Using national environmental objectives in green public procurement: Method development and application on transport procurement in Sweden

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A B S T R A C T

Green public procurement can play an important role in reducing the environmental impact of societies. While its uptake is continuously growing, barriers to its use still remain. One barrier previously identified in literature is related to the lack of accessible and easy to use tools that help standardize the development of criteria in green tenders. In this paper, to help overcome this barrier, a method is presented that can be used to develop green public procurement tools that follow previous studies recommendations about including life-cycle assessment-based data and basing procurement criteria on national environmental objectives. The method was then applied to develop a procurement tool for green procurement of public transport services in Sweden based on the Swedish environmental quality objectives. Results from the assessment of 18 pre-defined fuel systems are shown together with an illustrative example of how the tool can be used in the process leading up to procurements to set relevant criteria and during the procurement to adjust incoming tender prices. The results showed that waste-based biomethane and hydrogenated vegetable oil systems were well aligned with the Swedish environmental quality objectives due to being able to contribute positively to several objectives. Crop-based biofuels, on the other hand, performed worse due to negative effects from agricultural practices. The performance of the electric vehicle systems depended in large on how the electricity was generated, where renewable sources and low carbon sources performed better than non-renewable alternatives.

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1. Introduction

Green public procurement (GPP) is a demand-side policy tool that can contribute towards lower environmental impact and a circular economy (Lázaroiu et al., 2020; Sönnichsen and Clement, 2020). GPP is defined as a “process whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life-cycle when compared to goods, services and works with the same primary function that would otherwise be procured” (European Commission, 2008). GPP has been shown to be able to stimulate pro-environmental purchasing and the greening of markets (Brusselsaers et al., 2017; Lindström et al., 2020; Prieto-Sandoval et al., 2020). Furthermore, GPP may play a vital role in fostering new green innovations (Droste et al., 2016), increasing the local innovation capacity where it is used (Orsatti et al., 2020). This is mainly due to the large portion of a nation’s economy that is influenced by procurement, which could be directed towards green technologies with the use of GPP. For example, it was estimated that in 2013, 14 percent of the GDP of the European Union was spent through public procurement (European Commission, 2020) and for OECD members in the same year, it was on average 13 percent (OECD, 2020).

The use of GPP has increased in the last few decades, and so has research on the topic (Cheng et al., 2018; Renda et al., 2012). Recent publications have studied what drives and hinders the uptake of GPP in practice (e.g., Bernal et al., 2019; Liu et al., 2019; Sönnichsen and Clement, 2020; Testa et al., 2016). Specifically, Liu et al. (2019) and Sönnichsen and Clement (2020) point to officials’ awareness of GPP regulations, guidelines and supportive tools as a key influencing factor. In a similar vein, Testa et al. (2016) note that procurers often lack knowledge about how to design green tenders.
This study also identified a lack of tools that help standardize the process of designing green tenders, which, is echoed by other studies as well, describing a need for tools that help identify and formulate relevant procurement criteria (Bernal et al., 2019; Cheng et al., 2018; Guenther et al., 2013; von Oelreich and Philp, 2013). This is not entirely surprising since it is important that the criteria used in procurement are well designed in order for GPP to be an effective policy tool (Aldenius and Khan, 2017; Bratt et al., 2013; Lundberg et al., 2016). And while many recent studies highlight the need for GPP tools (e.g., Bernal et al., 2019; Cheng et al., 2018; Liu et al., 2019; Sönnichsen and Clement, 2020), only a few scientific publications on dedicated GPP tools exist (see, e.g., Vidal and Sánchez-Pantoja, 2019).

Regarding criteria formulation there are, within the European Union, two main ways of awarding tenders in public procurement: by lowest price or to the most economically advantageous tender (Lundberg and Bergman, 2011; Parikka-Allhola and Nissinen, 2012). This is reflected in two different ways of setting criteria in tenders, either as minimum compliance criteria or as award criteria. Both types of criteria may be used in GPP (Aldenius and Khan, 2017), that is, either defining a set of minimum environmental performance criteria that has to be met by offerings or defining a set of award criteria that gives points, or favourable price adjustments, to offerings with good environmental performance. When looking to literature, several recommendations for criteria formulation can be found. Specifically, criteria should promote solutions with better environmental performance than the current technological standard (Lundberg et al., 2016), they should encompass the relevant environmental impact areas (Bratt et al., 2013; Thomson and Jackson, 2007) and they should be precise and detailed (Aldenius and Khan, 2017). Furthermore, Cheng et al. (2018), Testa et al. (2016) and Parikka-Allhola and Nissinen (2012) suggest applying a life-cycle perspective and the use of life-cycle assessment-based data. In addition, Cheng et al. (2018) and Lundberg et al. (2016) recommend using pre-defined environmental objectives as reference for criteria formulation since it helps align GPP with other environmental policy efforts and enables a strategic, long-term, approach to GPP.

