Adaptation of emission factors for the Tunisian carbon footprint tool

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Abstract

In Tunisia, the National Agency for the Environment is encouraging the creation of a carbon footprint method specifically adapted to the Tunisian context. In cooperation with the French National Agency for the Environment, the adaptation of the French carbon footprint method is realised and has to go along with an adaptation of the emission factors. In this framework, this master thesis aims at presenting the emission factors adaptation process led to adapt the accounting tool.

First, a literature review enables to present the main notions useful to understand the precise definition of emission factor. Then, a preliminary study of the main carbon footprint tools is presented so as to identify the main characteristics of a carbon footprint method. A comparison is then done to present the differences which can occur between the previous methods.

Finally, for each category of emission factor, the adaptation process is presented showing three different ways to adapt emission factors: a replacing of the data in the calculations, an adaptation based on local studies and a more difficult adaptation requiring to develop a new method.
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Introduction

In 1894, the Swedish geologist Arvid Högbom listed the different ways in which CO$_2$ is produced or consumed and finally presented the really first account of the global carbon cycle with an estimation of the contribution from combustion of fossil fuels induced by humans (Crawford, 1997) (Rodhe, Charlson, & Crawford, 1997) (Högbom, 1894). In 1896, the Swedish chemist Svante Arrhenius completed the previous theory by assuming that the combustion of fossil fuels could cause a long-term and global warming of the climate (Arrhenius, 1896) (Lichtfouse, 2009).

On June 1992, by joining the United Nation Framework Convention on Climate Change, countries recognized the impact of GHG emissions on climate change and admitted that they should ensure a stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system (United Nations, United Nations Framework Convention On Climate Change, 1992). This treaty was the really first step towards a global awareness of the impact of the carbon society.

Today, the consequences of climate change are really clear and countries are taking action against climate change: GHG emissions are one of the main environmental issues that are currently challenging society.

Calculating and reducing GHG emissions has become a priority in countries’ strategies. Firms, organizations and communities are now strongly encouraged to quantify and reduce their emissions whether it is to reduce the costs, to preserve the environment or to have a better image (Rahman, O’Brien, Ahamed, Zhang, & Liu, 2011). Tools for measuring and analyzing carbon footprints are, in consequence, going to play a crucial role: they will enable a better awareness about the subject and they will help decision-makers to make strategic choices. Indeed, before people can set up any kind of action to reduce their emissions, it is actually essential to be able to identify the main sources of GHG emissions, so that people can aim at the most urgent opportunity for action.

The French National Agency for Environment and Sustainable Development, ADEME developed in 2004 a carbon footprint method, the Bilan Carbone, so as to enable the quantification of GHG emissions of firms and communities (Association Bilan Carbone, 2013).

In partnership with ADEME, the Tunisian government launched in 2012 the adaptation of a carbon footprint tool to propose to its firms a tool that could fit with Tunisian characteristics. I Care Environment has been chosen to conduct this adaptation.
1 Master Thesis background

1.1 The company

*I Care Environnement* is a consulting company, working on projects related to sustainable development. The company is mainly specialized in energy, carbon management and biodiversity. Others areas are also covered by *I Care Environnement* such as climate change vulnerability, smart grids or eco-cities.

The missions developed in *I Care Environnement* are:

- Ecological footprints: *I Care Environnement* realizes carbon footprints, life cycle analysis and develops environmental comparison tools...
- Impact reductions: *I Care Environnement* develops action plans (to reduce GHG emissions for instance) and management tools to evaluate environmental efficiency
- Strategy: *I Care Environnement* works on environmental/energy strategy and risk management.

1.2 The French tool “Bilan Carbone”

Since the Industrial Revolution at the beginning of the 19th century, the concentrations of most of the GHG gases have increased and, more recently, CO₂ concentration is increasing at a higher rate. To reduce our impact on the environment, it is necessary to measure and analyze carbon footprints so as to take actions to reduce GHG emissions.

In light of those observations, the French National Agency for Environment and Sustainable Development ADEME developed in 2004 a tool to calculate the carbon footprint, the Bilan Carbone. In France, this tool is the most widely-used for the quantification and reduction of GHG emissions. It was firstly made for companies and has then been extended to communities. The number of Bilan Carbone undertaken since 2004 is shown in Table 1 (Association Bilan Carbone, 2013).

<table>
<thead>
<tr>
<th>Year</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies</td>
<td>78</td>
<td>160</td>
<td>160</td>
<td>199</td>
<td>1000</td>
<td>1600</td>
<td>1690</td>
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<tr>
<td>Local authorities</td>
<td>41</td>
<td>171</td>
<td>371</td>
<td>631</td>
<td>631</td>
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<td>Governmental organizations</td>
<td>60</td>
<td>145</td>
<td>205</td>
<td>205</td>
<td></td>
<td></td>
<td></td>
<td>205</td>
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<tr>
<td>Total</td>
<td>78</td>
<td>160</td>
<td>160</td>
<td>240</td>
<td>1231</td>
<td>2116</td>
<td>2526</td>
<td>2526</td>
</tr>
</tbody>
</table>

It consists of an accounting method and different tools and has mainly 6 steps:

- Make people sensitive to greenhouse effect and climate change
- Define precisely the scope of study i.e. emissions that will be included in the study and those which will not
- Gather data by diffusing surveys or contacting specialized people
- Calculate and analyze the carbon footprints
- Establish actions plans to reduce emissions
- Implement the mitigation plans

The Bilan Carbone method intends to evaluate emissions caused by the whole physical processes that are necessary for an activity to occur or an organisation to operate. More precisely, the Bilan Carbone includes both the emissions that take place directly within the activity or the entity and the emissions that take place externally from the entity but which are counterparts of processes occurring.

The Bilan Carbone aims at being clear, flexible and easy to use. Moreover, this tool only gives approximations of GHG emissions and users have to keep in mind that the prioritization of emissions by size is the essential goal of the Bilan Carbone.

Nowadays, three different organisations are involved in the Bilan Carbone method:

- The ABC, Association Bilan Carbone, is the association which owns the Bilan Carbone tool and has to manage all its evolutions
- The IFC, Institut de Formation Carbone, is a training center which carries out the training of users of the Bilan Carbone tool
- The ADEME manages the emission factors evolution by creating new emission factors or modifying existing ones. Thus, all the emission factors are gathered in a national database called Base Carbone.

1.3 Need of a tool specialized for Tunisia

In Tunisia, the National Agency for the Energy, the ANME, is in charge of the coordination and the undertaking of operations with the aim of managing energy. In this framework, it also has to manage the measures concerning reductions of GHG emissions in the energy sectors by implementing different strategies in energy management.

At the same time and in the framework of its activities for climate change mitigations, the ANME is encouraging the creation of a carbon footprint method specifically adapted to the Tunisian context. Indeed, a carbon footprint method is a useful tool to implement environmental policies (such as taxes or regulations) or to help firms to limit their footprints (by identifying the potential of emission reductions, implementing actions...).

In cooperation with the ADEME, a call for tenders has been published for the adaptation of the French carbon footprint method, which has to go along with an adaptation of the emission factors for the Tunisian features to be reflected in this method. I Care Environnement has been chosen to conduct this study.
1.4 General objectives of the work

The overall project that this thesis is a part of consists of adapting a carbon footprint tool to propose a specific tool that could fit with Tunisian characteristics.

Different steps are involved in this adaptation project:

- First, the emission factors have to be adapted so that the data match with the Tunisian data
- Then, a tool enabling to calculate the carbon footprint has to be developed
- Finally, a training is organized in Tunisia by I Care Environnement so that the future users of the carbon footprint tool can learn how to use it. The carbon footprint of the Tunisian agency for Environment is also calculated by I Care Environnement: this aims at illustrating the way of using the carbon footprint tool.

This thesis focuses on the emission factors adaptation step of the project.

The emission factors adaptation part is split up in 3 main steps:

- Firstly, an insight into the Tunisian conditions needs to be gained in order to determine in what setting the Tunisian carbon footprint tool can be used. Indeed, even though the Tunisian tool must be really similar to the French one, some differences can appear due to differences of context.
- Secondly, it is necessary to study the French carbon footprint tool to understand the way the emission factors have been calculated for the French tool. Then, the points which need to be adapted to fit the Tunisian characteristics are identified, based on the insight from the previous point. In some cases, the French calculations simply need to be adapted whereas in other cases it is necessary to change the whole way to calculate emission factors (when some specific data is not available, for example).

The French methodology splits the emissions factors in 7 different groups. This division is respected during the adaptation of emission factors:
- Energy
- Transportation of people
- Transportation of goods
- Materials
- Agriculture
- Waste
- Capital assets
- Thirdly, it is necessary to gather Tunisian data to adapt the emission factors. For this step, different agencies need to be contacted in particular the ANME, the Tunisian National Waste Management Agency (ANGeD) and the Tunisian Company of Electricity and Gas (STEG). This is crucial to gathering all relevant data needed for the adaptation.
• The final part consists in the utilization of the data collected and the calculations of the Tunisian emission factors.

1.5 Objectives of the thesis

The first objective of this master thesis is to present the way emission factors have been calculated in the French Base Carbone. Indeed, in some cases, data to calculate emission factors can be impossible to obtain. It is then necessary to find other means to calculate these factors. This work is really important since it shows the possibility to modify emission factors to be adapted to another context. Indeed, developing countries have a need to limit their GHG emissions and local studies concerning these emissions can be really limited. This adaptation process can thus be useful to public or private organisations which intend to implement a carbon accounting method on a territory. The second objective is to define some basic concepts involved in a carbon accounting methodology.

1.6 Methodology

So as to fulfil the first objective of the master thesis, the process implemented to adapt French emission factors to Tunisian context is described and analysed.

A comparison of different guidance, developed by several organisations is also presented so as to highlight the main characteristics that an accounting method has to follow and the main differences which can exist between two carbon accounting methods.
2 Literature review

2.1 Definition of “Carbon footprint”

The term carbon footprint is derived from the concept of ecological footprint, which refers to the land or sea area required to nourish and sustain a human population (Wackernagel & Rees, 1996) (Stöglehner, 2003). According to this definition, carbon footprint would refer to the land and sea area required to assimilate the CO\(_2\) produced by an activity. However, the definitions of carbon footprint can differ and giving a precise definition of this concept can be a tough task. Based on their survey within the available literature and scientific studies, Wiedmann and Minx (Wiedmann & Minx, 2007) has defined the carbon footprint as a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. To track all the indirect emissions provoked by an activity, it is necessary to use a life cycle thinking approach: this approach enables to take the complete picture of the activity system (Wiedmann & Minx, 2007) (Finkbeiner, 2009) (Weidema, Thrane, Christensen, Schmidt, & Løkke, 2008) (Matthews, Hendrickson, & Weber, 2008).

Although a definition can be expressed, it is clear that there is a lack of uniformity over the selection of emissions to take into account for emission calculations and no consensus has been found on how to measure or quantify carbon emissions. A first problem is the selection of direct CO\(_2\) emissions or full life-cycle CO\(_2\) emissions, which are both direct and embodied emissions. Indeed, different boundaries can be chosen when doing the carbon footprint calculations. The company can be considered to be responsible for the fraction of the emissions for which it has a responsibility in case of partnership with other companies or can be considered to be responsible only for the direct emissions which are under its control (Pandey, Agrawal, & Pandey, 2011) (Kenny & Gray, 2009) (Schulz, 2010). To help to mark out direct and indirect emission sources, three scopes or tiers have been defined for GHG accounting (WRI/WBCSD, The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard - Revised Edition, 2004) (Entreprises Pour l’Environnement, 2011) (Huang, Eng, & Ng, 2012):

- **Scope 1**: This scope includes all direct GHG emissions. More precisely, all the emissions from sources owned or controlled by the company such as emissions from combustion in owned or controlled vehicles or boilers and furnaces.

- **Scope 2**: It accounts for GHG emissions produced by the generation of electricity purchased and consumed by the company. Scope 2 emissions physically occur outside from the organizational boundary of the company, at the facility where electricity is generated.

- **Scope 3**: Scope 3 covers all other indirect emissions. These emissions are a consequence of the activities of the company but are provoked by sources not owned or controlled. For example, the emissions occurring from extraction and production of purchased materials or transportation of purchased fuels are included in Scope 3.
Another question concerning carbon footprint calculations is whether we should only consider carbon dioxide emissions or other GHG emissions (BP, 2007). The Kyoto Protocol indentified 6 main greenhouse gases which are carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and sulphur hexafluoride (SF$_6$) (United Nations, 1998). As a result, most of the carbon footprint methodologies include these 6 gases. Some others also include water vapour and chlorofluorocarbons (CFC) (ADEME, 2010).

