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Adaptation to Climate Change and Eco-Efficiency (Cleaner Production) for More Effective Environmental Management in Industry

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Abstract—Climate change emerges as a multifaceted global problem those results in serious environmental and socio-economic consequences. National and international regulations on climate change initiated immense revolution process in industry. Manufacturing sector causes majority of the global emissions. Lately, new concepts emerged in manufacturing business including eco productivity, environmentally friendly technologies, and industrial ecology and thus essentiality of more efficient use of available potentials became imperious both for environmental quality and sustainability of production. Climate change could well be the most severe challenge facing our planet during the 21st century. It is also a truly cross cutting issue connected to many sectors. Tackling the climate challenge therefore requires bridging gaps between scientific disciplines and between science and policy. Practice of eco-efficiency (cleaner production) includes a wide range of opportunities from zero-cost simpler and better operations to high-cost and laborious equipment changes. For the companies in the metal coating sector, by defining the areas of intense resource use and waste production and the parts that could be improved, simple, low-cost and clean production implementation models both for saving resources and reducing waste production were developed. It is imperative to take precautions against elements and factors that will have direct adverse effect on production and competitiveness due to the imposed adaptation to the climate change. It appears that the use of environmentally friendly technologies which is considered to be the most vital method in management of effects resulted by the climate change could deliver substantial advantage for the corporation.

Keywords—climate change, eco-efficiency (cleaner production), metal coating, management, sustainable production

I. INTRODUCTION

Climate change is arguably the most severe challenge facing our planet during the 21st century. Human interference with the climate system (mainly through the emission of greenhouse gases and changes in land use) has increased the global and annual mean air temperature at the Earth’s surface by roughly 0.8 °C since the 19th century. This trend of increasing temperatures will continue into the future: by 2100, the globe could warm by another 4 °C or so if emissions are not decisively reduced within the next decades [1]. There is broad agreement that a warming of this magnitude would have profound impacts both on the environment and on human societies, and that climate change mitigation via a transformation to decarbonized economies and societies has to be achieved to prevent the worst of these impacts [2, 3].

There is a wide range of global threats that certainly require humanity’s urgent attention. These global risks include for example; water, food and energy security, population growth, infectious diseases, and international security. However, climate change is often regarded as one of the most profound global problems. This is mainly due to the sheer scale of climate change impacts both in terms of its global and temporal spread and of the variety of sectors affected by it that sets it apart from other planetary challenges. Adaptation to the inevitable impacts and mitigation to reduce their magnitude are both necessary. The international climate effort has focused predominantly on mitigation. The next stage of the international effort must deal squarely with adaptation coping with those impacts that cannot be avoided [4]. In order to establish the necessary strategies and enhance institutional capacity for Turkey to combat and manage the effects of climate change, a United Nations (UN) Joint Programme titled "Enhancing the Capacity of Turkey to Adapt to Climate Change" was carried out between 2008 and 2011. The Joint Programme aimed at integrating the climate change adaptation into national, regional and local policies within the framework of future development targets of Turkey in terms of sustainability [5].

The recent research and growth of knowledge about sustainable development have increased interest in sustainable development terminology, which has gained prominence over the past decade. It embraces terms such as cleaner production, pollution prevention, pollution control, and minimization of resource usage, eco-design and others. These terms are in common use in scientific papers, monographs, textbooks, annual reports of companies, governmental policy usage, and the media. Application of terms depends on their designation and recognition, rather than on domain concept. Yet, some of the terms are specific, permitting differentiation from the others. Also, differences amongst term usages, based upon geographical area, exist that often lead to imprecise definitions of the terms and their usage [6]. The availability of various information sources increases the spread of sustainability terms and their definitions, as employed by different authors and organizations. As a consequence, numerous new terms are emerging, or the existing ones are being extended in the sustainability field, but not enough critical attention has been given to the definitions and their semantic meanings.

Even with concerted efforts to curb global greenhouse gas emissions to slow the rate of climate change, it is still necessary to prepare for and respond to the adverse impacts that climate change will have on societies and economies across the globe. While some uncertainty exists about the exact nature, timing, location, and magnitude of these impacts, empirical scientific evidence clearly indicates the increasing likelihood and severity of climate related threats, including: water shortages and droughts; flooding; extreme, unpredictable weather patterns and events; declining agricultural yields; spread of disease and decline in human health; and loss of biodiversity [7].

