AG1815 Project report

Industrial emission & energy optimisation

Group 5

Student participants:

Dalvie Benu
Evgenii Venkov
Azer Hojlas
Hasti Mohebali Zadeh
Axel Forshällen

Company supervisor:

Erik Tutzauer

Course supervisor:

Jana Sochor

March, 2022
Word count: 5082

Abstract

All industries use energy for their activities, however, most industries tend to use more energy than required for their output, which leads to energy waste.

Fortum, a Finnish green energy provider, has commissioned the authors to create a platform that would assist managers to recognise areas of energy waste and how to reduce it. Lowered wasted energy is desirable from an environmental perspective as less energy used in industry means lower demand placed on the energy grid as well as lowered emissions from energy sources. Additionally, lowered wasted energy would lower costs for the industry.

As a proof of concept the group was given a task to create a simple service, that given some data, for example in form of an invoice containing a purchase for production materials (like fuel), it would convert it and present it to the user as the related emissions of greenhouse gasses. This allows the managers to see in a user-friendly way what effect their production has on the climate and how it can be mitigated.

Additionally the group has created a questionnaire to be answered by managers which based on user responses would provide insights on how to minimise energy usage relevant to the questions answered, for instance by using more sustainable technical solutions. A research period was conducted before the implementation of the questionnaire, during which a data bank of energy optimisation methods was compiled as well as data that allows for conversions from fuel to greenhouse gasses emissions.

The web service that was created consists of the aforementioned questionnaire and invoice conversion services. This service has met the goals laid out by the project proposal: creating a platform to assist managers to make informed decisions on lowering wasted energy and peak power usage.

Contents

Introduction with background and problem formulation

According to the Oxford dictionary the broad definition of sustainability is "the ability to continue or be continued for a long time". Additionally, this term has also a more narrower meaning - "the use of natural products and energy in a way that does not harm the environment" [1]. Currently, the energy that is used in industrial sector is responsible for 24.2% of greenhouse gasses emissions[2]. According to the source [3] these production processes often are not efficient and use more energy than they need to, meaning that there is room for optimisation of processes from an energy use perspective.

Greenhouse gasses (GHG henceforth) trap heat and make the planet warmer. Greenhouse gas emissions from industry largely come from burning fossil fuels for energy in the industrial sector, that produces goods and materials for later use. One could split the GHG emitted during industrial production into two sections: the emissions that are produced directly at the facility, and the emissions that occur off site, but are related to the facility's usage of energy [4]. If the energy and emissions footprint of the processes were measured more accurately, energy waste and emissions could be cut – ultimately to a minimum if managers chose or were required to do so by the agencies that control air pollution (for example).

As previously mentioned, all industries create varying amounts of wasted energy and the problem might lie in the fact that some boards or managers do not know the extent of this wasted energy. Therefore, it is important to find a way that can illustrate the wasted energy to management in a comprehensible way.

If one could model factory energy usage, unnecessary energy consumption could be reduced if they chose to do anything about it. So if this wasted energy model is provided to the managers, they could make decisions regarding how to reduce energy use. Managers have a financial incentive to reduce energy use as well, because lower energy use equals lower energy cost. Furthermore, lower energy usage would help meet corporate responsibility goals. The pre-requisites are that time consumed by processes and their output cannot be affected negatively or the cost savings on energy would be larger than the potential profit loss due to lower production.

Some platforms already exist that fill the function of illustrating wasted industrial energy. One example is Circularise[1] which helps users become more transparent towards customers. This platform also helps in increasing material value by making the materials traceable across supply chains. Additionally, they provide a dashboard from which clients can easily create and maintain Digital Assets

[1]Circularise website - `https://www.circularise.com/`

without the need for integration[5].

Another example is Ecovadis[2] which assists companies with managing their supply chain both upstream and downstream by sharing their performance with their stakeholders. Ecovadis can help users connect with their suppliers, resulting in strengthening the social, environmental and economic performance of their supply chain, hence, reducing their collective footprints [6].