However, pre-defined environmental objectives relevant to public organisations—such as national environmental objectives—tend to be very broad and vague, due to their need to cover many different environmental impact areas while being relevant in diverse socio–technological settings. The vagueness may also stem from the need to find a consensus in parliamentary settings where it may be difficult to find support for more concrete objectives (Larsson and Hanberger, 2016). Therefore, extensive analysis and knowledge may be needed to understand how, for example, certain operations, products, or services influence specific objectives. For example, Larsson and Hanberger (2016), when evaluating the Swedish environmental quality objectives, come to the conclusion that they can work well to guide environmental policy on the national level, but are less suited for regional and local public actors. This is problematic, as regional and local public actors are key actors in the work with national objectives. GPP provides an opportunity to bridge this gap if regional and local actors can procure in ways that are in line with the national objectives. To support regional and local public actors in this, methods of operationalisation are necessary, which enable these objectives to be integrated within GPP.

This paper aims to contribute towards the, so far sparse, literature on GPP tools that help identify and formulate relevant procurement criteria. It has two main parts, where the first describes a method to create GPP tools based on national environmental objectives, that supports identification, formulation, and implementation of green procurement criteria. The method relies on a participatory approach that enables the co-creation of public procurement tools with relevant stakeholders. The second part details how the method can be applied, as it presents how a procurement tool for public transport services has been created based on the Swedish environmental quality objectives (see Swedish Environmental Protection Agency, 2020 for an overview of these objectives). The paper contains assessment results for a number of different fuels, including biomethane, electricity, ethanol, hydrogenated vegetable oil (HVO), and rapeseed methyl ester (RME). While the tool that is described is specific to the procurement of public transport services in Sweden, insights and lessons learned in its development and from its results can be relevant to green transportation procurement in general. Furthermore, the method used to create the tool can be used to create similar tools in other political, geographical, and technical contexts.

Following this introduction, the method developed to create GPP tools based on national environmental objectives is presented in section 2 of the paper. In section 3, the method’s application to develop a GPP tool for public transport procurement in Sweden is described. Following that, the method and the case study results are discussed in section 4. Finally, in section 5, the paper’s practical and scientific contributions are highlighted and avenues for future research are suggested.

2. A method to develop GPP tools

The method developed to create GPP tools based on national environmental objectives is participatory, which enables participants to provide knowledge about practical needs, accessibility, and usability that influences the process and outcome of the research (Blok et al., 2015). The participatory approach also provides an opportunity to integrate top-down expert-based knowledge with bottom-up stakeholder-based knowledge, a trait that is proposed by Waas et al. (2014) as part of the ideal-typical methodology of sustainability assessments. Furthermore, participation of stakeholders may increase their understanding and acceptance of the outcome (Lang et al., 2012). For example, procurers participating in the creation process become more familiar with the tool and more willing to use it. The method can be summarized in six steps, which are illustrated in Fig. 1 and described in the coming sub-sections. Inspiration for the method comes from multi-criteria decision analysis methods (see, e.g., Diaz-Balteiro et al., 2017; Kumar et al., 2017; Lindfors et al., 2019; Mendoza and Martins, 2006 for an overview of these methods). Although the method is presented as linear, it commonly involves iterations. For example, additional alternatives to assess may be suggested at a later stage than the second step of the process and the normative scales used for assessment may need adjustment to differentiate between the alternatives, something which may not be discovered until the scales are applied.