Adaptation measures are needed to reduce vulnerability and increase human and environmental resilience against the impact of current and future climate change. Governments in both developed and developing countries have initiated comprehensive strategies to ensure that citizens have the capacity to cope with changing climatic conditions at a meaningful (i.e., local) level. Climate change adaptation requires enhanced disaster risk reduction and preparedness, and new weather risk transfer solutions. New agricultural practices, such as drought and saline tolerant crop varieties, need to be widely accessible and utilized; water and energy must be managed more efficiently; health systems must be fortified to respond to emerging threats, and new medicines are needed; biodiversity and ecosystem services must be preserved; and the livelihoods of poor people strengthened [7, 8].

Businesses have become increasingly aware of the critical role they play in enabling effective, timely, and appropriate adaptation. They recognize the risks that climate change poses, not only for their operations, but also to their suppliers, employees, customers, and people living in the areas in which they operate. Businesses have also begun to recognize opportunities to expand operations and increase their market share through developing climate resilient products and services to help people, other businesses, and governments adapt [1, 4, 7]. Business contributions to climate change adaptation play a very important role in supporting sustainable development and efforts to build the green economy, while also promoting a company's viability, profitability, and competitive edge. Some international market leading businesses have started to analyze climate change risks and opportunities, and important efforts are already underway to implement adaptation measures in many of the world's emerging economies and developing countries, which represent valuable markets for new business opportunities. Business led adaptation interventions are particularly important in developing countries, where poor communities have significant exposure to climate change impacts [6, 7]. In addition, in sustainable development, various terms are used to describe different strategies, actions, effects, phenomena, etc. Movement from usage of inappropriate terms and unambiguous definitions can help us to make more rapid progress in sustainable development science and engineering.

The term eco-efficiency was perceived within numerous definitions of cleaner production. Eco-efficiency is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity [4, 9]. It is based on the concept of ''doing more with less'' representing the ratio between economy and environment, with the environment in the denominator [7]. It is about more efficient use of materials and energy in order to provide profitability and the creation of added value. In the triangle, it could be located at the side between the economic and environmental dimensions. According to the usual usage, eco-efficiency specifically emphasizes production processes and services [10].

Adapting to the impacts of climate change in order to minimize its human and environmental toll is a significant challenge for all sectors. While some sectors are particularly at risk, all businesses face the possibility of property damage, business interruption, and changes or delays in services provided by public and private electricity and water utilities, and transport infrastructure. A more strategic and long-term approach for managing climate change risks will be necessary for all sectors including manufacturing industry. There are many adaptation options available to reduce the vulnerability of sectors. Eco-efficiency which is based on the concept of creating more goods and services while using fewer resources and creating less waste and pollution is one of these options that manufacturing industry can apply for adaptation purposes.

But climate change cannot be considered isolated from other challenges. Indeed, climate change is a truly cross-cutting issue affecting many sectors and connected to other global challenges. For example, climate change has the potential to impact global water supplies, agricultural production, human health, and our energy infrastructure. In turn, the way in which we produce our energy and food has a profound effect on the Earth's climate system. Finally, the impacts of policies in one of the fields on the other challenges need to be explored if truly sustainable solutions to global problems shall be achieved [11].

While it is ultimately governments' responsibility to meet the needs of poor and vulnerable populations, the private sector has much to contribute to the development and implementation of effective solutions, including sector specific expertise, new technology, significant levels of financing, the need to be efficient and make cost effective choices, and an entrepreneurial perspective. These case studies show how this potential can be harnessed to help address adaptation challenges and promote the public good: Overall, business engagement in adaptation is still at an early stage, particularly relative to mitigation; when it comes to climate change, the idea that community risks are business risks is salient and persuasive; companies are experiencing a diverse range of benefits from engaging in actions that increase climate resilience; companies point to a wide range of success factors in designing and implementing climate change adaptation measures; climate change adaptation and resiliencebuilding challenges present new opportunities for partnerships and engagement with stakeholders. There is tremendous scope for building climate-resilient companies while building climate-resilient communities. Companies that rigorously assess climate change risks and opportunities and implement creative solutions for long-term resilience will create business value while making important contributions to sustainable development and equitable green growth.