Fortum[3], a Finnish company that primarily operates in Nordic countries, supplies so-called "green" electric power and offers sustainable energy solutions to private and public enterprises. As power-plant operators, they have a key interest in illustrating aforementioned energy waste. By helping their industrial customer base better understand their own energy usage and demand, Fortum could in turn optimise their supply. Erik Tutzauer, innovation manager at Fortum, has commissioned the authors of this paper to create a dashboard-like service in order to allow managers to better understand where and how much energy is wasted. Additionally, according to Erik, energy usage optimisations could result in lower demand on the power grid. Therefore, it would be less expensive to maintain the power grid hardware, which is in interests of the energy supplier.

From an ICT perspective, the challenge lies in creating platforms that separate the physical data collection and illustration of how much waste is incurred. Ideally, managers with no underlying knowledge of how certain complicated processes work should be able to use these platforms without much confusion. Additionally, the aforementioned dashboard must be simple enough for individuals with no IT experience to use. This is especially relevant for senior level management that could potentially lack the engineering backgrounds. In the world of ICT, simplicity is usually harder to implement, but that makes it all the more interesting.

Summarising the points that have been made, from a sustainability point of view, the platform is of interest as it could lead to energy optimisation in the industrial sector and reducing the carbon footprint of that sector. These optimisations directly align with the United Nations Sustainable Development Goals (UN SDGs hencefoth) 7 and 12 that are "ensure access to affordable, reliable, sustainable and modern energy for all" and "ensure sustainable consumption and production patterns" accordingly [7]. The incentive for this course of action will be further elaborated on in the next section.

[2]Ecovadis website - `https://ecovadis.com/`

[3]Fortum website - `https://www.fortum.se/`

Purpose and goals

The aim of this project is to create a platform that is capable of assisting managers from industrial settings to identify inefficiencies in key areas of production where they may optimise energy usage and hence lower wasted energy. The platform should provide guidance that is relevant and applicable to the setting.

The initial scope of the project was extended so that the platform also includes IT heavy industries (like server farms) as well as typical office spaces(like a bank) as well as production based industries. This was decided as they are also a factor in the amount of global greenhouse gasses emissions. Commercial buildings have been the source 6.6% of energy related emissions in 2016 and have a trend of growing even more [2]. So it is important to allow for managers in those industries to lower wasted energy as well as production centred industries. Together, these industrial categories cover a wide range of potential industrial settings, resulting in the project platform being applicable to plenty of potential business users.

Furthermore, the aim was also limited to only optimise energy use, which in return reduces energy waste,rather than consider other aspects of production that contribute to wasted energy (like wasted materials, processes optimisation or life cycle analysis). The sustainability impacts of the industrial processes themselves or the sources of energy production will not be analysed in this report as this is outside the scope of this project.

However, the potential GHG emissions from production related invoices will be included. This allows for managers to get an understanding of how their supply chain spending affects GHG emissions outside their industrial processes. That is, how much GHG emissions they indirectly cause by purchasing goods and services necessary for their own production. It is intended that the target users of the platform are managers as they will have the relevant knowledge to interact with the platform as well as authority to bring about any changes once they have interacted with the platform.

Overall, the aim is to create a platform that provides solutions on how to reduce energy waste and monitor GHG emissions caused by industrial spending. In order to meet the aim, the platform shall consist of two parts, the first being a questionnaire and the second being an API (short for Application Programming Interface[4]).

The questionnaire intends to identify key areas of where energy can be optimised. It ensures that the presented solutions are relevant for the user rather than generic. Thus ensuring that the questionnaire is useful to most potential users that fit in the aforementioned industrial categories.

[4]An Application Programming Interface or API is a set of programming code that enables data transmission between one software product to another[8].

The API in its turn allows users to link their accounting software to the platform. The API will convert the incoming invoices to the GHG emission that are reflected in the invoice. The aim is to provide data on how their supply chain spending causes GHG emissions, as well as a way to gauge the effectiveness of GHG emission reduction policies.

The general long term idea being that managers will be given incentives to optimise energy usage due to the fact that said optimisation would bring about long term cost savings as well as a positive reductive effect on climate change. Furthermore, this platform would assist managers meet corporate social responsibility goals set by upper management (like board or directors or stockholders).

Project design

The group was given more detailed requirements during discussions with Erik Tutzauer. These are: the platform must have data retrieval, processing and presentation capabilities. Additionally, the presentation of the data should be in such fashion that allows non technical users to understand and grasp what is presented, as well as access it with ease.