Finally, the unit of measurement can be different depending on the different carbon footprint guidance: the carbon emissions can be expressed in carbon equivalent mass or in CO$_2$ equivalent mass. To convert from units of carbon to units of CO$_2$, we must simply multiply by 44/12, which is the molecular weight ratio of CO$_2$ to carbon (The Climate Registry, 2013). Although the conversion between units of carbon and of CO$_2$ is easy and can be quickly realised, it is more convenient for comparisons to express results with the same units. Thus, the CO$_2$ equivalent (CO$_2$e) mass is now considered as the reporting unit of carbon footprint. This equivalent is based on the 100 years global warming potentials (GWP) which are used to convert masses of different greenhouse gases into a single carbon dioxide-equivalent unit. Thus, multiplying a mass of a greenhouse gas by its 100 years-GWP gives the mass of carbon dioxide emissions that would produce the same warming effect over a 100 year period. Different values of GWP exist but it is generally advised to use GWP values provided by the Intergovernmental Panel on Climate Change (IPCC).
Table 2 - GWP values for some greenhouse gases (IPCC)

<table>
<thead>
<tr>
<th>Greenhouse gases</th>
<th>Global Warming Potential – 100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>25</td>
</tr>
<tr>
<td>N₂O</td>
<td>298</td>
</tr>
<tr>
<td>HFC-23</td>
<td>14 800</td>
</tr>
<tr>
<td>Sulphur hexafluoride</td>
<td>22 800</td>
</tr>
</tbody>
</table>

### 2.2 Importance of carbon footprinting

Carbon footprinting provides a quantitative expression of GHG emissions: it is essential for a company which intends to determine the origins of its GHG emissions, to define priorities in its emissions reductions and to enable the monitoring and the evaluation of mitigation measures. It can also be a way to inform stakeholders, whether intern or extern from the company, and to communicate with its clients and suppliers.


- Competitiveness: reducing costs and emissions bound to daily activities (energy savings, office supplies limitation...) in the firm and by convincing the suppliers to act identically can be profitable in most cases.
- Market/Product development: the integration or even the anticipation of customers’ expectations in terms of GES emission impacts and consumption can enable innovation.
- Corporate image: to valorise a brand through sustainability commitments is a way to create strong competitive advantages. It can help to meet customer requests for information on the company GHG gas emissions. This is becoming an increasingly important element of the procurement process. Indeed, according to the survey conducted by L.E.K. Consulting LLP (L.E.K. Consulting LLP, 2007), products which presented the information concerning their carbon footprint were preferred by 44% of customers. Moreover, 43% customers were ready to pay more for products with low carbon footprint.
- Respect of regulations: it is important to anticipate new rules and standards. Indeed, enduring new laws unexpected by a company can represent a big risk for it.
- Reporting: report the footprint to a third party can be a way to guarantee sustainable responsible investments for example (Schaltegger & Csutora, 2012).
2.3 Concept of emission factors

In most of cases, it is impossible to measure directly GHG emissions provoked by an activity of an organization. Indeed, even though measuring the GHG concentration in the air is now a standard use, it is exceptional that we can directly measure the GHG emissions from an activity (Asciu & Lovell, 2011).

The only way to assess these emissions is to calculate them from activity data, defined as data on the magnitude of human activity resulting in emissions. These data can be the number of trucks and the distance travelled or the amount of steel bought by a company. All the official inventories including the National GHG inventories produced under the Kyoto Protocol Accounting Framework are established in this way, which enables to convert quickly data activities to GHG emissions (ADEME, 2010). The figures enabling to convert concrete data into GHG emissions, expressed as CO₂ equivalent, are called emission factors.

In some cases, the emission factor calculations are based on estimations and methods to calculate them can differ, leading to discrepancies between the values (Hiete, Berner, & Richter, 2001).

Since the whole approach of carbon footprint methods is based on emission factors, these methods are only a way to get rough estimates and will enable to define the items of the company of which the emissions dominate. The hierarchical sorting of the emissions of the company will be a way to define mitigation measures and reduce the total emissions: therefore, the precise quantity of GHG emitted is not necessary and decision makers have to be aware of the uncertainties surrounding carbon footprint methods (Plassman, Norton, Attarzadeh, Jens, Brenton, & Edwards-Jones, 2010).

2.4 Comparison of different carbon footprint methodologies

An analysis of the following corporate carbon footprint methodologies is carried out in this report. The following carbon footprint guidance are described and compared:

- Corporate Accounting and Reporting Standards Greenhouse Gas Protocol from WRI/ WBCSD
- Bilan Carbon
- DEFRA – Carbon Disclosure Project
- ISO 14064

2.4.1 Description of the analyzed methods

and sector-specific (designed to calculate emissions in specific sectors such as aluminium, cement or oil and gas) calculation tools are provided with the guidance and a chapter on setting GHG targets has been added to help companies to define mitigation measures. The guidance indicated that companies should account for and report on scopes 1 and 2 at a minimum and that scope 3 is optional. It also recommends choosing a base year and explains how to recalculate base year emissions.

In October of 2011, the Corporate Value Chain (scope 3) was published as a supplement to the GHG Protocol Corporate Accounting and Reporting Standard (WRI/WB, The Greenhouse Gas Protocol: Corporate Value Chain (Scope 3) Accounting and Reporting Standard, 2011). It includes requirements and guidelines on calculation and reporting of scope 3 emissions of a company. It is based on a life cycle approach.

- **Bilan Carbone:** The Bilan Carbone is a GHG accounting guide and tool produced in France by the ADEME for organizations (ADEME, 2010). It is compatible with the GHG Protocol and the International Organization Standard ISO 14064. All greenhouse gases are considered: the six greenhouse gases covered by the Kyoto Protocol, chlorofluorocarbons and water vapor. The guidance clearly indicates that carbon sinks, carbon compensation and carbon sequestration are excluded from the calculations. Calculation tools which include emission factors and indicate outputs relevant to reporting are provided. The incertitude calculations are indicated in the tool for each component. The guidance finally provides features to manage the reduction objectives that the company intends to respect.

- **DEFRA:** The UK’s GHG accounting guide is aimed at helping all organizations to report their GHG emissions by presenting general principles for how to measure and report GHG emissions (DEFRA, Guidance on how to measure and report your greenhouse gas emissions, 2009). It is mainly based on the GHG Protocol and aligns with the norm ISO 14064-1. The minimum recommendations of the guidance are to measure and calculate scopes 1 and 2 emissions from the six greenhouse gases covered by the Kyoto Protocol in terms of CO$_2$e. The calculation of the significant scope 3 emissions in addition to the scopes 1 and 2 is optional but encouraged. The guidance also provides annually updated excel spreadsheets with emissions factors and a calculation tool which converts the data collected into GHG emissions. The guidance finally provides recommendations on how to report the company emissions and the emissions reduction but also to set reduction targets and recalculate the company base year.

- **ISO 14064:** the International Organisation for Standardisation has decided to provide a set of specifications and requirements to help organisations and companies to conduct GHG emissions mitigation projects. The creation of the norms ISO 14064 is derived from the observation that different approaches were used by governments and companies but no validation protocol was globally accepted (Weng & Boehmer, 2006). The ISO 14064 norm contains 3 different parts (European Commission – Joint Research Center, 2011). The first part indicates specifications and instructions which have to be followed to quantify and report GHG emissions and to remove these emissions at the organisation level. The second part specifies principles and instructions at the project level. The third part provides guidance for the verification of GHG assertions, which can have been quantified in accordance with ISO 14064-1 and ISO 14064-2.
2.4.2 Comparison of the carbon accounting methods

Only the first three carbon accounting tools presented previously are free. For this reason, the comparison is more accurate for them. As no access to ISO 14064 is possible without paying the license, only few points of comparison are detailed for this accounting method.

The following points have been compared:

- Provider of the method
- Licensing (free access, paying license)
- Language
- Year of release
- Geographic area the method can be used
- Original data sources
- Type of emission results (discriminated by GHG, by scopes...)
- Main topics handled (energy, transportation...)
- Uncertainties calculations: this point indicates if the method enables the calculation of uncertainties depending on the conditions selected during the accounting process
- Standard compliance (at least the GHG Protocol)
- Governance: this part shows the processes by which the accounting methods and the emissions factors are selected and monitored

The comparison results are shown in Table 3.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provider</strong></td>
<td>Agence de l’Environnement et de la Maîtrise de l’Energie (ADEME)</td>
<td>World Resources Institute/World Business Council for Sustainable Development (WRI/WBCSD)</td>
<td>Produced by AEA for DECC and Defra</td>
<td>Produced by International Organisation for Standardisation</td>
</tr>
<tr>
<td><strong>Licensing</strong></td>
<td>- Access to emissions factors is public</td>
<td>Free with registration</td>
<td>Free</td>
<td>Paying</td>
</tr>
<tr>
<td><strong>Languages</strong></td>
<td>French, English</td>
<td>English</td>
<td>English</td>
<td>English</td>
</tr>
<tr>
<td><strong>Year of release</strong></td>
<td>2004</td>
<td>2001</td>
<td>2006</td>
<td>2006</td>
</tr>
<tr>
<td><strong>Geography</strong></td>
<td>France, Europe</td>
<td>Global</td>
<td>UK, Global</td>
<td>Global</td>
</tr>
<tr>
<td><strong>Original data sources</strong></td>
<td>The Bilan Carbone Method was developed for ADEME by Jean-Marc Jancovici, from the Manicore Consulting Firm. Both individual industry experts and bibliographical sources (IEA, IPCC...) have been used for the development of the emissions factors.</td>
<td>Data from IPCC, US EPA, Defra/DECC and IEA</td>
<td>Data from original research, industry statistics, government publications and other LCA databases</td>
<td></td>
</tr>
<tr>
<td><strong>Emissions results</strong></td>
<td>GWP, separate GHGs for some data points</td>
<td>GWP, separate GHGs</td>
<td>Total CO₂e, Separate GHGs, Separate scopes, Direct and Indirect emissions</td>
<td></td>
</tr>
<tr>
<td><strong>Main topics</strong></td>
<td>Energy Carriers and Technologies; Transport Services; Materials Production; Systems; End-of-Life Treatment; Wastes</td>
<td>Energy carriers and technologies; Transport services</td>
<td>Electricity; Crude oil based fuels; Natural gas based fuels; Road; Rail; Air; End-of-life treatment; Water; Materials production; Other Services</td>
<td></td>
</tr>
<tr>
<td>Name of source</td>
<td>Bilan Carbone</td>
<td>Greenhouse Gas Protocol</td>
<td>2012 Guidelines to Defra-DECC’s GHG Conversion Factors for Company Reporting</td>
<td>ISO 14064</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Uncertainty calculations</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Standards compliance</td>
<td>ISO 14064; GHG Protocol; European directive No.2003/87/CE</td>
<td>GHG Protocol</td>
<td>ISO 14064; GHG Protocol; Possible to use in product footprints</td>
<td>ISO 14064</td>
</tr>
</tbody>
</table>
| Gouvernancy           | - The Bilan Carbone, firstly developped by the ADEME, has been taken over by the organism Association Bilan Carbone. The Association Bilan Carbone is now responsible for the evolution of the tool and the methodology forming the carbon accounting method. It is also in charge of the trainings of future users of the Bilan Carbone (carried out by the training center IFC) and the promotion of the methodology in Europe and in the whole world.  
 - The management of the emission factors used in the Bilan Carbone is realised by the ADEME and are indexed in a basis called Base Carbone. | - The Greenhouse Gas Protocol (GHG Protocol) is a multi-stakeholder partnership of businesses, governments, non-governmental organizations (NGOs), and others convened by WRI and the WBCSD.  
 - In case it is not possible to develop custom values, default values are always provided for the emission factors. The default values are averages based on the most extensive data available: they are mainly identical to those indicated by the Intergovernmental Panel on Climate Change (IPCC). However, the GHG Protocol recommends using custom values whenever possible: indeed, the industrial processes or the composition of fuels used by businesses can be different with time and region. | - The guidance is based on the GHG Protocol standard for the corporate accounting and reporting of GHG emissions.  
 - All the emission factors are updated reflecting some recent analysis published by international organisation, European Commission... | ISO 14064 |
3 Tunisian context

In this part, the very general information concerning Tunisia are presented and then the data useful in this master thesis is presented with more details.

3.1 General

Tunisia is a Northern Africa country bordered by Libya, Algeria and the Mediterranean Sea. Its surface area is around 164 000 square kilometres and its estimated population is around 10 836 000 in 2013 (US Central Intelligence Agency, 2013).

The official language is Arabic but French and Berber are also spoken.

In 2011, a revolution resulted in the overthrow of the president Zine El Abidine Ben Ali and elections for the new Constituent Assembly were held. Presidential and parliamentary elections have been proposed to be held in 2013 by the interim government.

3.2 Economy

The Tunisian GDP is estimated in 2012 to $ 107,1 billion. The growth rate is around 3.6 % in 2012 after having been negative in 2011 owing to the overthrow of Ben Ali which provoked a decrease of tourism and investments in Tunisia.

