This energy resource was not adapted and implemented in manufacturing until recent years, making it considerably a contemporary solution compared to other practices in this area developed a while ago. It's just a matter of time for this solution to be set to the next phase. It will be as reliable as the conventional methods without representing a significant investment that will carry on too much uncertainty.

The demand for manufacturing to electrify machinery, assembly lines, and everything related to the internal production processes is expected to grow within the next few years. The manufacturing industry has found itself with the need to eliminate the use of fuels and carbon emissions to generate energy. It's a project that cannot be achieved with drastic changes in the short term but making these changes in the long run and periodically changing the whole internal process can get us one step at a time. Another alternative for this problem is relocating these industries to sectors with better proximity to renewable energy power plants or incorporating these facilities within the manufacturing compounds. Developing this self-sustaining facility can result in significant economic and environmental advantages.

## Why electrification represents a better option than fossil fuels

Electrifying machinery and production processes result in a great advantage for the manufacturing industry in most cases, even though it can also come with certain disadvantages. Depending on the energy charge per joule in some sectors, this can be more expensive than that produced from fossil fuels and coal burning. In terms of efficiency and effectiveness in the manufacturing industry, machinery powered by electrification does not represent any advantage over that that works based on fossil fuels. Several financial factors increase the activity of specific sectors and companies for the electrification of processes. One of the most common and accessible practices adopted to reduce energy costs is to minimize the consumption of power generated by renewable resources and diversify the energy sources they can count on. With today's fossil fuel prices increasingly being evaluated, implementing electrification within manufacturing using renewable electricity could also allow consumers to redeem different government benefits as subsidies.

Decarbonization is a long-term investment that proves beneficial.

Depending on the heat consumption that some manufacturers need, they are beginning to adopt hybrid systems that are partially electrified, constantly changing between electricity and fossil fuels. Electricity is not always convenient in all cases. Electricity prices tend to change drastically in some regions. But the implementation of these hybrid systems takes advantage of electricity prices when it is at their most accessible, mostly when solar and wind energy production is at its maximum capacity.

This would allow direct access to renewable energy sources near the enclosures. Although this dual system does not reduce greenhouse gas emissions as in a fully electric system, it carries on several benefits for the industry and society. There is an increasing trend within the manufacturing industry to invest in electrification instead of conventional fossil fuels. Although these electrification systems can become more sensitive and require more maintenance in the long term, it is more convenient to invest in these systems from the beginning to go through an electrification process where manufacturing is forced to replace these machines gradually.

With today's technology, it is possible for manufacturing to switch from fossil fuels to electrification, including that energy prices in some sectors are accessible enough to rely only on these renewable sources. Decarbonizing manufacturing can be beneficial on several levels and aspects for this industry; even though some efforts must be made to be the number one option for developing manufacturing, there's been many improvements not only in the power generation systems and operations but nowadays, significant corporations and groups have adopted these practices, some of them for their benefit and others to make a difference and periodically stop carbon emissions.

### The benefits of decarbonizing manufacturing

The industry has reached a point where decarbonization has been set as a goal more than a benefit for the last couple of years, even; even if greenhouse gas emissions have been reduced in the previous three decades, there are still many changes to be made to create sustainable development of manufacturing activities.

This means that technological advances can be made in this field without sacrificing profits or other products that can help the industry grow. That's why lots of benefits have been encountered by too many corporations to incentive friendlier practices within manufacturing. Sometimes just setting regulations and acts that force their way to stay within their standards is not enough for the industry, in general, to be convinced of the changes that are planned in the future. Most of the time, these corporations must hold up to something that allows them to keep a sustainable industry; sometimes, the benefits offered or set to be achieved are not enough to make this drastic change. The more attractive benefits and the principal reason there's been assigned a shift toward lower carbon emissions can be divided into three major groups.

#### Economic incentives in the industry for using renewable energies.

Economically speaking, this is the benefit that most of the sectors in this industry are interested in; it offers a significant advantage by lowering operational costs and receiving monetary incentives from local governments that are eager to develop renewable energies and try to reduce carbon emissions. Raising profits may not be the best intention to address this problem, but it has found a way to take the attention of most of the essential conglomerates in this industry. Another fact that we must consider is the rise in oil and gas prices worldwide. Even if some of the systems necessary to implement renewable energies may be difficult to afford, especially for medium and small-sized groups, the cost of consuming energy that derives from renewable energies has been more advantageous than the prices of oil and gas that are managed nowadays.