As the group has further discussed the project, it was decided that some data can be entered by the user, by hosting a questionnaire. The reason that this solution was chosen was because it was assumed that it might be difficult to create a solution to lower wasted power without knowing what kind of data and format it would be. Additionally, it should also be expected that the provided data may differ between companies. Based on the user provided answers, the page will return suggestions on how the user can reduce energy usage in their specific industry.

The intent of having such questionnaire was to ask a series of questions that allow the website to understand the specific energy consumption state of the user and it also addresses the problem of data being too specific, that is, if it could not be parsed by the website.

During the discussions, it was also suggested to link the dashboard to some accounting software which would allow to convert invoices to GHG emissions. Since the converted data should presented in an understandable way, that is the main focus of this section of the dashboard and not the invoice. So in the current model of the website actual invoices are not necessarily used. In order to address this an Application Programming Interface (API) will be added to dashboard, which is separate from the questionnaire, to allow users to convert invoices to emissions.

The questionnaire

As stated in the aim, the questionnaire should be robust and versatile enough to provide energy optimisation solutions for production based industries as well as IT centred and regular offices. The creation of the questionnaire was split into 3 stages: research, design and implementation.

During the research stage, the research was conducted on different sectors in the three aforementioned industrial categories. The goal of such research was to find methods that allow for energy use reduction in lighting, heating and ventilation as these solutions are common among all three industrial categories, where utilities usage is high. Specific research was conducted on how to reduce energy usage for each industry as well. Furthermore, research was conducted into how one would go about designing a user friendly questionnaire/interface by studying popular industry examples like Ecovadis and Circularise that have been mentioned above.

In production based industries, solutions such as automation, timing and over-production were explored. These solutions improve the efficiency of industrial processes, hence reducing energy used in those processes.

In IT centred industries, solutions to reduce the energy used by servers were explored. These include solutions such as server consolidation, energy management and the cloud. For office industries, general solutions were explored that involved automation of admin processes using IoT[5] devices.

At this point there is a compiled list of various specific energy reduction solutions. So it only remains to implement such methods that could present the solutions that are appropriate to the user.

[5]Internet of Things

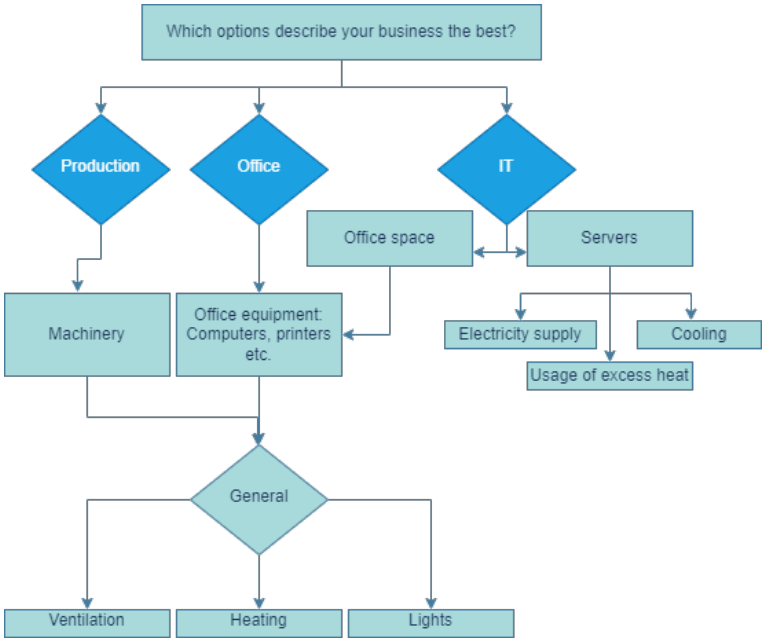

Figure 1: The diagram visualising the choices that are present on the website for different industries

During the design and implementation phase, the group has created a decision tree as seen in figure 1. This tree describes the potential paths that a user can take based on their answers. The questionnaire prompts the users about what solutions describe their company the best. Based on their responses they are provided with more sustainable alternatives. If the user selects the 'none' option, they will receive all sustainable suggestion for a possible source of energy consumption.