The main industries of Tunisia are petroleum, mining (in particular phosphate and iron ore), tourism and textiles.

The monetary value of exports is estimated to $ 17,02 billion in 2012 and the main exportation products are clothing, agricultural products (olives, olive oil, tomatoes, grain...), semi-finished goods, mechanical goods, phosphate and chemicals and hydrocarbons. The main exportation partners are France, Italy, Germany, Libya and USA in 2012, as shown in Figure 2.
The monetary value of imports is estimated to $23.32 billion in 2012 and the main importation products are textiles, machinery and equipment, hydrocarbons, chemical and foodstuffs. The main importation partners are France, Italy, Germany, China and Spain in 2012, as shown in Figure 3.

Figure 3 - Importation partners of Tunisia
3.3 Energy

3.3.1 Energy market
The Tunisian primary energy supply has increased constantly in the last 4 decades. It was around 1910 ktoe in 1971 and was around 9200 in 2009. The primary energy supply share for 2009 is shown in Table 4 (International Energy Agency, 2013).

Table 4 - Total primary energy supply in Tunisia in 2010

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Total Primary Energy Supply (in ktoe)</th>
<th>Total Primary Energy Supply (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil</td>
<td>421</td>
<td>4%</td>
</tr>
<tr>
<td>Oil products</td>
<td>3463</td>
<td>36%</td>
</tr>
<tr>
<td>Natural gas</td>
<td>4378</td>
<td>45%</td>
</tr>
<tr>
<td>Coal and peat</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Hydro</td>
<td>4</td>
<td>0,04%</td>
</tr>
<tr>
<td>Geothermal, solar...</td>
<td>12</td>
<td>0,12%</td>
</tr>
<tr>
<td>Biofuels and waste</td>
<td>1348</td>
<td>14%</td>
</tr>
<tr>
<td>Electricity</td>
<td>2</td>
<td>0,02%</td>
</tr>
<tr>
<td>Total</td>
<td>9628</td>
<td>100%</td>
</tr>
</tbody>
</table>

The share of coal and peat has always been reduced and now reaches zero. Moreover, the share of oil has always been important but has not increased in a significant way in the last decades. For each type of petroleum products, a part of the Tunisian consumption is produced in Tunisia and the other part is produced in foreign countries and then imported in Tunisia to be consumed: the petroleum production, consumption and import/export balance is presented in Table 5 (U.S. Energy Information Administration, 2013).

Table 5 - Production, consumption and import/export of fossil fuels in Tunisia in 2012

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Petroleum (Thousand barrels per day)</th>
<th>Natural gas (Billion cubic meters)</th>
<th>Coal (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total production</td>
<td>68,31</td>
<td>1,93</td>
<td>0,00</td>
</tr>
<tr>
<td>Consumption</td>
<td>89,28</td>
<td>3,71</td>
<td>0,00</td>
</tr>
<tr>
<td>Net Exports</td>
<td>-20,97</td>
<td>-1,78</td>
<td>0,00</td>
</tr>
</tbody>
</table>

During the last decades, Tunisia has increasingly turned to natural gas to meet its domestic energy demand.
The majority of Tunisia's natural gas production comes from Miskar field. This field supplies more than 50 percent of Tunisia's total natural gas demand. Tunisia has four other producing natural gas fields (El Franig, El Borma, Baguel, and Zinnia) which account for most of the remaining domestic natural gas production. Finally, the Trans-Mediterranean (TransMed) pipeline transports Algerian natural gas to Sicily, crossing the Mediterranean and Tunisia. Thus, Tunisia receives royalties (in cash or in kind) from the pipeline as payment for access through its territory. The gas production, consumption and import/export balance is presented in Table 5.

### 3.3.2 Electricity

In Tunisia, the STEG is the unique provider of electricity: all the clients connected to the national grid consume the same electricity. This electricity mixes all the productions of electricity occurring on the territory but also the electricity provided by other countries when the national production is not sufficient to meet the demand.

In 2011 the transmission grid sum up to a total of 5,953 km divided into three different voltages: 90 kV lines, 150 kV lines and 225 kV lines (STEG, 2011).

The transmission lines are connected to the European grid via the grids in Algeria and Morocco. The Tunisian grid is also directly linked with Libya.

The electrical mix of Tunisia is largely dominated by natural gas: more than 98% of the electricity is produced by gas plant and about 1.3% is produced by renewable energy sources (wind plant and hydroelectricity). The electrical mix is presented in Table 6.

**Table 6 - Electric mix in Tunisia**

<table>
<thead>
<tr>
<th>Type of power plant</th>
<th>Energy produced (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal power plant</td>
<td>5,544</td>
</tr>
<tr>
<td>Combined-cycle gas turbine</td>
<td>4,344</td>
</tr>
<tr>
<td>Gas turbine</td>
<td>1,851</td>
</tr>
<tr>
<td>Hydropower</td>
<td>54</td>
</tr>
<tr>
<td>Wind power</td>
<td>109</td>
</tr>
<tr>
<td>Independant producers</td>
<td>3,317</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>15,219</strong></td>
</tr>
</tbody>
</table>

According to the previous results, the main fuel consumed to produce electricity is gas, as shown in Table 7.
### Table 7 - Fuel consumption for electricity production in Tunisia

<table>
<thead>
<tr>
<th>Type of fuel</th>
<th>Fuel consumption (ktep)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>3 502</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3 505</strong></td>
</tr>
</tbody>
</table>

#### 3.4 Transportation

##### 3.4.1 Road

In 2006, Tunisia has 19,232 kilometres of roads separated into 12,655 kilometres of paved roads including 262 kilometres of motorway and 6,577 kilometres of unpaved roads.

Buses are operated by different regional firms.

Finally, a system of share taxis, called “louage”, is particularly developed in Tunisia. This mode of transport consists in minibuses which take passengers on a fixed or partially-fixed route without timetables: thus, the departure occurs as soon as all seats are filled and the louage can stop anywhere to pick up or drop off passengers.

##### 3.4.2 Rail

The railways are operated by the Société Nationale de Chemins de Fer Tunisiens (SNCFT), the Tunisian national railway. The national rail network covers 2,165 km in 2008 including 65 kilometres electrified (US Central Intelligence Agency, 2013).

**Suburban rail**

According to local specialists\(^1\), two suburban lines are operated in Tunisia:

- Line Sousse – Mahdia has a length of 51 kilometres and is electrified (FahrPlanCenter, 2013)
- Line Tunis – Southern suburbs has a length of 23 kilometres and has been recently electrified

**Metro rail**

The public transport operator in Tunis STT supervises the bus network, the metro and the light rail link to La Marsa called TGM.

In Tunis, there are 5 metro lines.

---

\(^1\) ALCOR and APEX (ALCOR is a R&D and consulting firm)
The light rail line TGM, whose name comes from the 3 main stops of the lines (Tunis, La Goulette and La Marsa), is a 19 kilometres-line and the stops are distributed as shown in Figure 4. This line is electrified (FahrPlanCenter, 2013).

Figure 4 - Map of the TGM line
4 Emission Factors Adaptation

The French tool splits the emissions factors in seven different groups. During the emission factors adaptation process, the choice done has been to respect this dividing:

- Energy
- Transportation of people
- Transportation of goods
- Materials
- Agriculture
- Waste
- Capital assets

In this chapter, the adaptation of emission factors will be treated, specifically for the parts Energy, Transportation of people, Transportation of goods and Materials, which are the main themes and needed the most important adaptations.

4.1 Energy

Energy utilisation provokes consequent GHG emissions. These emissions are due to:

- Carbon dioxide from fossil fuel combustion (oil, gas)
- Other gases emitted during the combustion process: that is mostly the case of ozone and NOx
- Methane leakages occurring during fuel extractions

Emission factors concerning energy correspond, for the greatest part, to CO2 emissions. In the Base Carbone, the only gases considered are the CO2, the N2O and the methane.

4.1.1 Fossil fuels

Fossil fuels are all the crude products and by-products derived from petroleum, gas and coal.

The emission factors calculated aim at converting data easily available in an audited company (such as tons of coal, kWh of gas, litres of oil...) to GHG emissions. They concern all the fossil energy usages: heating, furnace supplying or engine consumption. They can also be used to calculate other emission factors which are linked to fossil fuel emission factors: for instance, they will be very helpful to calculate emission factors concerning transportation.

For each fuel, two types of emission factors can be defined:

- The first one concerns the emissions provoked by the extraction, the production and the transport of the consumed fuel, called upstream emission factors or well-to-pump emission factors (Leister, 2012).
• The second one is reflecting the emissions provoked by fuel combustion, also called pump-to-wheel emission factors.

**Liquid fuels**

**Pump-to-wheel emissions**

Concerning liquid fuels, the French Base Carbone gives some emission factors which only consider the fuel combustion. These factors derive from different publications done by French and European organisations (the ADEME, the French Professional Petroleum Council, the European Commission...).

<table>
<thead>
<tr>
<th>Liquid fuel</th>
<th>Emission factor (kg of CO₂ equivalent per ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied petroleum gas, LPG</td>
<td>2944</td>
</tr>
<tr>
<td>Gasoline</td>
<td>3212</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>3150</td>
</tr>
<tr>
<td>Fuel oil domestic</td>
<td>3150</td>
</tr>
<tr>
<td>Heavy fuel</td>
<td>3120</td>
</tr>
<tr>
<td>Crude petroleum</td>
<td>3065</td>
</tr>
<tr>
<td>Jet fuel</td>
<td>3124</td>
</tr>
</tbody>
</table>

These values only take into account the combustion phase and don’t include the emissions occurring before the combustion, which are associated to the drawing, the transportation and the refining of the fuels.

The intrinsic content of liquid fuels can be different from a country to another depending on the type of crude petroleum used and the refinery where the by-products are produced. However, according to specialists of the carbon footprint calculations¹, an adaptation of the pump-to-well emission factor needs data that are not available in Tunisia while the difference between initial emission factors and adapted emission factors is very low and remains into the margin of error: the pump-to-well emission factors can be considered as similar and do not need to be adapted.

**Well-to-pump emissions**

The well-to-pump emissions of liquid fuels concern the petroleum drawing, the transportation, whether by boat or pipeline, and the refining which is the most emitting operation. In the Base Carbone, studies provided by different organisations² are used to calculate the well-to-pump emission factors of different fuels, as shown in Table 9.

---

¹ I CARE ENVIRONNEMENT

² IFP (French Institute for Petroleum), CEREN (French observatory for energy demand), DGEMP (French department for energy and raw materials)
Table 9 - Well-to-pump emission factors of different liquid fuels

<table>
<thead>
<tr>
<th>Liquid fuel</th>
<th>Emission factor (kg of CO₂ equivalent per ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied petroleum gas, LPG</td>
<td>550</td>
</tr>
<tr>
<td>Gasoline</td>
<td>542</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>333</td>
</tr>
<tr>
<td>Fuel oil domestic</td>
<td>333</td>
</tr>
<tr>
<td>Heavy fuel</td>
<td>425</td>
</tr>
<tr>
<td>Crude petroleum</td>
<td>220</td>
</tr>
<tr>
<td>Jet fuel</td>
<td>286</td>
</tr>
</tbody>
</table>

These emission factors are particularly dependant on the geographical context so they have to be adapted in order to reflect the Tunisian context.

For each type of liquid fuel, a part of the fuel consumed in Tunisia is produced in Tunisia and the other part is produced in foreign countries and then imported in Tunisia to be consumed. Firstly, concerning the proportion directly produced in Tunisia, calculating the precise well-to-pump emissions provoked by fuel production in Tunisia is not possible: thus, the well-to-pump emissions of fuels produced in Tunisia are considered to be the same as the well-to-pump emissions of fuels produced in France, with the endorsement of specialists of the carbon footprint calculations¹.

Then, concerning the proportion of liquid fuels produced in foreign countries, the refined products imported in Tunisia come mainly from refineries located in European countries (from France, Italy, Belgium and the Netherlands). Thus, the French emission factors concerning the production of liquid fuels are kept identical. Moreover, the emissions corresponding to the fuel transportation from the refineries to Tunisia have to be added to the proportion of liquid fuels produced in foreign countries. Thus, for each types of fuel, the calculation done to obtain the emission factor concerning the fuel production is presented in Formula (1).

\[
EF_{\text{fuel production}} = EF_{\text{fuel production Europe}} \times \%_{\text{fuel Tunisia}} + (EF_{\text{fuel production Europe}} + Emission_{\text{transportation}}) \times \%_{\text{fuel foreign countries}}
\]  

(1)

where \(EF_{\text{fuel production Europe}}\), \(\%_{\text{fuel Tunisia}}\), \(Emission_{\text{transportation}}\) and \(\%_{\text{fuel foreign countries}}\) are respectfully the well-to-pump emission factor indicated in the Base Carbone, the percentage of fuel produced in Tunisia, the emissions due to the transportation of fuels produced in foreign countries and the percentage of fuel produced in foreign countries.