2.1. Step 1: Defining the scope

The first step is to set the scope, that is, to determine the area of application for the subsequent GPP tool. This may be by selecting a target sector, such as, public transportation, printers, furniture, or food or by identifying a functional need to be fulfilled, such as, transporting people from point A to B. While the scope can be broad or narrow (food, would be a broad scope; printers, a fairly narrow

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1 The procurement tools created by this method can be seen as a type of sustainability assessment since it provides decision-makers with knowledge on what actions to take, or not take, to contribute towards sustainable development (Ness et al., 2007).
scope), broad scopes may involve too many alternatives, making the assessment problematic to perform. On the contrary, if the scope is too narrow, it may mean that certain solutions may be excluded unintentionally, and that the procurement tool is only usable in very few cases. Since the creation of tools requires dedicated resources, it is recommended to find a scope where the tool can find as many uses as possible. Therefore, the size of the scope should be deliberated upon and defined by those participating in the creation of the tool.

2.2. Step 2: Identifying alternatives

In the second step, alternatives to be assessed are identified within the chosen scope. While alternatives can be added after the assessment framework and normative scales have been created (steps 3 and 4), knowledge about potential alternatives is necessary to understand their related environmental impact and which national environmental objectives are influenced by the procurement. Identification of alternatives can, for example, be done through interviews with experienced procurers, a market study, or a literature review.

2.3. Step 3: Creating the assessment framework

The assessment framework is created by identifying, analysing, reviewing, and transforming relevant national environmental objectives into assessment criteria and indicators. This process is detailed in Fig. 2. First, relevant objectives are identified. Second, a list is created from the indices used to measure progress within the identified objectives. It is common that national environmental objectives have sub-objectives and several different indices. This list of indices is then analysed by reviewing if indices are positively or negatively impacted by any of the alternatives identified in Step 2. Indices not impacted by any alternative are excluded, providing a first sorting of indices affected by the procurement. Then, to avoid the possibility of double counting, this first sorting is reviewed to ensure that there are no indices that measure the same thing. Since national environmental objectives are not designed to be used as analytical frameworks, it is common that one index may be used to measure progress in several objectives. If any fully overlapping indices are found, these should be merged into one index. Then, all remaining indices are transformed into indicators by making them specific to the scope selected in Step 1. This means that the unit used to measure each index is transformed into a unit specific to assessing the identified set of alternatives. These new units are similar to functional units of life cycle assessment methodology (Bjørn et al., 2018, pp. 84–88). This transformation simplifies the assessment of the indices (after the transformation referred to as indicators), which can now be assessed in their unit of analysis. An example from the case in this paper (see Section 3) is that an index measuring the total amount of nitrogen oxide emissions in Sweden was transformed into an indicator measuring the amount of nitrogen oxide emissions per megajoule of fuel used for transportation. It is, however, important that such transformations do not change the substance of the index, that is, what environmental impact the index is measuring. After the indicators are formulated, criteria are defined to facilitate overview. Since there may still be partial overlaps and similarity between indicators, some criteria will be based on several indicators. Finally, the connection between each criterion and the national environmental objectives is made by backtracking each indicator to its original indices and their parent objectives.

2.4. Step 4: Defining the normative scales

Next, normative scales are defined for each criterion in order to normalize the criteria for aggregation. These scales are used to score assessments within the criteria, which enable procurers to get a rudimentary overview of how the different fuel systems perform. Each criterion scale consists of five grades, large positive effect, small positive effect, negligible effect, small negative effect and large negative effect. A normative scale was chosen as an absolute scale could be confusing since a “high” score in, for example, particulate matter emissions would be considered bad while a “high” score in biodiversity would be considered good. The scales should be defined as part of the participatory approach, that is,
stakeholders should be involved in the definition of each grade of each scale. Hence, the scales should ideally represent a consensus between stakeholders with different value orientations and areas of expertise but who are in some way affected by the procurement. As for the amount of levels on the scale, there are some considerations to be made. First, an odd number of levels may be beneficial since that allows for a “neutral” middle score. Second, while it may seem intuitive to include many levels to increase the specificity of the result, there are uncertainties related to the data availability and interpretation that would make narrowly defined levels difficult to use without giving multiple scores to some alternatives. While it is certainly possible to have, for example, a three-level scale or a seven-level scale, a five-level scale was found to be the preferred choice in the case study, allowing for the best compromise between specificity and usability, and therefore it is the recommended amount of levels for the method. However, if the method is used in other political or technical contexts, more or fewer levels may be preferred.