In the first question the user is asked to pick which industry best describes them with the options: production, IT and office.

After this section, the website will ask questions about the specific industrial setting which the user belongs to. This can be seen as the middle of the diagram. If the user opts for an IT focused company: How are the servers configured regarding energy settings? Based on the answer it will provide a suggestion on how to improve the energy usage of the server farm, or if the energy usage is already optimised then it will not provide a suggestion as it is already optimised. In practice, as the user navigates the site they will traverse down the tree answering questions upon which they will be presented with a list of suggestions that the tree has picked out. All decision paths can be seen in figure 1.

The questionnaire then proceeds to ask the user about their light, heating and ventilation systems. Based on the answers provided to these questions, the site will queue up picked solutions that will reduce energy usage.

For example, if the industry does not use insulation and relies on personnel to monitor the Heating, Ventilation and Conditioning[6] (HVAC henceforth) system, the website will offer the solution to add insulation to reduce heating requirements and to employ a smart HVAC solution to improve efficiency.

After an agreement regarding the general design was reached, the questionnaire was added to the platform and tested for its functionality.

The API

It was decided that the API would be a part of the website but operate independently. The intent of the interface is to create a platform for users to understand, monitor and optimise their GHG emissions. These emissions are the result of operational costs, that is, the result of invoices that are produced when spending on goods and services required in in-house production. Therefore, managers can get a full understanding of their environmental impact from direct operations (from the questionnaire) as well as from their supply chain spending. Furthermore, they can use the API to monitor the effect of policies enacted by managers to reduce emissions, such as optimising their supply chain to limit the amount of materials bought. API development was split into a research and implementation phase.

Research for the API was centred around how general APIs work. Commonly used APIs were studied to understand how they worked and if the group could use similar strategies. The Jira framework REST API [10] was a heavily studied framework and their ease of use was a strong contributing factor.

Further research was conducted on the backend (the part of the code inaccessible to the user) of the API, where the conversion of the invoice to emissions would occur. The European Environment Agency air pollutant emission inventory guidebook 2019 [11] was decided to base the conversion data on. The guidebook contains the emission factors of many materials per unit and the API will use that data to convert from invoices (materials) to emissions. Furthermore, other invoices could also be integrated such as transport and electricity and the data from these invoices will be converted from other sources such as online sources for electricity prices and transport cost among others. At this point all the necessary details to implement the API are present.

As mentioned before, the API is a way to communicate between two applications. The interface itself allows anyone who has access to it to request data, given that the user also provides some data to the service. This is also known as a POST request.

A technical solution was made, which allows for a user to change data on the

[6]HVAC units are installed in buildings and control the indoor environment by circulating air between outside and inside [9].

website in a JSON format and then with the click of a button, that data will be sent to the server, analysed and then sent back to the website, where it will be presented in a user-friendly way.

With this solution the data gathering and the data processing parts of the project that were discussed earlier are met.

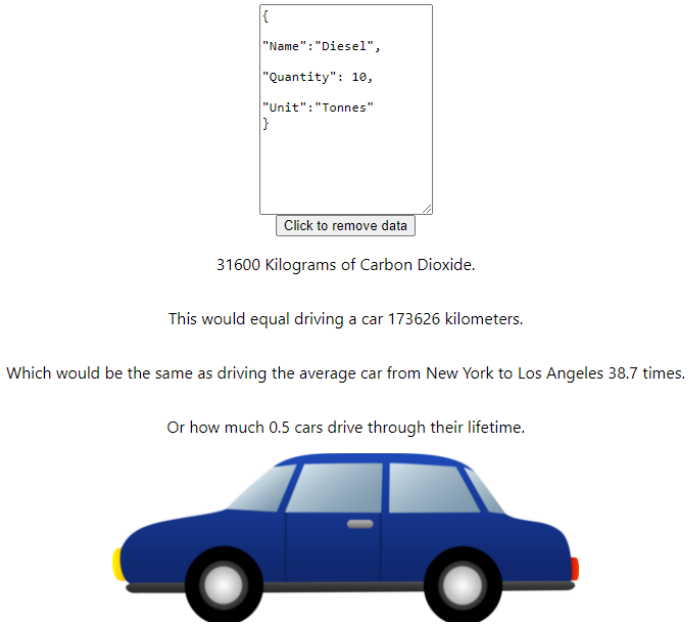

Figure 2: Image showing the presentation of the emissions data after sending an invoice.