As an example, the emission factors calculation for gasoline is presented. Gasoline imported in Tunisia comes from Italy, Greece, Spain, Bulgaria, Croatia and Malta with the proportions indicated in Table 10.

---

¹ I Care Environnement
Thus, from these data, we know that the imported volumes of gasoline is 509 000 tons and represent a total payload distance of 470 000 000 ton.kilometers by boat. By dividing this payload distance by the total volumes of gasoline imported, it is then easy to conclude that, for each ton of gasoline imported, the payload distance is 922,8 ton.kilometres for the boat transportation.

Finally, to calculate the emissions provoked by the importation of one ton of gasoline in Tunisia, the payload distance is multiplied by the emission factors concerning the two means of transport, as shown in Formula (2). In this case, giving the fact that there is no pipeline transportation, the term $Payload_{\text{pipeline}}$ is equal to 0.

$$Emission_{\text{transportation}} = Payload_{\text{pipeline}} \times EF_{\text{pipeline}} + Payload_{\text{boat}} \times EF_{\text{boat}}$$

(2)

where $Payload_{\text{pipeline}}$, $EF_{\text{pipeline}}$, $Payload_{\text{boat}}$ and $EF_{\text{boat}}$ are respectfully the payload distances and the emission factor of the pipeline transportation and the payload distances and the emission factor of the boat transportation.

Thus, the emissions provoked by the importation of one ton of gasoline in Tunisia are equal to 12,64 kg CO$_2$e, as shown in Table 11.

Finally, the import share of the consumption of petroleum products in Tunisia is provided by the national energy agency (named in French Observatoire National de l’Energie) for the year 2011, as shown in Table 12.
Table 12 - Percentage of imports for different petroleum products

<table>
<thead>
<tr>
<th>Petroleum product</th>
<th>Percentage of imports as a share of consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquefied petroleum gas</td>
<td>71%</td>
</tr>
<tr>
<td>Gasoline</td>
<td>98%</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>80%</td>
</tr>
<tr>
<td>Jet fuel</td>
<td>96%</td>
</tr>
<tr>
<td>Heavy fuel</td>
<td>80%</td>
</tr>
<tr>
<td>Crude petroleum</td>
<td>100%</td>
</tr>
</tbody>
</table>

So, giving the fact that Tunisia imports 98% of its gasoline consumption, we can apply the emissions provoked by the importation process on only 98% of the gasoline consumed, fuel, as shown in Formula (2). Then, the total GHG emissions provoked by the consumption of 1 ton of gasoline is 621,4 ton of CO$_2$e, as shown in Table 13.

Table 13 - Total GHG emissions provoked by the consumption of gasoline

<table>
<thead>
<tr>
<th>Emission factor for production of 1 ton of gasoline Well-to-wheel (kg CO$_2$e / ton)</th>
<th>Percentage of imports as a share of consumption</th>
<th>Emission provoked by transportation of 1 ton of gasoline (kg CO$_2$e / ton)</th>
<th>Emission factor for the consumption of 1 ton of gasoline in Tunisia (kg CO$_2$e / ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 754,0</td>
<td>98%</td>
<td>12,64</td>
<td>3 766,4</td>
</tr>
</tbody>
</table>

**Natural Gas**

We can notice that the context for natural gas is really different between Tunisia and France whose natural gas mainly comes from Norway, Russia, Algeria and Netherlands: a direct adaptation of the French emission factors does not seem to be the method providing the best results.

The calculations concerning natural gas have been done by a local specialist$^1$. The well-to-wheel emissions of natural gas are 2424 kg CO$_2$e / tep.

**Combustibles solid**

In Tunisia, there is currently no more consumption of coal and other by-products (anthracite, peat, brown coal) according to local specialists$^2$. As a result, we can consider that the emission factors given in the Base Carbone can be sufficient if we need these factors.

---

$^1$ APEX

$^2$ ALCOR and APEX
4.1.2 Biofuel

With the endorsement of local specialists, no adaptation is done concerning emission factors concerning biofuels. If some emission factors are necessary, they can be taken in the Base Carbon and used directly. In case biofuel consumption will develop in Tunisia in the next decades, an adaptation of the French emission factors could be possible by using studies made about biofuel emissions in Tunisia.

4.1.3 Electricity

As seen in chapter 3, the STEG is the unique provider of electricity in Tunisia. This electricity mixes all the productions of electricity occurring on the territory but also the electricity provided by other countries when the national production is not sufficient to meet the demand.

In compliance with the Base Carbone, the electricity produced in Tunisia is only included for the calculation of the emission factors of electricity and the electricity coming from other countries is not included: the main reason is that the precise origins of the electricity consumed are particularly difficult to determine. Thus, the emission factor for 1 kWh of electricity on the Tunisian network corresponds to the sum of the emissions provoked by the Tunisian plants used to feed the network over the sum of the energy produced by these plants.

The electrical mix of Tunisia is largely dominated by natural gas: more than 98% of the electricity is produced by gas plant and about 1.3% is produced by renewable energy sources (wind plant and hydroelectricity).

Thanks to the figures provided by the STEG (gas and diesel fuel consumptions, energy produced by each plant and energy produced by hydroelectric plants and wind plants), the total amount of GHG emissions provoked by electricity production coming from fossil fuel combustion can be calculated.

The Base Carbone also gives emission factors for the electricity produced by hydroelectric plants and by wind turbines. The technology of wind turbines and hydroelectric plants is quite similar between France and Tunisia. Moreover, the quantity of energy produced by these two types of plants is not significant in comparison with the quantity produced by gas plants: thus, the adaptation of the emission factors for these two kinds of plants seems difficult to process in comparison with the importance of the emissions provoked by them. With the endorsement of carbon footprint calculations specialists, the emission factors of these two kinds of plants are considered as similar between France and Tunisia: the values proposed in the Base Carbone can be kept identical.

Finally, the emission factor for the consumption of 1 kWh of electricity is calculated by defining the average consumption of fossil fuels (natural gas and diesel fuel) used to produce one kWh of electricity and the average amount of energy produced by hydropower and wind power in one average kWh of Tunisian electricity. Thus, the emission factor for the consumption of 1 kWh of electricity is calculated thanks to Formula (3).

---

1 ALCOR and APEX

2 I CARE ENVIRONNEMENT
\[ EF_{electricity} = Consumption_{gas} \times EF_{gas} + Consumption_{diesel\ fuel} \times EF_{diesel\ fuel} + Production_{wind\ power} \times EF_{wind\ power} + Production_{hydropower} \times EF_{hydropower} \]  

(3)

Where \( Consumption_{gas} \) and \( Consumption_{diesel\ fuel} \) are respectfully the average consumption of natural gas and diesel fuel for the production of 1 kWh; \( Production_{wind\ power} \), and \( Production_{hydropower} \) are respectfully the average amount of energy produced by wind power and hydropower for the production of 1 kWh and \( EF_{gas}, EF_{diesel\ fuel}, EF_{wind\ power} \) and \( EF_{hydropower} \) are respectfully the emission factor of natural gas, diesel fuel, wind power and hydropower. The final emission factor is 0,56 kg CO2e / kWh, as presented in Table 14.

<table>
<thead>
<tr>
<th>Type of power plant</th>
<th>Fuel consumption</th>
<th>Total electricity production</th>
<th>Energy amount for 1 average kWh</th>
<th>Emission factor</th>
<th>Total emissions for the production of 1 kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>3 501 tep</td>
<td>9 513 GWh</td>
<td>2,3E-04 tep</td>
<td>2 424 kg CO2e / tep</td>
<td>5,6E-01 kg CO2e</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>2 893 tep</td>
<td>5 544 GWh</td>
<td>1,9E-07 tep</td>
<td>3 483 kg CO2e / tep</td>
<td>7,3E-04 kg CO2e</td>
</tr>
<tr>
<td>Hydropower</td>
<td>54 GWh</td>
<td></td>
<td>3,5E-03 kWh</td>
<td>0,000 kg CO2e / kWh</td>
<td>0,0E+00 kg CO2e</td>
</tr>
<tr>
<td>Wind power</td>
<td>109 GWh</td>
<td></td>
<td>7,2E-03 kWh</td>
<td>0,007 kg CO2e / kWh</td>
<td>5,0E-05 kg CO2e</td>
</tr>
<tr>
<td>Total</td>
<td>15 220 GWh</td>
<td>Total</td>
<td>Total</td>
<td>5,6E-01 kg CO2e</td>
<td>Total</td>
</tr>
</tbody>
</table>

Table 14 - GHG emissions provoked by electricity production

4.2 Transportation of people

Transportation is a source of GHGs due to:

- CO₂ emitted during the fuel combustion
- Emissions due to infrastructure construction (roads, bridges, train stations...)
- Emissions provoked by the manufacturing of means of transport
- Leakages in air conditioning systems provoking emissions of halocarbons
- Local atmospheric pollutants, which can be direct greenhouse gases (such as nitrous oxides) or ozone precursors. Indeed, ozone is a greenhouse gas and is responsible for about 15% of the human perturbations of the climate system.

The Base Carbone does not take into account the GHG emissions provoked by infrastructure construction. This choice may be justified with regard to old infrastructure whose emissions due to construction have been amortised. However, concerning recent infrastructure (such as recent metro
lines or new roads), neglecting these emissions leads to underestimate them. The method chosen to adapt the Base Carbone is to keep as close as possible to the Base Carbone so, with the endorsement of specialists of the carbon footprint calculations\(^1\), these emissions are not included for the adapted method.

### 4.2.1 Road

Apart from leakages of fluids from conditioning systems (which are not included into the emission factors calculations), the emissions for transportation are all provoked by fossil fuel use.

For each types of vehicle, we can divide GHG emissions into two main parts: the emissions provoked by the fabrication of the vehicle, which can be seen as an amortisation, and the emissions due to fuel combustion.

**Cars**

**Vehicles amortisation**

Concerning the emissions provoked by car fabrication, no data are available in Tunisia. Moreover, no official figures concerning the car manufacturer market share in Tunisia is available. The only data that could be used are the car importation quotas for the year 2010 (GNET, 2013). Considering these car importation quotas and with the endorsement of local specialists\(^2\), the assumption done is that the car manufacturer market share is quite similar to the French one. Considering these facts, the emissions induced by the car manufacturing are supposed to be the same as in France. As soon as a study concerning CO\(_2\) emissions provoked by Tunisian car manufacturing will be published, an adaptation of these factors will be carried out. Table 15 gives a repartition of the fabrication emissions used in the Base Carbone. These emission factor calculations are based on studies provided by different organisms\(^3\).

---

\(^1\) I CARE ENVIRONNEMENT

\(^2\) ALCOR and APEX

\(^3\) IFP (French Institute for Petroleum), the French observatory for energy, APME (Association of Plastic Manufacturers), IRSD (Research Institute of Steel Industry)
Table 15 - Manufacturing emission per travelled kilometre

<table>
<thead>
<tr>
<th>Description</th>
<th>Emission (kg CO₂e / vehicle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions provoked by car manufacturing</td>
<td>1 283</td>
</tr>
<tr>
<td>Emissions due to energy consumption of equipment manufacturer</td>
<td>1 283</td>
</tr>
<tr>
<td>Emissions due to production of materials</td>
<td>3 487</td>
</tr>
<tr>
<td>Other emissions (worker displacements, freight...)</td>
<td>605</td>
</tr>
<tr>
<td>Total manufacturing emissions</td>
<td>6 658</td>
</tr>
<tr>
<td>Average car longevity</td>
<td>About 150,000 to 200,000 km</td>
</tr>
<tr>
<td>Manufacturing emissions per travelled kilometre</td>
<td>40 g CO₂e / km</td>
</tr>
</tbody>
</table>

These results do not include additional emissions provoked during the car use (maintenance, emissions provoked by the car distributor...) and these results should be integrated. However, no study has been done previously concerning these emissions and the Base Carbone does not include these emissions.

Fuel consumption
In the Base Carbone, the emission factors for fuel consumption of cars are distributed by type of fuel (diesel fuel or gasoline) and by tax horsepower (hp) of the engine. The tax horsepower or fiscal horsepower is a non-linear rating of a motor vehicle for tax purposes. This taxation system is mainly used in European countries. In France, it is calculated using the following equation:

\[ P_f = \frac{C}{45} + \left(\frac{P}{40}\right)^{1.6} \]  

(4)

where \( C \) is the CO₂ emissions per kilometers and \( P \) is the power of the motor.

Thanks to this taxation system, the French government encourages car manufacturers to build cars with small engines emitting reduced amount of CO₂.