Supporting two significant facts of the emerging renewable energies in the last couple of years, first, the market of renewable energies is projected to change in a way that fossil fuels will be left aside in the next couple of decades due to the costs of extracting this material and the process that is necessary for their refinement. The second important aspect being considered here is the fact that nonrenewable resources have been known to be the primary source of power generation since the last century, are projected to be extinguished or demeanor in a way that will no longer be able to comply with the demand that is set for the upcoming years.

Even if we find ourselves several years from encountering a situation where alternative fuels and energy sources must be developed due to the lack of energy production, it's better to start developing renewable energies daily instead of relying on future generations to carry the burden of past generations suffering the consequences.

#### Environmental benefits greenhouse gases levels

The second significant effect that can be caused by decarbonizing this industry is separated into two equally important aspects, improvement in the population's general health and the reconstruction of several environments that have been affected negatively due to the carbon emissions and significant effects climate change. They are both strictly related to achieving an environment that is not damaging to the population in general and the renewable sources that must prevail to keep life as we know it. Even if it doesn't seem like it, greenhouse gas emissions have significantly impacted the population's health. Some circumstances are set to be more common now than earlier in humankind.

Several diseases have arisen in the last couple of decades due to the highly toxic atmosphere we are encountering nowadays. Some places around the world, narrowing a little bit, in Asia, are in some populations around several countries that are not able to process some water and ground resources that are fundamental for their living, even presenting some cases of genetic malformation due to the gases that are trapped in these natural resources, and later consumed by the population. It is true that some years ago, we didn't count on the technological advances that we have nowadays, but that's just another reason why we should address this problem and mark a precedent that improvements can be made not just for economic purposes but considering the human factor. Several factors need to be changed to set a specific change within the industry to accomplish significant steps in this matter. It's not just about the technical part that needs to be paid attention to develop some severe progress; changing the mindset of the prominent entities that run the industry and the general population's opinion can grant a huge step forward. It's not only about business and profits that we can achieve a common goal to reduce carbon emissions; the culture within the industry can also be changed if we propose to—emphasizing the benefits that we that can be granted in general can start changing people's consciousness and start actually “worrying” for the environment instead of just being a political topic that they can take advantage of. Yes, the economy does matter, but it can clearly be said that it's a significant factor that should matter within the industry and society in general. Otherwise, instead of making relevant changes to a whole economic culture where the mindset will be set towards having a sustainable development, we will continue to engage with several individuals that will only comply to a certain point where “acceptable” pollution levels will have to be admitted instead of making a relevant change to mitigate the impact that has been already done.

## Conclusions

- Decarbonizing manufacturing can grant us a large variety of benefits in multiple facets. Not only oriented into the benefits or advantages that can be taken inside the industry, but some situations are proven to enhance population life in general by implementing renewable energies and reducing carbon emissions. The most relevant benefits from decarbonizing manufacturing, in general, can be separated into two major groups. The decarbonization of manufacturing, economically speaking, can represent a significant change in the industry's long-term future. With oil and gas every day being less viable and the local governments granting subsidies, tax exemptions, and other economic boosters for the industry, a significant trend for changing to renewable energies has been set in the last couple of decades, expecting to grow even more to a point where the dependency nowadays on fossil fuels will drop considerably. The second most significant advantage of decarbonizing manufacturing is based on the general improvement generated in the environment and other essential aspects that can determine how far carbon emissions went into the population's health and the current condition of the natural resources.
- Renewable energies are the best modern-day solution for decarbonizing manufacturing; despite other options or solutions that we can find today, the most significant improvements in this area have been achieved by leaving aside fossil fuels allowing the industry to reduce carbon emissions.

- The focus of leaving fossil fuels aside within this industry is to stop the significant dependency we have on this power generation source; by relying on friendlier power generation sources that depend on renewable energies, carbon emissions can be reduced shortly, including as well other common pollutants that are generated as well by manufacturing making the industry friendlier to the environment. Decarbonizing manufacturing can also be achieved by implementing alternative power resources into the internal operations and methods handled within the industry. The electrification of machinery and several other processes in the industry can be as crucial as changing to renewable energies. The sector has large energy consumption without considering the minimum base energy consumption required for a manufacturer to operate correctly. Depending on the area in that the manufacturer is developing its economic activities, it can have a high fossil fuel consumption on its machinery, generating considerable pollution. That's why decarbonization is more than just concentrating on power generation sources; it's by addressing the complete functioning of the industry that significant changes can be made.