Furthermore, although the API is separated from the website, the two will communicate in order to create a section on the website that visualises the total emissions data from invoices. This is illustrated in the form of an animation that displays how many kilometres travelled by car would be produce by the corresponding amount of emissions, and how many trips from Los-Angeles to New York that would equal to. An example of this information is shown in figure 2. This is done for users to better understand the emissions data and it also meets the data presentation requirement. It is important to note that the platform does not provide an interpretation of the emissions. That is, this amount of emissions from invoices this month is acceptable but over said amount is not. As this limit between acceptable and non-acceptable emissions may not be the same in every users company. Rather, the API part of the platform aims to present the emissions resulting from invoices in a user understandable fashion. The user then will use this platform to interpret the emission as they see fit, based of legislation of their industry as well as internal corporate social responsibility goals.

Results

The aim for the project was to create a platform that assists managers to lower wasted energy and monitor greenhouse gasses emissions resulting from their spending.

In order to meet the goal of identifying areas of industry where energy can be optimised, a questionnaire was created according to the details described in the method above. It was required by the aim for the platform to provide relevant guidance. This was accomplished through conducting amount of research to compile a bank of different suggestions on how to lower wasted energy. The types of solutions (and the industry or the source of consumption that these solutions are useful in), that where chosen to be the most the most relevant and are displayed on the website once a user completes a questionnaire, are shown on table 1.

Then the questionnaire refining these suggestions according to the responses given. Hence, it only returns relevant suggestions from its data bank and does not return suggestions that are either already in place or irrelevant for the user.

Source of energy consumption	Suggestions
Production [12]	Maintaining equipment Investing in more efficient equipment Limiting overproduction Automating processes
General office space [13], [14]	Using portable computers Allowing remote work
Server-related industry [15]	Consolidating lightly used servers Implementing efficient data storage measures Managing efficient airflow Use sensors and controls for smart cooling
Ventilation [16]	Using smart ventilation
Lighting [17], [18]	Using natural lights Using energy efficient lights
Heating [18], [19]	Invest in quality insulation Utilising the IoT technology Deploying smart buildings system

Table 1: Table that shows the summary of all of the solutions that are presented on the website.

Furthermore, the scope of the aim was increased to include IT and regular office based industries. The questionnaire also provides relevant guidance for these industries through asking the user which industry best fits them, hence the results

from the questionnaire are tailored for that specific industry. This prevents users from receiving suggestions that they are not able to implement. For example, production based users will not receive suggestions on how to optimise server farms. However, all users will get suggestions on how to improve their heating, lighting and ventilation systems (where appropriate) as these are common between all users. Therefore, it can be seen that the questionnaire meets the authors aim of creating a platform capable of assisting managers in industrial setting with locating areas in their processes where they may optimise energy usage and lower wasted energy.

The aim was extended for the platform to include potential GHG emissions as a result of the spending by the industry. As specified earlier, this spending is in the form on invoices that relate to production and operations. This could be invoices for materials or for other needs such as electricity. The goal is to allow for managers to gain a general understanding of how the company spending contributes to GHG emissions (and in turn global warming). In order to meet this goal, an API was created according to the details described in the method section. The API provides the required understanding of industry spending by allowing users to provide invoices. These invoices are then converted to GHG emissions and then displayed on the website in a user friendly manner. Hence, the API has met the required goals of providing managers with an understanding of the significance of their spending on GHG emissions. Furthermore, it was required that this API could be used to measure the performance of emission cutting policies enacted by managers. An example of such a policy that could be monitored by the API could be a policy to lower purchases of materials (but still meet production quotas) that have historically contributed to a large portion of company emissions. This was goal was met as the API stores emissions data from this periods invoices and this data can be compared against future invoices to compare how the policy is working (assuming the policy was aimed at reducing supply related emissions).

Overall, by viewing the project through an IT lens it is evident that the questionnaire and API together satisfy the stated aim, which is creating a platform that provides solutions on how to reduce energy waste and monitor GHG emissions caused by industrial spending. Thus, all that is required has been accomplished.