In France, the Base Carbone presents emission factors for 3 different classes of tax horsepower:

- Under 5 hp
- Between 6 and 10 hp
- 11 hp and more

Thus, the Base Carbone proposes different types of emission factors: in case the user of the tool can precisely know the type of fuel and the power of each car used by a company and its employees, 6 emission factors are proposed depending on the type of fuel and the power of the cars:
• diesel fuel, under 5 horsepower
• diesel fuel, between 6 and 10 horsepower
• diesel fuel, 11 horsepower and more
• gasoline, under 5 horsepower
• gasoline, between 6 and 10 horsepower
• gasoline, 11 horsepower and more

In case the user cannot define the precise characteristics of the cars used by the firm, 6 other emission factors are provided. Indeed, when doing a GHG emission accounting it can be hard to get the tax horsepower of all the cars owned by the company and driven by employees when they are commuting from home to work. As a consequence, different average values have to be proposed in the accounting tool. These average values are based on statistics. The 6 other emission factors are:

• under 5 horsepower cars, without data on the type of fuel used
• between 6 and 10 horsepower cars, without data on the type of fuel used
• 11 horsepower and more cars, without data on the type of fuel used
• gasoline powered cars, without data on the tax horsepower
• diesel fuel powered cars, without data on the tax horsepower
• mean cars, without data on the tax horsepower nor the type of fuel

Depending on the data he can obtain from the company, the user of the tool will use these emission factors.

In Tunisia, the tax horsepower repartition is usually:
• Under 4 hp
• Between 5 and 7 hp
• 8 hp and more

The first problem encountered concerns the precise definition of the tax horsepower in Tunisia. Contrary to France where the formula of tax horsepower is clearly defined, the formula enabling to convert real characteristics of the car (such as real power, cylinder dimensions) into tax horsepower cannot be found for Tunisia. Indeed, according to the local specialists\(^1\), the formula is not public in Tunisia and cannot be provided. Considering these observations and the fact that Tunisia has

\(^1\) APEX and ALCOR
historically based its norms on the French ones, the assumption made is that the tax horsepower is the same in Tunisia and in France.

The second problem encountered is that no study has been done in Tunisia concerning the CO$_2$ emissions of vehicles. Nevertheless, a study on the energy used in the transportation sector in Tunisia carried out by the ANME in 2007 (ANME, 2007) provides a large amount of data as shown in Table 16. These data can be used to define some emission factors.

<table>
<thead>
<tr>
<th>Table 16 - Data provided by the study on the Tunisian transportation sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Repartition of vehicles by types of vehicles (trucks, cars, public transportation...)</td>
</tr>
<tr>
<td>• Repartition of cars by tax horsepower (under 4 hp, between 5 and 7 hp, 8 hp and more)</td>
</tr>
<tr>
<td>• Repartition of cars by type of fuel (diesel, gasoline)</td>
</tr>
<tr>
<td>• Repartition of cars by type of fuel and tax horsepower</td>
</tr>
<tr>
<td>• Mean age of cars by type of fuel and tax horsepower</td>
</tr>
</tbody>
</table>

The first solution that could be used to calculate relevant emission factors is by using the data concerning the mean age of cars by type of fuel and tax horsepower given by the study quoted above. The study highlights the mean ages of different car categories as shown in Table 17.

<table>
<thead>
<tr>
<th>Table 17 - Mean age of different types of cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age</td>
</tr>
<tr>
<td>Under 4 hp</td>
</tr>
<tr>
<td>Between 5 and 7 hp</td>
</tr>
<tr>
<td>8 hp and more</td>
</tr>
</tbody>
</table>

The French National Agency for the Environment ADEME provides every year the mean consumption of all the new cars sold during the year by category of power. By assuming that the car manufacturer share market is similar in France and in Tunisia as done previously, it is possible to define the mean consumption of vehicles. For example, Table 17 indicates that diesel fuel cars under 4 horsepower are, on average, 5 years old. It enables to conclude that these types of cars have been manufactured around 2008. Thanks to the French study on the mean consumption of vehicles sold in 2008, it is finally possible to define the mean consumption of this type of vehicles.

However, the French study presents the fuel consumptions for each category of real power of the vehicles (in kW) and not for each category of fiscal horsepower. As seen previously, the formula defining the tax horsepower depends on the real power of the car and on the CO$_2$ emissions of it. As
a result, the conversion between real power and tax horsepower is impossible without knowing the emissions of CO₂ per kilometre, which is an unknown parameter.

Finally, this solution could have been really interesting and brought quite relevant results. Nevertheless, the conversion between real power and tax horsepower of the vehicles is not possible and making assumptions about this conversion would not be efficient.

The other solution proposed to calculate the emission factors relating to fuel combustion for cars is to adapt the data used in the Base Carbone to calculate these factors. Indeed, the Base Carbone indicates the mean consumption of vehicles in France for each French tax horsepower class (under 5 hp, between 6 and 10 hp and 11 hp and more) but these classes have to be adapted to the Tunisian context (under 4 hp, between 5 and 7 hp and 8 hp and more).

The data which the French emission factors are built on are given for each tax horsepower, as presented in Table 18. Thus, defining mean consumption of the different Tunisian tax horsepower classes is easy. For example, the mean consumption of the cars under 4 horsepower is done by calculating the average of the 2 values corresponding to the cars of 3 and 4 horsepower.

Finally, by multiplying the mean consumption per class by the emission factor corresponding to the fuel combustion of gasoline calculated page 31, the emissions provoked by cars are calculated as shown in Table 18:

Table 18 - Emission factor for each tax horsepower class for gasoline cars

<table>
<thead>
<tr>
<th>Tax horsepower class</th>
<th>Tax horsepower</th>
<th>Mean consumption (liters per 100 kilometers)</th>
<th>Mean consumption per class (liters per 100 km)</th>
<th>Emission factor (kg CO₂e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 4 hp</td>
<td>3 hp</td>
<td>5.8</td>
<td>6.3</td>
<td>0.186</td>
</tr>
<tr>
<td></td>
<td>4 hp</td>
<td>6.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 - 7 hp</td>
<td>5 hp</td>
<td>7.7</td>
<td>8</td>
<td>0.236</td>
</tr>
<tr>
<td></td>
<td>6 hp</td>
<td>7.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 hp</td>
<td>8.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;7 hp</td>
<td>8 hp</td>
<td>9.1</td>
<td>10</td>
<td>0.295</td>
</tr>
<tr>
<td></td>
<td>9 hp</td>
<td>9.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 hp</td>
<td>10.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 hp and more</td>
<td>10.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Similarly, the emission factors for diesel fuel cars are obtained by multiplying the mean consumptions by the emission factors of diesel fuel calculated page 31, as presented in Table 19.
Table 19 - Emission factor for each tax horsepower class for diesel fuel cars

<table>
<thead>
<tr>
<th>Tax horsepower class</th>
<th>Tax horsepower</th>
<th>Mean consumption (liters per 100 kilometers)</th>
<th>Mean consumption per class (liters per 100 km)</th>
<th>Emission factor (kg CO2e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 4 hp</td>
<td>3 hp</td>
<td>4</td>
<td>4,8</td>
<td>0,153</td>
</tr>
<tr>
<td></td>
<td>4 hp</td>
<td>5,6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 - 7 hp</td>
<td>5 hp</td>
<td>6,5</td>
<td>7</td>
<td>0,217</td>
</tr>
<tr>
<td></td>
<td>6 hp</td>
<td>6,7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 hp</td>
<td>7,2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;7 hp</td>
<td>8 hp</td>
<td>8,3</td>
<td>10</td>
<td>0,309</td>
</tr>
<tr>
<td></td>
<td>9 hp</td>
<td>9,4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 hp</td>
<td>9,9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 hp and more</td>
<td>11,1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The study “Stratégie transport à faible intensité énergétique en Tunisie” (Enerdata, 2009) indicates the number of vehicle-kilometers done by private cars in Tunisia and the total energy consumed by these cars for the year 2006. The results are presented in Table 20 and the consumptions of cars per 100 kilometers are calculated so as to compare them with the results found previously. The car consumptions calculated are 8,27 liters / 100 kilometers for gasoline cars and 7,11 liters / 100 kilometers for diesel cars which is really close to the figures found previously (and particularly for the cars with a horsepower between 5 and 7).

Table 20 - Consumption of gasoline cars and diesel fuel cars

<table>
<thead>
<tr>
<th>Type of cars</th>
<th>Vehicle-kilometers traveled per year (vehicle-kilometre)</th>
<th>Total energy consumed per year (ktep)1</th>
<th>Consumption of cars (liter / 100 kilometres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline cars</td>
<td>5 940 000 000</td>
<td>380</td>
<td>8,27</td>
</tr>
<tr>
<td>Diesel cars</td>
<td>2 280 000 000</td>
<td>138</td>
<td>7,11</td>
</tr>
</tbody>
</table>

In addition to the emission factors presented previously, in case the user of the tool cannot define the precise characteristics of the cars used by the firm, it is necessary to calculate some emission factors concerning the average fleet in Tunisia.

Firstly, when it is not possible to know the fuel of the car, users need some mean values for each tax horsepower class. The study presented previously (Enerdata, 2009) indicates the proportions of gasoline cars and diesel fuel cars for each horsepower class: for each class of horsepower, by multiplying these factors by the emission factors calculated above, 3 new emission factors can be

1 tep of gasoline = 1293 liters; 1 tep of diesel fuel = 1176 liters
calculated, as reported in Table 21. For example, for the cars under 4 horsepower, the formula used is:

\[ EF_{\leq 4\ hp} = \frac{\%_{\leq 4\ hp,\ gasoline} \times EF_{\leq 4\ hp,\ gasoline} + \%_{\leq 4\ hp,\ diesel\ fuel} \times EF_{\leq 4\ hp,\ diesel\ fuel}}{\%_{\leq 4\ hp}} \]  

(5)

where \%_{\leq 4\ hp,\ gasoline} and \%_{\leq 4\ hp,\ diesel\ fuel} are respectively the proportion of gasoline cars and diesel cars and \( EF_{\leq 4\ hp,\ gasoline} \) and \( EF_{\leq 4\ hp,\ diesel\ fuel} \) are the emission factors of gasoline cars and diesel cars calculated above.

**Table 21 - Emission factor for average cars for each tax horsepower class**

<table>
<thead>
<tr>
<th>Tax horsepower class</th>
<th>Gasoline cars proportion</th>
<th>Diesel fuel cars proportion</th>
<th>Emission factor (kg CO2e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 4 hp</td>
<td>80%</td>
<td>20%</td>
<td>0.179</td>
</tr>
<tr>
<td>5 - 7 hp</td>
<td>70%</td>
<td>30%</td>
<td>0.230</td>
</tr>
<tr>
<td>&gt;7 hp</td>
<td>50%</td>
<td>50%</td>
<td>0.302</td>
</tr>
</tbody>
</table>

Then, in case users do not know the tax horsepower class, it can be necessary to have some average values calculated in the same way as previously. Two new emissions factors are calculated and presented Table 22.

For example, for the gasoline cars, the formula use to calculate the emission factor is:

\[ EF_{\text{gasoline}} = \frac{\%_{\leq 4\ hp} \times EF_{\leq 4\ hp,\ gasoline} + \%_{5-7\ hp} \times EF_{5-7\ hp,\ gasoline} + \%_{>7\ hp} \times EF_{>7\ hp,\ gasoline}}{\%_{\text{total}}} \]  

(6)

**Table 22 - Emission factor of average gasoline cars and diesel fuel cars**

<table>
<thead>
<tr>
<th>Tax horsepower class</th>
<th>Tax horsepower class repartition</th>
<th>Gasoline car average emission factor (kg CO2e / km)</th>
<th>Diesel fuel car average emission factor (kg CO2e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 4 hp</td>
<td>55%</td>
<td>0.217</td>
<td>0.196</td>
</tr>
<tr>
<td>5 - 7 hp</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;7 hp</td>
<td>15%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Finally, knowing the repartition between gasoline cars and diesel cars, it is possible to know the emission factor of a mean car in Tunisia shown in Table 23. The emission factor is calculated thanks to the formula:

\[
EF_{\text{Tunisian car}} = \frac{\%_{\text{gasoline}} \times EF_{\text{gasoline}} + \%_{\text{diesel fuel}} \times EF_{\text{diesel fuel}}}{100}
\]  

(7)

Table 23 - Emission factor for average cars

<table>
<thead>
<tr>
<th>Pourcentage de voitures essence</th>
<th>Pourcentage de voitures Diesel</th>
<th>Emission factor (kg CO2e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>20%</td>
<td>0.213</td>
</tr>
</tbody>
</table>

Finally, when users want to calculate the GHG emission accounting of an important company, it will be rarely possible to do a really precise calculation related to the commuting journeys of employees. Indeed, it will suppose to know all the cars used, the precise distance traveled, the car types, etc. In this framework, the Base Carbone proposes some emission factors which enable to calculate the emissions provoked by the commuting travels by only knowing the number of cars and the location of the employees' houses.

The Base Carbone proposes to lessen or increase the mean emission factor depending on where the employees' houses are situated to calculate average emission factors: 4 more emission factors can be calculated as shown in Table 24.