The case studies examine companies' motivations for action, and describe where and how they are applying their technical expertise and capacity to innovate to address climate change challenges, while at the same time improving their bottom line and maintaining their social license to operate. While it may not yet be possible to identify the full suite of best practices in private sector adaptation to climate change, the emerging approaches presented here show promise based on results achieved to date [11-13]. They are examples of actions that will need to be expanded and scaled-up for companies to reach their full potential as providers of effective climate change solutions. Many of these approaces have potential for replication in other country and sector contexts to promote adaptation and resilience.

Moreover industries that invest in water saving and waste minimisation techniques could put themselves in a better marketing position as people are becoming more concerned with the rational use of natural resources and environmental degradation. Consumption of natural resources including raw materials, water, energy, and commodities is fast increasing due to mining, industrial and agricultural activities. Consequently; solid, liquid and gas wastes generated by these activities have adverse effect on the environment. Metal coating sector-the objective of this work is one of the leading sectors for state economy due to exportation extent and potentials, creating market for by-products, and generating recruitments. Most important environmental effects of the metal coating sector include use of chemicals, consumption of high energy and water, emissions to both surface and ground waters and toxic wastes [14].

Cleaner production in industrial processes seeks to deal with the operations of an industrial process in many levels at once. It is an integrated approach requiring cooperation from all and commitment from the top tier of management to implement and sustain policies that aim to ensure that production is carried out in a manner that is both cost-effective and environmentally sound. Unlike end of pipe treatment systems, cleaner production in most industrial processes can be applied to different stages of the process, and a project implemented by stages according to a company's needs and possibilities [15, 16].

The process of absorbing climate knowledge can be considered an essential condition for any organizational adaptation to climate change related disruptions in the natural environment. In situations in which the anomaly and significance of disruptions in the natural environment increase, organizations need to internalize information about the dynamics, intensity, sources, consequences, and future developments of these disruptions. This information internalization process is essential in order to be able to prepare for adapting to climate related disruptions [17, 18]. As global warming was acknowledged as a business issue rather recently, firms do not yet possess much knowledge of how steady changes of mean temperatures and increasing frequency and intensity of extreme weather events will affect their business. Similar to any critical knowledge, the process of climate knowledge absorption is based on two knowledge sources, external and internal [19]. Based on these sources, the climate knowledge absorption capability can be ascribed to two components: knowledge creation and utilization [20].

This paper contributes to the literature on organizations and the natural environment. The analysis illustrates the exposure of electric utilities to climate change related disruptions, and discusses detailed organizational capabilities for adaptation measures which firms require in order to address the outside in effects of climate change [17-21]. Strategic climate integration refers to the organizational capability to address and incorporate climate change into the continuous, long-term innovation process. Continuous innovation can be defined as the ''changing experiential base of organizational activities, routines, and goals (targeting the long-term optimization of) technologies, processes, specifications, inputs, and products''.

II. DEFINITIONS OF PRINCIPLES: CLIMATE CHANGE

Principles are fundamental concepts that serve as a basis for actions, and as an essential framework for the establishment of a more complex system. Semantically, principles are narrow and refer only to one activity or method. They provide guidance for further work and, therefore, occupy the lowest position in the hierarchy. We have positioned the principles within environmental and ecological, economic, and societal dimensions. Environmental principles denominate those terms that describe environmental performance, in order to minimize the use of hazardous or toxic substances, resources and energy. These terms are: renewable resources, resource minimization, source reduction (dematerialization), recycling, reuse, repair, regeneration, remanufacturing, recovery, remanufacturing, purification, end of pipe, degradation, and are arranged from preventive to control principles [6].

Renewable resources are available in a continually renewing manner, supplying materials and energy in more or less continuous ways. In other words, renewable resources do not rely on fossil fuels of which there are finite stocks. The fact that natural resources will not last forever is leading to widespread concerns about energy, raw materials and water supply. Therefore, a resource minimization principle has been developed. The definition of the term has not been proposed, yet. Therefore, the term encompasses not only raw materials, water, and energy, but also applies to natural resources such as forestry, watersheds, other habitats, hunting, fishing, etc. All these resources and processes which enable ecosystems to survive and are essential for helping societies to make progress toward sustainability must be addressed. Thus, resources can be conserved, their availability improved and maintained. Reduction in the usage of materials and energy can result in dramatic cost savings [6, 8].