Discussion and Conclusions

To restate the problem this project has targeted, Industries use energy in their production stage, however they tend to use more energy then required[3]. Expended energy that has not gone towards output is said to be wasted. Wasted energy can also be framed as: The difference in energy when producing the same amount of output just as fast but with smaller required amounts. Besides the financial cost of paying for more energy than required, there is also a negative effect on environmental sustainability. An opportunity cost is also incurred as this wasted energy could be used elsewhere. This places higher stress on the energy grid as more energy is demanded as a whole. Furthermore, depending on the source of the energy, wasted energy leads to GHG emissions that are not required.

The project group solution does not solve this sustainability issue directly. As how and where energy is wasted may differ from factory to factory and one solution that works for one may not work for the other. Rather, the project platform aims to understand the specifics of the managers energy usage situations and hence offer solutions tailored for that user. As a result, it is difficult to accurately measure the sustainability effects that occur due to this solution, as it solely depends on what solutions are suggested and if users are willing to implement them. It can however be noted that merely hosting this site will require energy. This could become significant if the solution is applied in a bigger scale to industrial levels depending on how consistently the API part of the platform is being used.

Visualisation in different forms, which in this case is in the form of displaying emissions for invoices in terms of distance travelled by car, can help to communicate abstract or difficult ideas in a simple form [20]. Communicating complex data in an easy to understand fashion is an important aspect of the project. As this solution is intended to be used by many managers, some of whom may not have the same level of technical knowledge as the individuals who provide the data. It is therefore important that the platform communicates solutions and emissions data in an understandable way rather than just providing emission numbers that are hard to comprehend on their own. It should be easier for individuals to understand the emission numbers if they are compared to the emissions released of a benchmark like travelling a certain distance with an average car. As stated before, it was difficult to create a quantitative benchmark to compare the resulting emissions data to, such as an industry average.

Managers from different industries may use this tool and hence the same average may not apply to them. Rather, the intention was to present the resulting emissions in an easy to understand fashion. The data can then be interpreted by managers on how good or bad it is relative to their specific field. In short, the platform presents information on the emissions resulting from their invoices (as

explained earlier) for managers to interpret and make decisions on.

The visualisation aims to show the direct link between industrial carbon emissions and climate change. This then motivates managers to take action and steer their company towards more sustainable behaviour that convinces stakeholders to take climate change reduction more seriously. This may not have been the case if carbon emissions from invoices had been presented without context.

In order to categorise the project solution and link it to specific UN Sustainable Development Goals (SDGs), this website directly relates to goal twelve which is "Ensuring sustainable consumption and production patterns". That is due to the fact that it acts as a platform that provides users with solutions on how to reduce wasted energy as well as decreasing their material footprint [7].

This solution also ties to goal number thirteen of UN SDGs which is "Taking urgent action to combat climate change and its impacts" since it involves suggestions about long and short term strategies as well as adaptation plans for industries that can lead to taking sustainable actions to affect the climate positively [21] or mitigate their current negative effects.

Some of the platform provided solutions encourage industries to plug into the cities smart grid in order to facilitate the transfer of energy related data to and from industries. This relates to UN sustainable goal number eleven (smart cities) as the better connected the smart grid is to the city, the more efficient the energy sources can be.

Since this solution focuses on increasing the rate of improvement in energy efficiency, it could also be related to goal 7 of UN SDGs. Specifically, the reduction of wasted green energy that could be used elsewhere in the energy grid.

There are some negative impacts that this platform might have: one could be that the initial cost of implementing this system and similar technologies can be high; then, there is a need for IoT devices and equipment for all the precise measurements of used energy in production which have limited life-cycles, resulting in a first order impact (Life cycle impacts) when using the terminology from Lorenz Hilty's article as can be seen in figure 3.

The reason that this could be a first level impact is due to the cost of providing ICT services as well as the disposal of ICT tools [22].