Table 24 - Emission factors of cars depending on the location of employees' houses

<table>
<thead>
<tr>
<th>House location</th>
<th>Percentage of the mean emission factor</th>
<th>Corresponding emission factor (kg CO2e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural suburbs</td>
<td>82%</td>
<td>0.175</td>
</tr>
<tr>
<td>Suburbs</td>
<td>100%</td>
<td>0.213</td>
</tr>
<tr>
<td>Urban suburbs</td>
<td>125%</td>
<td>0.266</td>
</tr>
<tr>
<td>City center</td>
<td>138%</td>
<td>0.293</td>
</tr>
</tbody>
</table>
Bus

Vehicles amortisation
Concerning the emissions provoked by bus manufacturing, no data are available in Tunisia. With the endorsement of local specialists\(^1\), the assumption done is that the CO\(_2\) emissions provoked by bus manufacturing are similar in France and in Tunisia: the majority of Tunisian buses are actually imported from Europe.

The Base Carbone proposes an emission factor of 5,5 tons of CO\(_2\) equivalent emitted per ton of bus produced (dry weight). This emission factor derives directly from the emission factor concerning the car manufacturing. Indeed, the Base Carbone considers that the mean weight of a car is 1,19 tons. As seen in the part concerning car, the total emissions provoked by car manufacturing is 6,658 tons of CO\(_2\) equivalent which is equivalent to about 5,5 tons of CO\(_2\) equivalent per ton of car.

This figure of 5,5 tons of CO\(_2\) equivalent emitted per ton of vehicle produced is kept for the calculations in the Tunisian context. As indicated in the part concerning cars, an adaptation of this factor will be proceed is case a study concerning CO\(_2\) emissions provoked by Tunisian bus manufacturing will be published.

The weight of different types of buses and their longevity are presented Table 25. These figures are given by different bus manufacturer\(^2\).

Table 25 - Emission factors for manufacturing of different types of buses

<table>
<thead>
<tr>
<th>Type of bus</th>
<th>Mean weight (tons)</th>
<th>Longevity (km)</th>
<th>Emission factor concerning manufacturing (g CO2e / km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minibus</td>
<td>3,5</td>
<td>300 000</td>
<td>64,2</td>
</tr>
<tr>
<td>Bus / Coach</td>
<td>11</td>
<td>1 000 000</td>
<td>60,5</td>
</tr>
</tbody>
</table>

Fuel consumption

Concerning the emissions provoked by fuel consumption of minibus, no data are available in Tunisia. With the endorsement of local specialists\(^3\), the assumption done is that the fuel consumption of these type of vehicle is the same in Tunisia and in France. Thus, the consumption of 15 litres per 100 kilometers indicated in the Base Carbone is kept identical for the minibus.

Concerning the buses and coaches, the study “Stratégie transport à faible intensité énergétique en Tunisie” (Enerdata, 2009) indicates the number of vehicle-kilometers done by buses in Tunisia and the total energy consumed by these buses for the year 2006. The results are presented in Table 26

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\(^1\) ALCOR and APEX

\(^2\) Volvo, Scania, Renault and Heuliez

\(^3\) ALCOR and APEX
and the consumption of buses per 100 kilometers is calculated (all the buses are fueled with diesel fuel). The bus consumption calculated is 39,6 liters / 100 kilometers.

Table 26 - Mean consumption of buses

<table>
<thead>
<tr>
<th>Vehicle-kilometers traveled per year (vehicle-kilometer)</th>
<th>Total energy consumed per year (ktep)</th>
<th>Consumption of buses (liter / 100 kilometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>380 000 000</td>
<td>128</td>
<td>39,6</td>
</tr>
</tbody>
</table>

So as to confirm the results found, it is possible to compare them with other figures that can be found thanks to another study: the surveys on energy consumptions in the transport and industry sectors (ANME, 2007) indicates that the mean consumption of buses is 39 litres / 100 kilometres for the year 2004.

Finally, by knowing the consumption of the different types of buses, it is possible to use the Tunisian emission factor concerning diesel fuel to get the emission factor adapted to the Tunisian context, as presented in Table 27. To obtain the emission factor per passenger, the total emission factor is divided by the average number of passengers. Giving that no data are available concerning the average number of passengers in the buses in Tunisia, the figures indicated in the Base Carbone are used, as presented in Table 27. In case future surveys are carried out to adapt them to the Tunisian context thanks to future surveys, these figures will be adapted.

Table 27 - Emission factor per passenger for each type of bus

<table>
<thead>
<tr>
<th>Type of bus</th>
<th>Average consumption (litres per 100 km)</th>
<th>Emission factor (kg CO₂e / vehicle.km)</th>
<th>Average number of passengers</th>
<th>Emission factor per passenger (kg CO₂e / passenger.km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minibus</td>
<td>15</td>
<td>0,479</td>
<td>5</td>
<td>0,096</td>
</tr>
<tr>
<td>Bus</td>
<td>39,6</td>
<td>1,263</td>
<td>25</td>
<td>0,051</td>
</tr>
<tr>
<td>Coach</td>
<td>39,6</td>
<td>1,263</td>
<td>35</td>
<td>0,036</td>
</tr>
</tbody>
</table>

**Taxi**

Vehicles amortisation

The vehicles used as taxi are the same used as private cars. As the consequence, the emissions provoked by their manufacturing is kept identical to the emissions indicated in the part concerning private cars, which is about 40 g of CO₂e per kilometer.

---

1 tep of diesel fuel = 1176 litres
Fuel consumption

The study “Stratégie transport à faible intensité énergétique en Tunisie” (Enerdata, 2009) indicates the number of vehicle-kilometers done by taxis in Tunisia and the total energy consumed by these taxis for the year 2006. The results are presented in Table 28 and the consumption of taxis per 100 kilometers is calculated (as indicated in the study “Stratégie transport à faible intensité énergétique en Tunisie”, all the taxis are fueled with diesel fuel). The taxis consumption calculated is 8,22 liters / 100 kilometers.

Table 28 - Emission factor concerning fuel consumption of taxis

<table>
<thead>
<tr>
<th>Vehicle-kilometers traveled per year (vehicle-kilometer)</th>
<th>Total energy consumed per year (ktep)</th>
<th>Consumption of taxis (litre / 100 kilometers)</th>
<th>Emission factor for fuel consumption (g CO2 eq / 100 km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 760 000 000</td>
<td>123</td>
<td>8,22</td>
<td>272,9</td>
</tr>
</tbody>
</table>

Louage

Vehicles amortisation
The vehicles used for louage are minibus. The emission factor for the manufaturing of minibus is calculated in the part concerning the buses and is of 64,2 g CO2e / kilometer.

Fuel consumption
The study “Stratégie transport à faible intensité énergétique en Tunisie” (Enerdata, 2009) indicates the number of vehicle-kilometers done by louage in Tunisia and the total energy consumed by these louage for the year 2006. The results are presented in Table 29 and the consumption of louage per 100 kilometers is calculated (as indicated in the study Stratégie transport à faible intensité énergétique en Tunisie, all the louage are fueled with diesel fuel). The louage consumption calculated is 10,2 liters / 100 kilometers.

Table 29 - Emission factor concerning fuel consumption of louage

<table>
<thead>
<tr>
<th>Vehicle-kilometres traveled per year (vehicle-kilometre)</th>
<th>Total energy consumed per year (ktep)</th>
<th>Consumption of louage (litre / 100 kilometres)</th>
<th>Emission factor for fuel consumption (g CO2e / 100 km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>830 000 000</td>
<td>72</td>
<td>10,2</td>
<td>338,6</td>
</tr>
</tbody>
</table>

4.2.2 Air
With the endorsement of specialists, the aircrafts in Tunisia can be considered as the same than in France: thus, it is not necessary to adapt the emission factors for air transportation. All the emission factors provided in the Base Carbone are kept identical.

1 tep of diesel fuel = 1176 litres
2 tep of diesel fuel = 1176 litres
4.2.3 Rail

Concerning the manufacturing of trains and railway means of transport, the Base Carbone does not include the emissions provoked by trains manufacturing. Thus, the only emissions taken into account in this part are emissions due to fuel combustion and electricity consumption. The adaptation of the Base Carbone keeps this choice to neglect others emissions.

Three emission factors are calculated concerning the transportation of people by train:

- National intercity rail
- Suburban rail which operates between Tunis and the outer suburbs
- Metro rail which operates in Tunis

**National intercity rail**
The national railway company of Tunisia SNCFT provides some data concerning the transportation of people for the year 2009. The data obtained, which are the consumption of electricity and diesel fuel and the number of passenger per year are indicated in Table 30. Thanks to the Formula (8), the emissions provoked by the transportation of one passenger per kilometre is calculated. The result is about 52 grams of CO$_2$e / passenger.km.

\[
EF_{\text{train}} = Consumption_{\text{electricity}} \times EF_{\text{electricity}} + Consumption_{\text{diesel fuel}} \times EF_{\text{diesel fuel}} \tag{8}
\]

where $EF_{\text{electricity}}$ and $EF_{\text{diesel fuel}}$ are respectively the emission factors of electricity and diesel fuel; $Consumption_{\text{electricity}}$ and $Consumption_{\text{diesel fuel}}$ are respectively the consumption of electricity and diesel fuel.

**Table 30** - Emission factor per passenger for national intercity rail

<table>
<thead>
<tr>
<th>Diesel fuel consumption (m³)</th>
<th>Emissions related to the fuel combustion (tons eCO₂)</th>
<th>Electric trains consumption (MWh)</th>
<th>Emissions related to the electricity generation (tons eCO₂)</th>
<th>Annual number of passenger.km</th>
<th>Emission factor (kg CO₂e / passenger.km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 000</td>
<td>95 100</td>
<td>7 000</td>
<td>2 940</td>
<td>1 900 000 000</td>
<td>0,052</td>
</tr>
</tbody>
</table>

**Suburban rail**
Two suburban lines are operated in Tunisia:

- Line Sousse - Mahdia
- Line Tunis – Southern suburbs

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1 I CARE ENVIRONNEMENT

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The SNCFT, which is also in charge of the suburban rail network, provides some data concerning the suburban lines as presented in Table 31. The number of passenger-kilometre carried for each line is not available, but the total for both lines is provided. Besides, the line Tunis – Southern suburbs has been recently electrified. As a consequence, the annual consumption of electricity of this line is still not published. Giving that the number of passengers carried on the line Tunis – Southern suburbs is 4 times more important that the number of passengers for the line Sousse – Mahdia, the assumption made, with the endorsement of local specialists\(^1\), is that the consumption of electricity is 4 times higher than for the line Sousse – Mahdia. Thus, the electricity consumption of the line Tunis – Southern suburbs is around 17 847 MWh per year, as presented in Table 32.

Table 31 - Number of passenger-kilometers, of passengers and consumption of suburban lines

<table>
<thead>
<tr>
<th>Line Sousse - Mahdia</th>
<th>Line Tunis - Southern suburbs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of passenger-kilometres</td>
<td>-</td>
<td>523 000 000</td>
</tr>
<tr>
<td>Passengers transported</td>
<td>8 600 000</td>
<td>26 000 000</td>
</tr>
<tr>
<td>Electricity consumption (MWh)</td>
<td>5949</td>
<td>-</td>
</tr>
</tbody>
</table>

The emission factor concerning the suburban lines is calculated thanks to the formula:

\[
EF_{\text{suburban rail}} = \frac{\text{Consumption}_{\text{electricity}} \times EF_{\text{electricity}}}{N_{\text{passengers-kilometre}}} 
\]

(9)

where \(\text{Consumption}_{\text{electricity}}\), \(EF_{\text{electricity}}\) and \(N_{\text{passengers-kilometre}}\) are respectively the consumption of electricity, the emission factor of electricity and the number of passenger-kilometre carried yearly on the suburban lines.