Source reduction contributes to a lowering of disposal and handling costs, because it avoids the costs of recycling, municipal composting, landfilling, and combustion. Source reduction also conserves resources and reduces pollution, including greenhouse gases that contribute to global warming. The recycling is defined as a resource recovery method involving the collection and treatment of waste products for use as raw material in the manufacture of the same or a similar product. Regeneration is an activity of material renewal to return it in its primary form for usage in the same or a different process. This activity enables an internal restoration and, therefore, decreases the environmental impacts. Recovery is an activity applicable to materials, energy and waste. It is a process of restoring materials found in the waste stream to a beneficial use which may be for purposes other than the original use, e.g. resource recovery in which the organic part of the waste is converted into some form of usable energy.

Remanufacturing is defined as substantial rebuilding or refurbishment of machines, mechanical devices, or other objects to bring them to a reusable or almost new state. This prevents many reusable objects from becoming waste. The remanufacturing process usually involves disassembly, and frequently involves cleaning and rebuilding or replacing components. Remanufactured objects are sometimes referred to as rebuilt objects.

Purification is the removal of unwanted mechanical particles, organic compounds and other impurities. The process of removal could be mechanical, chemical or biological in order to improve the environment and quality of life. End of pipe is defined as a practice of treating polluting substances at the end of the production process when all products and waste products have been made and the waste products are being released (through a pipe, smokestack or other release point).

Term degradation could be understood as a biological, chemical or physical process, which results in the loss of productive potential. From the biological point of view, degradation can lead to the elimination and extinction of living organisms. It can also refer to biological degradation of plant and animal residues, thereby making their elemental components available for future generations of plants and animals.

Industrial and all other human systems have their origin in natural systems that must obey natural laws. The most important feature of natural systems is their interconnection. Ecological principles have to be considered in order to understand the relationships between natural ecosystems. These principles are essential for the interaction of various systems. Every sub-system in nature is linked with every other sub-system through indirect or direct interconnections. In the natural ecosystem, many relationships exist between species, each with different consequences. Among the possible interrelationships, the following are the most common:

- competition: influences the species in a negative way and none of the species benefits; the main objective is the elimination of other species from an ecological niche.
- predatory: one species eats the prey; the predator has the benefit.
- amensalism: one species is impaired and the other is neither positively nor negatively affected.
- parasitism: one species benefits and the other is impaired.
- neutralism: a hypothetical category where one species does not harm or benefit the other species.
- commensalism: one species receives benefits and the other is not impaired.
- protocooperation: both interrelated species receive conditional benefits, but they can survive separately.
- mutualism: both species receive benefit.

The last three relationships are understood as symbiosis, because systems are either not impaired or receive benefits due to the interactions [6-8, 12].

In this paper represent a wide range of industries, from financial services to construction to consumer products, and adaptation solutions applied across the globe. The cases illustrate how companies contribute to climate change adaptation in three spheres of action by:

- Instituting new practices within their own operations to manage climate risks and impacts,
- Developing products and services that help vulnerable countries and communities adapt to climate risks and impacts,
- Engaging with governments, communities, and other stakeholders to put policies and ground-level practices in place that contribute to long-term resilience.

The case studies examine companies’ motivations for action, and describe where and how they are applying their technical expertise and capacity to innovate to address climate change challenges, while at the same time improving their bottom line and maintaining their social license to operate [7]. Many of these approaches have potential for replication in other country and sector contexts to promote adaptation and resilience.

The companies profiled here see a clear and robust business case for strategic engagement in adaptation at the nexus of company needs and community needs to support sustainable development (Figure 1). Companies see the inextricable connections between their ability to operate and prosper and the well-being of the communities that comprise their value chain: suppliers, employees, customers, and people living in the areas in which they operate. Companies are committed to tackling business challenges and community challenges in an integrated fashion.

Figure 1. The strategic nexus for private sector adaptation efforts

Companies profiled reported numerous positive benefits from their engagement in climate change adaptation, including:

- Ability to mitigate and better manage risk,
- Assured continuity of operations (for example, by avoiding damage to assets or interruptions in supply of inputs),
- Financial benefits (either due to lower costs, or new revenue streams),
- Expansion into new markets,
- Reputational benefits with external stakeholders, including continued social license to operate, and meeting current (and anticipated future) customer expectations,
- A competitive edge over companies that are failing to respond to climate change challenges.