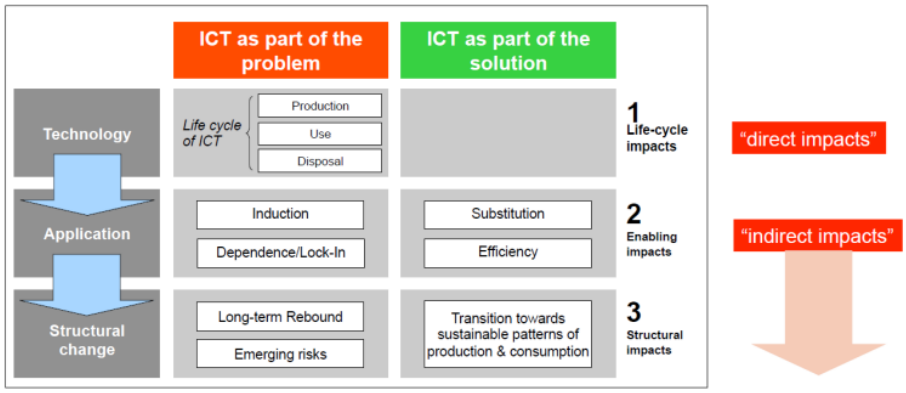

Figure 3: A matrix of ICT effects, ref. [22]

It is also worth mentioning that the impact of the aforementioned devices could be larger. For example, in order to pursue sustainable conduct, it would be rational to recycle these devices properly, according to established guidelines.

The possible positive effect of such ICT solution that could also be discussed is that it has a second order impact or more specifically, it has an "optimisation effect", also seen in figure 3. This is due to the fact that this platform encourages reducing the use of some resources, like coal, organic fuels etc. that are currently used to produce energy [22] and nudge businesses into moving towards "greener" sources of energy. Depending on what sections the users have marked in the questionnaire, they could be provided with a suggestion on how to use less energy for heating or cooling in the office area space.

After reviewing the accomplished work with the help of the supervisor, it was evident that problems could occur on some parts of the website. In the questionnaire specific part of the platform, where it is required that the user enters data, the required answers might be distorted as the user could be biased towards portraying themselves in favourable light. This they might do by attempting to answer questions falsely either deliberately or not. Hence, the results produced by the questionnaire may become skewed. However, there is no real solution to this problem from the designers perspective.

Future work

There are a number of improvements and extensions to the platform that could be implemented given the appropriate time and resources. First of all, the API implementation is quite basic. As seen on figure 2, right now the API acts as a proof of concept since it only converts diesel purchase invoices into emissions, however it still meets the goals that were stated in the aim. This could be expanded with low efforts to include other materials described in the emissions database provided

by the European Emissions Agency[11], as well as other common spending targets like electricity and food.

Secondly, the presentation of the emissions data from emissions currently only displays total carbon dioxide emissions. However, it is known that there are other gases that have an effect on global warming such as, methane CH_4 or nitrous oxide N_2O. These gases could be included in the data presentation as well.

However, this reverts back to the already mentioned issue of having a user friendly website, that it may be overwhelming for the user to have a lot of information presented to them. Instead, the solution of having a visualised tree that grows or dies according to the amount of emissions from invoices could be added. This could be a benchmark that is implemented to visualise the potential impact of emissions by representing a tree rather than showing the quantity of the emissions. Furthermore, personalization features could be added to the API part of the platform. Such as, user could add industry averages or goals for their emissions. This would allow the API to provide more relevant information to the user as the emissions from invoices can be compared to these benchmarks as well. This would be easier and more intuitive to understand than having a breakdown of the amount of gases emitted. This tree could also be made available for viewing by competitors and the general public in order for them to get an understanding of the effect on environmental sustainability that the user and their platform provides. This would also create an incentive for industry competitors to improve sustainability in order to out compete their peers, as well as having a positive effect on the public perception of a business.

Additionally, rather than have the user submit invoices manually. The API could be linked directly to the accounting software of an enterprise that automatically forwards invoices to the API, thus updating the emission presentation site in real time. This could partially solve the problem of that the data provided to the service is biased by eliminating the human factor. The bias occurs due to the reason that the data could entered by managers that might not be aware of the details of their invoices or they might want to make their emission presentation appear better.

Finally, it would be desirable to add more pages to the platform. A page which details the importance of environmental sustainability in the context of energy usage and waste. Perhaps another page that allows for users to rate how useful each solution provided was for their needs. Based on this feedback the decision tree could also improved.