2.5. Step 5: Assessing the alternatives

In step 5, each alternative is assessed for each indicator. Recommendations by Cheng et al. (2018) and Testa et al. (2016) to use a life-cycle perspective and life-cycle assessment–based data are echoed here. Data can be gathered through, for example, literature reviews, interviews with experts, workshops, or document studies depending on what data is to be gathered and its availability. Data for each indicator is then used together with the scales defined in Step 4 to score each alternative.

2.6. Step 6: Compiling data and results

The last step is to compile information about the alternatives, indicators, criteria, environmental objectives, and scales. This can, for example, be done in Excel, although other software tools that support information storing and simple mathematical calculations can also be used. This information can either be used to support the formulation of technical criteria, such as setting a minimum emission levels for offers to meet, or it may be used to select the most economically advantageous offer. In general, when selecting the most economically advantageous offer in public procurement, one can either award points based on different offers’ performance within different criteria or favourably adjust their price. In this method, a price adjusting method was chosen because it scores offers independent of other offers, something that is not the case for point awarding methods that often rely on the relative performance of offers (Lunander and Andersson, 2004). The price adjusting function utilizes the scores from the scales in Step 4 and translates them to numerical numbers. Each score is given a number, 0 for negligible effect, 0.5 for small effect and 1 for large effect (positive or negative, depending on whether the effect is positive or negative). These scores are then used in a weighted mean function to calculate the adjusted price of incoming tenders, which can be seen in Eqs. (1) and (2). Eq. (1) describes how prices are adjusted if the weighted mean score is positive and Eq. (2) describes how prices are adjusted for a fuel with overall negative effects. If the weighted mean score is zero, the price remains unadjusted.

\[
\text{If } \sum_{j=1}^{6} w_j S_{nj} > 0: P_{\text{adjust}} = P_{\text{tender}} \left( 1 + \left( \sum_{i=1}^{n} Q_i \sum_{j=1}^{6} S_{ij} \times w_j \right) \times W \right)
\]

Eq 1
If \( \sum_{j=1}^{n} w_j S_{nj} < 0 \), \( P_{\text{adjust}} = P_{\text{tender}} \times \left( \sum_{j=1}^{n} Q_j \frac{S_{j} \times W_j}{6} \right) \times W - 1 \)  

Eq 2

In the equations, \( P_{\text{adjust}} \) represents the adjusted price of the tender, \( P_{\text{tender}} \) is the price of the tender, \( Q_j \) is the share of the fuel mix of fuel i, \( S_{ij} \) is the score of fuel i in criterion j, \( W_j \) is the weight of criterion j, and \( W \) is the weight of environmental performance in the tender. The function uses weights for both how important environmental performance is and the relative importance of each criterion. These weights are defined by the procuring organisation and represent their willingness to pay for increased environmental performance and their prioritization between different environmental objectives. As both willingness to pay and the importance of environmentally benign efforts are subjective in nature, these weights are something each public organization has to choose for themselves. Weights can be set directly or using various methods for subjective weighing (see e.g., Wang et al., 2009 for an overview of such methods), such as, the analytical hierarchy process (Saaty, 1977) or the swing method [Jia et al., 1998]. The relative weights for each criterion will range between 0 and 1, where a criterion with a weight of 1 has twice the importance of a criteria with a weight of 0.5. The absolute weight of environmental performance is relative to the other areas relevant to the procurement such as social criteria, technical standards, and the price. In theory, the environmental performance can be of a larger importance than the price, in which case it is set above 100 percent. However, in practice, environmental criteria are often given quite low priority, for example, Braulio-Gonzalo and Bovea (2020) found that environmental criteria in GPP in the Spanish furniture sector hold an average weight of around 6 percent. This indicates a narrow focus on procurement budgets rather than on broader socio-economic effects (Günther et al., 2013; Luttenberger and Luttenberger, 2017; Nurhadi et al., 2014).

3. Exemplifying case: a GPP tool for Swedish public transport

The method was applied to create a tool for the procurement of public transport services in Sweden. This section describes how the method was applied, what assumption and choices were made, and how participation was integrated in the different steps of the method.