Table 32 - Emission factor of suburban rail

<table>
<thead>
<tr>
<th>Electricity consumption (MWh)</th>
<th>Line Sousse - Mahdia</th>
<th>Line Tunis - Southern suburbs</th>
<th>Total</th>
<th>Number of passengers-kilometres</th>
<th>Emission factor (kgCO(_2)e / voyageur.km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 949,00</td>
<td>17 847,00</td>
<td>23 796,00</td>
<td>523 000 000,00</td>
<td>0,033</td>
</tr>
</tbody>
</table>

Metro rail

The public transport operator in Tunis STT supervises the bus network, the metro and the light rail link to La Marsa called TGM. It provides some data concerning the metro and light rail network for

\(^1\) ALCOR and APEX
the year 2010, as presented in Table 33. Three emission factors can be calculated for the rail network of Tunis:

- Emission factor corresponding to the metro
- Emission factor corresponding to the light rail TGM
- Emission factor which is a mean of the two other, in case the user of the tool does not know the precise mean of transport used

Table 33 - Total distance travelled, number of passengers transported, average travel distance and electricity consumption of metro rail

<table>
<thead>
<tr>
<th></th>
<th>Metro</th>
<th>Light rail TGM</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total distance travelled per year</td>
<td>9 401,20</td>
<td>1 227,40</td>
<td>10 628,60</td>
</tr>
<tr>
<td>Percentage of total</td>
<td>88%</td>
<td>12%</td>
<td>100%</td>
</tr>
<tr>
<td>Passengers transported</td>
<td>91 800 000</td>
<td>15 930 000</td>
<td>107 730 000</td>
</tr>
<tr>
<td>Percentage of total</td>
<td>85%</td>
<td>15%</td>
<td>100%</td>
</tr>
<tr>
<td>Average travel distance (km)</td>
<td>5,7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Electricity consumption (MWh)</td>
<td>-</td>
<td>-</td>
<td>41 091</td>
</tr>
</tbody>
</table>

The average travel distance for the TGM is not indicated as well as the electricity consumptions for each mean of transport. Giving the fact that some data are missing, some assumptions have to be done:

- Concerning the average travel distance for the TGM, the TGM is a 19 kilometres-line and the stops are distributed as shown in Figure 4. Thus, the distance between the two first stops, Tunis and Le Bac, are separated by a distance of 9 kilometres so, with the endorsement of local specialists\(^1\), the average travel distance is considered of 12 kilometres. This figure will be adapted as soon as some surveys will be realised. The number of passenger-kilometre for each mean of transport can then be calculated, as shown in Table 34.

Table 34 - Average travelled distance per passenger, number of passengers per year and number of passengers.kilometre per year

<table>
<thead>
<tr>
<th></th>
<th>Metro</th>
<th>Light rail TGM</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average travelled distance per passenger(km)</td>
<td>5,7</td>
<td>12,0</td>
<td>-</td>
</tr>
<tr>
<td>Number of passengers per year</td>
<td>91 800 000</td>
<td>15 930 000</td>
<td>-</td>
</tr>
<tr>
<td>Number of passengers.kilometre</td>
<td>523 260 000</td>
<td>191 160 000</td>
<td>714 420 000</td>
</tr>
</tbody>
</table>

\(^1\) ALCOR and APEX
Concerning the electricity consumptions of each mean of transport, the only data provided is the total electricity consumption. As the total distance travelled per year by metro represents 88% of the total distance travelled, the electricity consumption of the metro can be considered to be 88% of the total electricity consumption, as shown in Table 35.

<table>
<thead>
<tr>
<th>Table 35 - Electricity consumption of metro rail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of the total electricity consumption</td>
</tr>
<tr>
<td>Electricity consumption (MWh)</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Finally, the emission factors concerning the metro and light rail network can be calculated thanks to the formulas (10), (11) and (12), as presented in Table 36.

\[
EF_{\text{metro}} = \frac{\text{Consumption}_{\text{electricity, metro}} \times EF_{\text{electricity}}}{N_{\text{passengers-kilometre, metro}}} \tag{10}
\]

\[
EF_{\text{TGM}} = \frac{\text{Consumption}_{\text{electricity, TGM}} \times EF_{\text{electricity}}}{N_{\text{passengers-kilometre, TGM}}} \tag{11}
\]

\[
EF_{\text{total}} = \frac{\text{Consumption}_{\text{electricity, total}} \times EF_{\text{electricity}}}{N_{\text{passengers-kilometre, total}}} \tag{12}
\]

where \(\text{Consumption}_{\text{electricity, metro}}\), \(\text{Consumption}_{\text{electricity, TGM}}\) and \(\text{Consumption}_{\text{electricity, total}}\) are respectively the electricity consumptions of the metro, the TGM and the total rail and light metro network; \(N_{\text{passengers-kilometre, metro}}\), \(N_{\text{passengers-kilometre, TGM}}\) and \(N_{\text{passengers-kilometre, total}}\) are the numbers of passenger-kilometres of the metro, the TGM and the total rail and light metro network; \(EF_{\text{electricity}}\) is the emission factor of electricity.
Table 36 - Emission factor of metro rail

<table>
<thead>
<tr>
<th></th>
<th>Electricity consumption (MWh)</th>
<th>Number of passengers per year</th>
<th>Emission factor (g CO₂e / passenger-kilometre)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metro</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Light rail TGM</strong></td>
<td>4 930,92</td>
<td>191 160 000,00</td>
<td>18,57</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>41 091,00</td>
<td>714 420 000,00</td>
<td>41,41</td>
</tr>
</tbody>
</table>

4.2.4 Maritime

As for the air transportation, the boats and ferries can be assumed to be the same in Tunisia and in France (with the endorsement of I Care Environnement), therefore it is not necessary to adapt the emission factors for maritime transportation. As a consequence, the emission factors indicated in the Base Carbone are kept identical.

4.3 Transportation of goods

As for the transportation of people, the best method to calculate consists in calculating the emissions provoked by fuel combustion (known from the fuel consumptions) and the emissions provoked by the manufacturing of the means of transport.

4.3.1 Road

In the same way as done in the part concerning the transportation of people, the emissions for transportation of goods are all provoked by fossil fuel use apart from leakages of fluids from conditioning systems which are not included into the emission factors calculations.

It is possible to divide GHG emissions into two main parts: the emissions provoked by the fabrication of the vehicle and the emissions due to fuel combustion.

In Tunisia, trucks are divided into 3 different categories depending on the payload, which refers to the maximum cargo weight a truck can safely carry:

- Light trucks, with a payload inferior to 10 tons
- Medium trucks, with a payload between 10 and 19 tons
- Semi-trailers, with a payload superior to 20 tons

Few data concerning transportation of goods by trucks are available in Tunisia. Because of the lack of data, the French data are kept identical and no adaptation is carried out with the endorsement of carbon footprint specialists. Some studies have to be realised so as to adapt these emission factors.
4.3.2 Air
As seen for the transportation of people, the aircrafts in Tunisia can be considered to be the same than in France\textsuperscript{1}, therefore it is not necessary to adapt the emission factors for air transportation. As a consequence, the emission factors indicated in the Base Carbone are kept identical.

4.3.3 Rail
The national railway company of Tunisia SNCFT provides some data concerning the freight in Tunisia. These data are presented in Table 37. Thanks to them, we can calculate the emission factor per ton-kilometres thanks to the formula:

\[ EF_{\text{freight}} = \frac{\text{Consumption}_{\text{diesel fuel}} \times EF_{\text{diesel fuel}}}{N_{\text{ton-kilometres}}} \]  \hspace{1cm} (13)

where \( \text{Consumption}_{\text{diesel fuel}} \) is the total diesel fuel consumption per year, \( EF_{\text{diesel fuel}} \) is the emission factor of diesel fuel and \( N_{\text{ton-kilometres}} \) is the number of ton-kilometres travelled per year.

Table 37 - Emission factor for freight by rail

<table>
<thead>
<tr>
<th>Diesel fuel consumption (m3)</th>
<th>Ton-kilometres travelled per year (ton-km)</th>
<th>Emission factor (kg CO\textsubscript{2}e / ton-km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 407</td>
<td>1 820 000 000</td>
<td>0,030</td>
</tr>
</tbody>
</table>

4.3.4 Maritime
With the endorsement of specialists\textsuperscript{2}, it is not necessary to adapt the emission factors for maritime transportation, as done in the part concerning transportation of people. All the emission factors provided in the Base Carbone are kept identical.

4.4 Materials
The production of materials (glass, metal, plastic...) provokes GHG emissions which are mainly due to the consumption of fossil energy and electricity during the industrial process.

The adaptation of emission factors related to materials is only done for materials produced in Tunisia and, with the endorsement of the carbon footprint calculation specialists\textsuperscript{2}, the emission factors will be kept identical to the ones in the Base Carbone for the materials produced in foreign countries. Indeed, when the users of the tool intend to calculate the emissions provoked by materials consumption of a company, they need to know the place where the materials are produced: in case the production is in Tunisia, they will use the emission factor related to Tunisia and will add the emissions due to transportation of materials from the plant to the company; otherwise, in case the

\textsuperscript{1} with the endorsement of I CARE ENVIRONNEMENT

\textsuperscript{2} I CARE ENVIRONNEMENT
production of materials is realised outside from Tunisia, the emission factors used in the Base Carbone will be applied and the emission provoked by the transportation from the plant to the company will be added (it can be by boat, train, truck...).

The emission factors are obtained thanks to 2 different methods:

- by using published life-cycle assessments
- by direct calculations when the consumptions of each type of energy used to produce the material are known

These emission factors are designed to be updated depending on the progress of industrial processes involved in the production and on new data obtained from industries.

### 4.4.1 Metal – Steel

In Tunisia, according to local specialists, no virgin steel is produced but the steel is recycled. The emission factor used in the Base Carbone is, consequently, kept identical for virgin steel.

Giving the fact that some steel is recycled in Tunisian plants, the emission factor concerning recycled steel has to be adapted: no data are available concerning the emissions due to recycled steel in Tunisia. As a consequence, the data provided by the life-cycle inventory database Ecoinvent are used. These data are the mean consumptions of energy induced by the production of 1 ton of recycled steel as presented in Table 38.

By multiplying these energy consumptions by the emission factors concerning electricity and gas in Tunisia (as presented by the Formula (14)), we can obtain the emission factor concerning the production of recycled steel. We finally obtain 323 kg CO2e per ton of steel.

\[
EF_{\text{recycled steel}} = EF_{\text{electricity}} \times Consumption_{\text{electricity}} + EF_{\text{gas}} \times Consumption_{\text{gas}}
\]

(14)

where \( EF_{\text{electricity}} \) and \( EF_{\text{gas}} \) are respectively the emission factors of electricity and gas in Tunisia; \( Consumption_{\text{electricity}} \) and \( Consumption_{\text{gas}} \) are respectively the consumptions of electricity and gas.

**Table 38 - Emission factor of steel**

<table>
<thead>
<tr>
<th>Energy</th>
<th>Gas (MJ)</th>
<th>Electricity (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumptions for the production of 1 ton of steel</td>
<td>975</td>
<td>424</td>
</tr>
<tr>
<td>Emissions provoked by the production of 1 ton of steel (kg CO2e)</td>
<td>56</td>
<td>267</td>
</tr>
</tbody>
</table>

1 APEX and ALCOR
4.4.2 Paper and cardboard

**Paper**

Three emission factors can be calculated concerning the paper:

- When the user of the tool knows that the paper comes from Tunisia, an emission factor specially adapted to the Tunisian context can be calculated.
- When the user of the tool knows that the paper comes from another country, the emission factor used in the Base Carbone is used and the emissions due to the transportation from the foreign country, where the paper is produced, to the consumer, in Tunisia have to be added.
- Finally, when the user cannot define the origins of the paper, a mean emission factor is used.

First, to calculate the emission factor representing the Tunisian context, some data concerning the local production of paper are provided by local specialists\(^1\), as shown in Table 39. These data concern a paper plant and correspond to the production of paper and the energy consumption (fuel and electricity) for the years 2009, 2010 and 2011.

<table>
<thead>
<tr>
<th>Paper production (tons)</th>
<th>Fuel consumption (tep)</th>
<th>Electricity consumption (kWh)</th>
<th>Emission factor (kg CO(_2)e/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 000</td>
<td>5 656</td>
<td>47 353 000</td>
<td>1 382</td>
</tr>
</tbody>
</table>

Thanks to these data, it is possible to calculate an emission factor for the paper produced in Tunisia, thanks to the Formula (15).

\[
EF_{\text{Tunisian\ paper}} = \frac{EF_{\text{electricity}} \times Consumption_{\text{electricity}} + EF_{\text{fuel}} \times Consumption_{\text{fuel}}}{Production_{\text{paper}}} \quad (15)
\]

where \(EF_{\text{electricity}}, Consumption_{\text{electricity}}, EF_{\text{fuel}}, Consumption_{\text{fuel}}\) and \(Production_{\text{paper}}\) are respectively the emission factor of electricity, the electricity consumption, the emission factor of fuel, the fuel consumption and the production of paper for the years 2009, 2010 and 2011.

When the user of the tool cannot define the origins of the paper used in the firm, a pro-rata emission factor is used. This emission factor is calculated knowing that the ratio of imported paper out of the total consumption in Tunisia is 17%\(^1\), as shown in Formula (16). The calculated emission factor is presented in Table 40.

\[
EF_{\text{mean\ paper}} = 17\% \times EF_{\text{Tunisian\ paper}} + 83\% \times EF_{\text{foreign\ paper}} \quad (16)
\]

\(^1\) APEX
Table 40 - Emission factor for different paper productions

<table>
<thead>
<tr>
<th>Base Carbone emission factor (kg CO₂e / ton)</th>
<th>Tunisian emission factor (kg CO₂e / ton)</th>
<th>Mean emission factor (kg CO₂e / ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 320</td>
<td>1 382</td>
<td>1 371</td>
</tr>
</tbody>
</table>

**Cardboard**

Identically to the emission factors concerning the paper, three emission factors can be calculated concerning the cardboard:

- an emission factor specially adapted to the Tunisian context
- the emission factor used in the Base Carbone
- a mean emission factor

Firstly, to calculate the emission factor representing the Tunisian context, some data concerning the local production of cardboard are provided by local specialists¹, as shown in Table 41. These data concerns several cardboard plants and are the production of cardboard and the energy consumption (fuel, gas and electricity) for the years 2009, 2010 and 2011.