In addition to these benefits, a few companies also see future possibilities to leverage and expand their adaptation efforts, particularly the development of products and services that facilitate adaptation and promote resilience, by accessing new public financing streams earmarked for climate change adaptation. However, the companies profiled in this report have not yet experienced this benefit through their current adaptation activities [7, 10, 13].

These on the ground perspectives underscore the business case for adaptation that supports sustainable development, a described in "Adapting for a Green Economy" (Figure 2). These cases illustrate how climate change and resilience building efforts have been initiated, implemented, and, in some cases, institutionalized within companies.

Figure 2. The business case for climate change adaptation

Companies currently engaged in addressing adaptation challenges and opportunities have found it useful to [7, 22]:

- Treat community well-being not as something to be addressed solely through corporate philanthropy, but rather as a goal that must be incorporated into the company's mainline growth strategy and everyday business decision making,
- Secure senior level support for and commitment to addressing climate risks,
- Link climate change adaptation to the company's other efforts, such as managing weather variability, or developing cutting edge technology, and cast the purpose and impact of adaptation in terms that resonate with staff, such as "increased efficiency", "ensured continuity of operations", and "market innovation",
- Integrate the company's response to climate change risks and opportunities into established, core business policies, plans, and processes; use existing (well-working) channels rather than creating brand new ones,
- Put together cross-functional teams to identify and assess climate risks, opportunities, and to address, monitor and evaluate, and communicate the company's climate adaptation response,
- Evaluate, recognize, and reward business units and individual employees for their ability to innovate, implement new approaches, and meet company goals for increasing resilience and contributing to sustainable development.

Companies mentioned partnerships as an additional, important success factor and cited numerous assets that external stakeholders contribute, including [7]:

- Additional sector-specific technical knowledge.
- Convening power from the local to national level.
- A nuanced understanding of community development needs and of appropriate, effective climate change adaptation interventions.
- Research and analytical capabilities.
- Ability to disseminate information and lessons learned from resilience building interventions to key audiences.
- Materials and equipment, co-financing for projects.
- Ability to "own" and sustain local level adaptation measures once companies have provided initial financial, planning, and technical inputs.

Companies find that a creative combination of assets and perspectives enables them to achieve more than they would on their own.

With respect to management strategies in the general ecological context, research has discussed the evolution of environmental strategies, environmental management practices and systems, ecology oriented investment decisions, and the role of organizational capabilities [23-27]. Explicitly focusing on direct effects of climate change, Porter and Reinhardt [21] argue that companies also need to develop capabilities to proactively manage disruptions stemming from "ecological discontinuities". However, thus far little research has been conducted regarding the question of which capabilities organizations can build upon towards this end [18]. A few authors investigate climate change related disruptions in specific industries and derive suggestions from an organizational capability perspective.

III. THE IMPACTS OF CLIMATE CHANGE

We have seen that climate change is complex and variable both in space and time. The likely impacts on human communities and ecosystems will also be complex. There is also much variability in important factors relevant to climate change such as sensitivity (i.e. the degree to which a system is affected either adversely or beneficially), adaptive capacity (i.e. the ability of a system to adjust) and vulnerability (i.e. the degree to which a system is susceptible to or unable to cope with adverse effects). Different ecosystems, for instance, will respond very differently to changes in temperature, precipitation or other climate variables. For humans, it is the least developed countries that in general are most vulnerable; they are likely to experience more of the damaging climate extremes and also have less capacity to adapt [28].

3.1. Food industry

The firm is operational in food industry producing marinated, smoked and frozen seafood products. Before the eco-efficiency applications firm was responsible for consuming of 75.000 m^3 of groundwater annually. Since one of the major products of the firm is anchovy fillet, processing of anchovy is the major source of water consumption. Anchovy processing is carried out in two steps in the firm: First, anchovies which are stored in cold store is thawed by the help of fresh water. Second, thawed anchovies are gutted (filleted) manually by workers using continuous supply of fresh water serving for simultaneous cleaning of anchovies. Before applications, it was calculated that annual groundwater consumption of the firm was 22.000 m^3/year in the thawing step alone. In addition to that firm was consuming 36.000 m^3/year of water in the gutting (filleting) step. In other words, 77% of total water consumption of the firm was recorded in the anchovy processing [5, 29, 30].