Bibliography

[1] *Definition of sustainability noun from the Oxford Advanced Learner's Dictionary*. URL: https://www.oxfordlearnersdictionaries.com/definition/english/sustainability (visited on Mar. 20, 2022).

[2] Hannah Ritchie and Max Roser. "CO2 and Greenhouse Gas Emissions". In: *Our World in Data* (2020). https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions. (Visited on Feb. 28, 2022).

[3] Teresa Phillips and Larry West. *How to reduce energy waste in the manufacturing sector*. URL: https://www.processingmagazine.com/maintenance-safety/asset-management/article/21140469/how-to-reduce-energy-waste-in-the-manufacturing-sector (visited on Feb. 27, 2022).

[4] *Sources of Greenhouse Gas Emissions*. URL: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (visited on Feb. 27, 2022).

[5] *Circularise for Manufacturers*. URL: https://www.circularise.com/manufacturers (visited on Feb. 27, 2022).

[6] *EcoVadis - The World's Most Trusted Business Sustainability Ratings*. URL: https://ecovadis.com/ (visited on Feb. 27, 2022).

[7] *UN Sustainable Development Goals*. URL: https://sdgs.un.org/goals (visited on Feb. 27, 2022).

[8] *What is API: Definition, Types, Specifications, Documentation*. URL: https://www.altexsoft.com/blog/engineering/what-is-api-definition-types-specifications-documentation/ (visited on Feb. 25, 2022).

[9] *HVAC basics: What is HVAC and what does HVAC stand for?* URL: https://www.petro.com/resource-center/what-is-hvac.

[10] *Jira REST API/About*. URL: https://developer.atlassian.com/cloud/jira/platform/rest/v3/intro/ (visited on Feb. 14, 2022).

[11] European Environment Agency. *EMEP/EEA air pollutant emission inventory guidebook 2019 : technical guidance to prepare national emission inventories*. 2019. DOI: 10.2800/293657. URL: https://op.europa.eu/en/publication-detail/-/publication/ce310211-4bc5-11ea-8aa5-01aa75ed71a1/language-en (visited on Feb. 15, 2022).

[12] *7 Tips to Optimize the Performance of Your Manufacturing Plant*. URL: https://www.eammosca.com/blog/tips-to-optimize-the-performance-of-your-manufacturing-plant/ (visited on Feb. 17, 2022).

[13] Sanchi. *Top 6 environmental benefits of remote work*. URL: https://www.airmeet.com/hub/blog/environmental-benefits-of-remote-work (visited on Feb. 17, 2022).

[14] *Computers - buying guidance*. URL: https://www.energystar.gov/products/computers (visited on Feb. 17, 2022).

[15] *16 More Ways to Cut Energy Waste in the Data Center*. URL: https://www.energystar.gov/products/16_more_ways_cut_energy_waste_data_center (visited on Feb. 17, 2022).

[16] *MyAir – Smart exhaust ventilation for apartment buildings*. URL: https://climeconair.com/fi-en/myair-smart-ventilation/ (visited on Feb. 17, 2022).

[17] *7 Ways Your Office Space Can Improve Productivity*. URL: https://myturnstone.com/blog/7-ways-office-space-can-improve-productivity/ (visited on Feb. 17, 2022).

[18] *Strategies to Save Energy in Commercial Buildings*. URL: https://www.bartingalemechanical.com/strategies-to-save-energy-in-commercial-buildings/ (visited on Feb. 17, 2022).

[19] *10 ways smart offices are saving energy and lowering their carbon footprint*. URL: https://www.zdnet.com/article/10-ways-smart-offices-are-saving-energy-and-lowering-their-carbon-footprint/ (visited on Feb. 17, 2022).

[20] Rajesh Sigdel. *Using Infographics to Make Climate Change More Visible to the Public*. URL: https://nightingaledvs.com/using-infographics-to-make-climate-change-more-visible-to-the-public/ (visited on Feb. 27, 2022).

[21] *Goal 13 of UN SDGs - Take urgent action to combat climate change and its impacts*. URL: https://sdgs.un.org/goals/goal13 (visited on Feb. 27, 2022).

[22] Lorenz M. Hilty and Bernard Aebischer. *ICT for Sustainability: An Emerging Research Field*. URL: https://www.tiny.uzh.ch/142 (visited on Feb. 27, 2022).