Table 41 - Emission factor for cardboard production

<table>
<thead>
<tr>
<th>Cardboard production (tons)</th>
<th>Fuel consumption (tep)</th>
<th>Gas consumption (tep)</th>
<th>Electricity consumption (kWh)</th>
<th>Emission factor (kg CO₂e / ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>133 780</td>
<td>7 636</td>
<td>14 676</td>
<td>113 347 000</td>
<td>1 015</td>
</tr>
</tbody>
</table>

Thanks to these data, it is possible to calculate an emission factor for the paper produced in Tunisia, thanks to the Formula (17).

\[
EF_{\text{Tunisian cardboard}} = \left( EF_{\text{electricity}} \times Consumption_{\text{electricity}} + EF_{\text{fuel}} \times Consumption_{\text{fuel}} + EF_{\text{gas}} \times Consumption_{\text{gas}} \right) / Production_{\text{cardboard}}
\]  

(17)

where \( EF_{\text{electricity}}, Consumption_{\text{electricity}}, EF_{\text{fuel}}, Consumption_{\text{fuel}} \), \( EF_{\text{gas}}, Consumption_{\text{gas}} \) and \( Production_{\text{cardboard}} \) are respectfully the emission factor of electricity, the electricity consumption, the emission factor of fuel, the fuel consumption, the emission factor of gas, the gas consumption and the production of cardboard for the years 2009, 2010 and 2011.

¹ APEX
When the user of the tool cannot define the origins of the cardboard used in the firm, a pro-rata emission factor is used. This emission factor is calculated knowing that the ratio of imported cardboard out of the total consumption in Tunisia is 17\%, as shown in Formula (18). The calculated emission factor is presented in Table 42.

\[
EF_{mean \, cardboard} = 17\% \times EF_{Tunisian \, cardboard} + 83\% \times EF_{foreign \, cardboard}
\] (18)

<table>
<thead>
<tr>
<th>Base Carbone emission factor (kg CO(_2)e / ton)</th>
<th>Tunisian emission factor (kg CO(_2)e / ton)</th>
<th>Mean emission factor (kg CO(_2)e / ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 015</td>
<td>1 063</td>
<td>1 055</td>
</tr>
</tbody>
</table>

**4.4.3 Glass**

Some glass is produced in Tunisia. Some data concerning the local production of glass are provided by local specialists\(^1\), as shown in Table 43. These data, which are from 3 plants in Tunisia, are the production of glass, the energy consumption of the furnaces and the GHG emissions due to the fabrication process for the years 2008 and 2009. Thanks to the Formula (19), it is then possible to calculate the emission factor corresponding to glass production.

\[
EF_{glass} = \frac{EF_{electricity} \times Consumption_{electricity} + EF_{gas} \times Consumption_{gas}}{Production_{glass}}
\] (19)

where \( EF_{electricity} \), \( Consumption_{electricity} \), \( EF_{gas} \), \( Consumption_{gas} \), \( Emission_{process} \) and \( Production_{glass} \) are respectfully the emission factor of electricity, the electricity consumption, the emission factor of gas, the gas consumption, the emissions due to the fabrication process and the production of glass for the years 2008 and 2009.

<table>
<thead>
<tr>
<th>Glass production (tons)</th>
<th>Emissions due to fabrication process (tons CO(_2)e)</th>
<th>Gaz consumption (tep)</th>
<th>Electricity consumption (kWh)</th>
<th>Emission factor (kg CO(_2)e / ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>46 146</td>
<td>8 081</td>
<td>14 673</td>
<td>50 814 470</td>
<td>1 639</td>
</tr>
</tbody>
</table>

\(^1\) APEX
4.5 Quick review of the other parts

4.5.1 Agriculture
Animal rearing and agriculture provoke 13.5% of the GHG emissions in the world (IPCC, 2007).

The GHG emissions due to agriculture are mainly provoked by the production of:

- fertilisers
- phytosanitary products (herbicide, fungicide, insecticide...)

Similarly, the GHG emissions due to animal rearing are mainly provoked by:

- the production of plants necessary to feed the animals
- the heating of the buildings
- the fermentation of animal excrements
- methane emissions due to ruminants metabolism

No data are available concerning the emissions provoked by agriculture and animal rearing in Tunisia. As a consequence, the data provided in the Base Carbone are used. These data could be adapted in case new studies are published during the next years.

4.5.2 Waste
The emission factors calculated in this part aim at assigning GHG emissions to the process enabling the end-of-life treatment of waste. These emission factors have to include the emissions provoked by the transportation of waste to the facilities where they are treated. Moreover, some of the waste can be valorised: indeed, waste can be used as fuels to recover the energetic value they contain, they can be recycled as new materials (such as metals, glass and paper) or the methane they emit during their fermentation process can be used.

Solid waste
Concerning solid waste, a unique emission factor is given by a local specialist (APEX) which is of 896 kilograms of CO₂ equivalent per ton of solid waste. Thus, this figure can be used for all the waste a company emit.

Wastewater
Concerning wastewater, a study published by the Australian Department of Environment (Aquatech Pty. Ltd. & Environment Australia, 1997) indicates that the maximum amount of methane emissions provoked by waste deterioration is 0.25 kilogram of methane per kilogram of organic carbon present in the wastewater.

The quantity of organic carbon in a body of water is also the biochemical oxygen demand or BOD, which is the amount of dissolved oxygen needed so that biological organisms break down organic
material present in the water. Thus, the quantity of methane produced by wastewater can be found thanks to Formula (20).

\[ Q_{\text{methane}} = 0,25 \times BOD \] (20)

Where \( Q_{\text{methane}} \) is the quantity of methane produced during the wastewater deterioration process and \( BOD \) is the biochemical oxygen demand.

Finally, knowing that the global-warming potential of methane is equal to 25, as seen in Chapter 2, the quantity of CO\(_2\) equivalent emitted during the deterioration process is given by Formula (21).

\[ Q_{\text{CO}_2eq} = 25 \times 0,25 \times BOD \] (21)

Where \( Q_{\text{CO}_2eq} \) is the quantity of CO\(_2\) equivalent produced during the wastewater deterioration process and \( BOD \) is the biochemical oxygen demand.

The national sanitation utility of Tunisia ONAS provides a mean value of the BOD of the wastewater rejected in the Tunisian wastewater network (ONAS, 2013). Thanks to this value, the value calculated thanks to Formula (21) is 2,1 kg of CO\(_2\) equivalent per cubic meter of wastewater as shown in Table 44.

<table>
<thead>
<tr>
<th>BOD (kg O(_2)/m(^3))</th>
<th>CO(_2) eq emissions (kg CO(_2)e/m(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,4</td>
<td>2,5</td>
</tr>
</tbody>
</table>

Table 44 - Emission factor of wastewater

4.5.3 Capital assets

The emission factors calculated in this part are an estimation of the GHG emissions provoked by the construction of buildings or the manufacturing of tools.

With the endorsement of the carbon calculation specialists, the emission factors calculated in the Base Carbone are kept identical for this version of the adaptation. Indeed, the part concerning capital assets is not a major challenge and the emission factors concerning capital assets are not really different from a country to another.
## Conclusion

Throughout the work carried out during the master thesis presented here, different methods to adapt emission factors to the Tunisian context are exposed. Indeed, data enabling to adapt emission factors can be sometimes unknown or restricted. Three different ways to adapt emission factors are presented in this study:

- When the precise data is available, an adaptation can be directly done. This adaptation is based on the same calculations than the ones made in the Base Carbone. This is the case for emission factors concerning liquid fuels and electricity in this project.

- When local studies providing statistical data are directly available, the adaptation can be done easily, even if the calculation process is not the same than in the Base Carbone. That is the case with emission factors concerning buses, taxis, louages and trains.

- When no local data is available, another method has to be defined so as to find the most accurate emission factors. This method is the most difficult to handle and needs a good knowledge of the local context. This case is encountered for the emission factors concerning cars and trucks.

### Limits of the adaptation process:

Different issues can be encountered during the adaptation process. Often, these issues cannot be resolved, leading to approximations. The main limits encountered during this project are:

- Some data are missing, because precise studies do not exist in the country. This problem is encountered many times in this project and leads to approximations.
- Some data are provided without explanations: only the final result is provided, without explanations about the process enabling to obtain it. This can be a problem to control and verify data accuracy.

Thus, because of the previous limits presented previously, some approximations are made during the adaptation process and these approximations conduct to uncertainties in the final emission factors. Nevertheless, as presented in chapter 2, emission factors are only a way to get rough estimations. The important matter is not to get the precise amount of GHG emitted but a hierarchical sorting of the GHG emissions. This sorting is then a way to define mitigation measures.

This adaptation project presented in this master thesis is only the first step of a long process enabling the development of a local tool to account GHG emissions which will be carried out by the Tunisian government in the next decade. Thus, the emission factors calculated will be changed as soon as more data will be available. For example, some studies should be done in the next years to define...
more precisely the elements which are approximated in this project and, thus, to improve the accuracy of the emission factors.
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Annex – The Carbon Footprint Tool

Objectives
The main objective of the tool is to provide a simple and ergonomic tool which can enable the users to realise GHG emission accountings easily.

Presentation
The principles of the approach to provide this GHG emission accounting tool are:

- Adapting the existing tool: the created tool had to be based on the French tool but could be improved, particularly in terms of ergonomics
- Being transparent: all the data and the formula calculations will be clearly indicated
- Being ergonomic: the tool has to enable a quick input of the data
- Being informative: all the results will be clearly indicated so they are easily understandable and are quickly mastered by the company.

The tool is divided into 4 types of tabs:

A presentation tab:
The first tab of the tool is aimed at indicating the general data concerning the GHG emission accounting: the year of the assessment, the organisation name, turnover and activity, the corporate reporting approach (financial control, operational control or equity share approach – See Chapter 2 for more details), the organisational boundaries. The second part of the screen enables to access directly to the different tabs by clicking on the links: thus, it is possible to access to the input tabs (Energy, Displacements ...) and to the results tabs.

![Figure 5 - Introduction page of the carbon accounting tool](image-url)
**Data input tabs:**
The input tabs enable the users to complete the data which will be used to calculate the GHG emission accounting. The tool contains six different tabs on different subjects:
- Energy and direct emissions: this tab deals with energy consumption and other direct GHG emissions such as refrigerating gas leakages
- Materials and freight: it contains data concerning materials and services purchases and freight use
- Personal and professional travels
- Waste
- Building and equipment: this part deals with the amortisation of buildings, computer hardware and appliances
- Use and end-of-life of products produced and sold by the company

![Image of data input - GHG emissions accounting tool](image)

Figure 6 - Page for data input concerning energy of the carbon accounting tool

All the input tabs are designed in the same way: for each category of emission source, 3 arrays are provided. The first array on the left enables to enter data by selecting the class and the sub-class the data is referring to and then indicating the data and the corresponding unit.

The central array corresponds to optional data. The user can indicate the uncertainty of the data, the GHG reduction objectives and the material characterization (to indicate the precise owner of the equipment).

The array on the right gives some intermediate results for each data collected: the GHG emissions and the corresponding uncertainty. Thanks to this array, the user can check if the data indicated can be realistic in terms of tons of carbon dioxide equivalent.

**Calculation tabs:**
These tabs enable to implement all the calculations with the data indicated by the user. No direct interaction with the user is needed; these tabs are only a way to guarantee the transparency of the tool. The tabs are protected to avoid any involuntary modification but can be modified by the user if needed.
**Results tabs:**
Two results tabs are provided in the tool. The first one indicates the GHG emissions of the company split up by emission sources. The user can therefore identify the domains where the company can settle some mitigation measures, so as to reduce the amount of greenhouse gas emitted. One graph also indicates the impact of a reduction of emissions. These results are a good synthesis of the GHG emissions.

**Figure 7 - Results page of the carbon accounting tool – emissions split by emission sources**

The second tab provides a view of the different emissions divided according to the 3 scopes defined in the ISO norm 14064 in accordance with the GHG Protocol.
Thanks to 3 colors, we can very clearly identify the impact of each scope on GHG emissions. The uncertainties are also indicated in the graph; indeed, if a user needs to compare the results, it is important that he can be informed of the uncertainties related to the different parameters: input data, emission factors...

Figure 8 - Results page of the carbon accounting tool – output for GHG Protocol