3.2. Beverage industry

The firm produces beverages including fruit juice and carbonated drinks. Before cleaner production applications 851.000 m^3 of water was being consumed in fruit processing and soft drink production processes, which are most water intensive processes in the firm. In the fruit processing step fruits are washed, pre-processed (crushing, evaporation etc.) and pasteurized before being sent to fruit juice production. In fruit processing step 346.000 m^3/year cooling water (once-through cooling) was being consumed before cleaner production applications. In the fruit juice production step 173.000 m^3/year cooling water was being consumed for cooling purposes as a similar case to fruit processing step (once-through cooling). As part of the cleaner production pilot applications two separate recycle and reuse systems (closed-loop water cooling) were introduced in the production facility of the firm. Both closed-loop water cooling systems consisted of the following equipments with different operational parameters: cooling tower, stainless steel water pumps, stainless steel pipes/fittings, inverter and control panel [5, 31, 32].

3.3. Metalworking industry

This project was implemented in a company producing metal parts for automotive industry. The company uses fresh groundwater in production processes and most water intensive process was determined as heat treatment where cooling process requires 20.200 m^3/year of water. Before cleaner production applications cooling was performed by means of continuous supply of groundwater without reuse/recycle in heat treatment process. Since no major contamination was determined in cooling water it was possible to recirculate it to the main water tank, used for process water supply of the whole factory. In addition to the heat treatment process, major cleaner production measures were taken in the surface coating process in which 3.717 m^3 of annual water consumption was recorded. Energy was also saved due to decreased water supply rate in groundwater wells supplying water to the firm. So 31.000 kWh of electricity was saved which corresponds to 18.3 tons of annual CO_2 emission [5, 14, 33].

3.4. Chemicals industry

The firm is active in the field of chemical products sector manufacturing polyester fibers, filament and various polymers including specialty polymers and chemicals thermoplastic polyester elastomers and dimethyl terephthalate. Total annual water consumption of the firm is around 2.295.000 m^3. Out of this amount, 835.640 m^3/year of water is processed and softened by means of an ion exchange system before being used as permutit water in various processes. Before cleaner production applications, 324.300 m^3/year of permutit water was being used for cooling of the heat transfer pumps in order to prevent the pumps fail as a result of excessive heating. Within the scope of the cleaner production project, a group of water-cooled heat transfer pumps were replaced by air-cooled heat transfer pumps. This implementation led to the elimination of permutit water consumption in the corresponding production lines. In addition to the water saving of 93.000 m^3/year, 121.000 kWh/year of energy was saved [5, 14].

3.5. Textile industry

The firm produces various fabrics (polyester, cotton and lycra based) for womens' wear with a monthly production capacity of 1.500.000 meters. The firm which has wet processes such as dyeing and finishing had a water consumption of 300.000 m^3/year before cleaner production applications. 80-85% of total water consumption was recorded in dyeing and finishing processes. Therefore, the focus of cleaner production applications was on dyeing and finishing processes which were responsible for 260.000 m^3/year water consumption. Applications led to 54% of water saving which corresponds 162.000 m^3/year. Specific water consumption was also monitored before and after cleaner production applications. Results indicate that specific water consumption of the firm was decreased from 111.8 L/kg fabric to, 50.88 L/kg fabric. Since water is used at around 70-90 °C for dyeing and washing purposes in the firm, water saving increased energy efficiency and 22% of energy was saved accordingly [5, 34, 35].

3.6. Metal coating and painting industry

The firm is specialized in coating and painting of metal parts/accessories for various sectors like automotive, defense etc. Before cleaner production applications two different methods were applied for surface finishing purposes. In the first method, surface of the materials were cleaned with thinner prior to painting process. Approximately 7.650 kg of thinner was used annually for surface finishing purposes, accounting for 85% of thinner consumption in the company. In the second method, some portion of the materials outsourced for cadmium plating in which the cadmium oxide and sodium cynanide are used as chemicals. After cleaner production implementations, thinner and cadmium plating systems were replaced by the oxsilan process. When used on clean metal surfaces, the silane-based oxsilan forms a thin layer (60 nm), which together with paint improves the adhesiveness and corrosion protection of the paint, depending on the material [5, 14, 28, 33].

IV. RESULTS AND CONCLUSION

Climate change emerges as a multifaceted global problem those results in serious environmental and socio-economic consequences. The assessment of climate change impacts, adaptations and vulnerabilities draws on a wide range of physical, biological and social science disciplines and consequently employs a large variety of methods and tools. It is, therefore, necessary to integrate information and knowledge from these diverse disciplines. Terminology in the field of sustainable development is becoming increasingly important because the number of terms continues to increase along with the rapid increase in awareness of the importance of sustainability. Various definitions of terms are used by different authors and organizations, for example, green chemistry, cleaner production, pollution prevention, etc. The importance of this topic has stimulated research into the problems of clarifying ambiguity and classifying terms used in the sustainability field.

As the demonstration projects, eco-efficiency applications which improves environmental and economical performance were implemented in 6 industrial facilities analyzing production processes, water consumption and wastewater generation. As a result of the applications, 784.550 m^3 of water was saved annually besides 4.947.000 kWh savings achieved in energy consumption. 978 tons/year of CO_2 emmision was also avoided. Not only water and energy but also raw materials, chemical and manpower was saved as a result of project activities which decreased associated costs.

The discussion thus far has illustrated that organizational responses to disruptions in the natural environment, such as climate change, require substantially different knowledge as compared to responses to other dynamics in the broader organization environment context. Building on this, the main propositions of this paper are:

1. There is a nexus between organizational behavior and issues related to the natural environment, in this case climate change-related disruptions. As such, organizations are in general able to reduce their exposure to these disruptions by acquiring knowledge about them and implementing adequate adaptation measures.
2. Managing these issues can generate a competitive benefit. Thus organizations should in fact reduce their exposure to these disruptions from a competitive point of view. In order to avoid negative consequences on business due to physical damages, it is necessary for organizations to proactively adapt to climate change [8]. It therefore seems to be appropriate and sensible for organizations to develop and deploy capabilities in order to do so.

Organizations can adapt to climate change in three main ways:
1. anticipatory adaptation, which takes place before climate change impacts are observed;
2. autonomous adaptation, which does not constitute a conscious response to climatic change effects but is triggered by changes in natural and human systems;
3. planned adaptation, which is the result of a policy decision based on an awareness that climatic conditions have changed or are about to change and that human action is therefore required to return to, maintain, or achieve a certain state [36].

Dynamic and intensified changes in the natural environment require organizations to develop and deploy organizational capabilities that enable them to adapt to the resulting disruptions. Building on eleven case studies in the electricity sector, this study not only addresses the exposure and adaptation to climate change related disruptions of operational processes, but also covers supply chain and product distribution aspects. This change in the global climate system constitutes a sphere of substantial disruptions within an organization's surrounding environment [35, 36]. In summary, a company's resource supply, production processes, and product distribution can be affected due to steady changes of mean temperatures and increasing frequency and intensity of extreme weather events (Figure 3): within the supply chain, climate change related disruptions can decrease the quantity and quality of required resources or even disrupt the supply chain entirely. Within production processes and facilities, organizations can be exposed to climate change related disruptions in terms of physical damages and slowed or interrupted operation. In addition, climate change related disruptions may affect the distribution and quality of products and services.

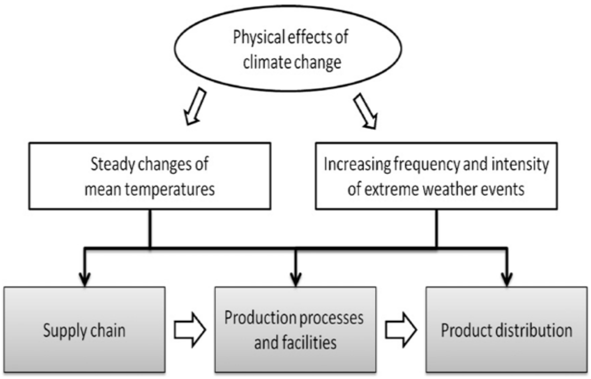

Figure 3. Physical effects of climate change on companies

Dynamic and intensified changes in the global ecosystem result in significant disruptions to the natural environment. One of the most prominent examples of this is climate change and the resulting natural disasters. As firms are embedded within the natural environment, they need to adapt to any environmental disruptions that transpire. Climate knowledge absorption as an essential information generating and internalizing capability, climate related operational flexibility as a short-term adjustment capability, and strategic climate integration as a long-term, innovation-focused capability.

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