3.1. Step 1: Defining the scope

The area of application was defined as public transport services, specifically, public transportation by bus and public goods transportation by lorry. Transportation was chosen because it is described as a key sector for GPP by the European Commission (European Commission, 2016, p. 72) and because the sector in Sweden has a long history of using GPP (Aldenius, 2018; Aldenius and Khan, 2017; Xylia and Silveira, 2017) and, is therefore, a good testing ground for new tools and approaches. Until now, green transport procurement has been driven by regional policies and guidelines and thus, large differences exist between different regions in Sweden when it comes to the greenness of public transport (Xylia and Silveira, 2017). For example in 2016, regions such as Stockholm, Blekinge, and Västmanland reached around 95 percent renewable fuels in their buses while regions like Gotland and Norrbotten lagged behind at around 10 and 25 percent respectively (Gustafsson et al., 2018). Furthermore, the majority of bus transportation procurements in Sweden until now have relied on functional criteria that focus on the share of renewable fuels and these fuels’ greenhouse gas emissions (see, e.g., Aldenius, 2018). This means that other environmental impact categories such as acidification, biodiversity loss, land use, eutrophication, and so forth, are seldom included in GPP of transport services. While some actors have solved this by setting specific criteria, for example, choosing a particular fuel that is deemed to have good environmental performance across many impact categories, this is seen as a less flexible method and may mean a lower cost-effectiveness, as the procurement will be locked into a certain fuel (Aldenius and Khan, 2017). Therefore, a tool designed to help procurers establish functional criteria for public transport services encompassing a wider range of environmental impact categories was desired.

3.2. Step 2: Identifying alternatives

After the scope was defined, stakeholders were identified primarily through a convenience selection by sending out invitations in the authors’ contact network, through a regional cooperative organisation for renewable fuels and through the National Biogas Research Center (BRC). The participants were a mixed group of civil servants, procurers, environmental strategists, fuel producers and transport solution providers. The participants consisted of a group of between 10 and 20 individuals that grew during the development as some participants joined at a later stage.

Identification of alternatives was made together with all participants primarily through two workshops where the aim of the procurement tool was presented, and participants were free to suggest whatever alternatives they thought would be plausible for public transport services. Due to the fact that the majority of environmental impact from transportation comes from fuel use (see, e.g., Chan et al., 2013; Cooney et al., 2013), and because other sources of environmental harm related to chassis material, paint, end-of-life treatment and particles from tires are not substantially affected by choice of vehicle model (within the same category of vehicles), it was decided to focus on different fuel systems. In the case of electricity as a fuel system, batteries were included since it is a feature specific to electric vehicles that represents a significant amount of environmental impact (see, e.g., Cusenza et al., 2019; Sen et al., 2019). The specific fuel systems were identified by looking at what possible fuels were available on the Swedish market. This came down to five different alternative fuels: biomethane, electricity, ethanol, hydrogenated vegetable oil (HVO) and rapeseed methyl ester (RME). In order to assess the reference alternatives, fossil diesel and fossil methane were also included. Because some fuels differ a lot in environmental impact depending on production techniques and input materials used (e.g., biofuels from different input materials and electricity generated by different means), some fuels were differentiated in the assessment based on input material, production technique and geographic origin. This totalled 18 different fuel systems, which are shown in Table 1.

3.3. Step 3: Creating the assessment framework

The first part of constructing the assessment framework was to choose what national environmental objectives to use. In this case, the Swedish national environmental quality objectives (Swedish Environmental Protection Agency, 2020) were chosen because the study took place in Sweden, with Swedish public organisations as its target audience. The Swedish environmental quality objectives are made up of 16 objectives that cover a variety of environmental issues, such as, climate change, radiation, noise, acidification,
eutrophication, and protection of various natural habitats. In addition, there is an overarching objective, called the generational objective, which focuses on societal and economic aspects that need to be changed to reduce environmental impact. Each of the objectives consists of indices—in total 71—used to follow progress. These 71 indices were reviewed and sorted according to the process described in Section 2.3 and Fig. 2. In addition, an account of how each index was reviewed, sorted, and transformed can be found in the supplementary materials. The first part of this sorting process (that is, excluding indices that are not affected by any alternative) was supported by a literature study and discussions with practitioners such as vehicle manufacturers and sustainability analysts. Literature was reviewed by use of the Scopus and Google Scholar search engines, the search strings used related to each fuel system and each index. For example, search strings such as, “life cycle” + “acidification potential” + “ethanol” + “heavy duty transportation” was used to review if ethanol had any impact on the index of nitrogen oxides emissions to sea and land. This exclusion step shrunk the list of indices from 71 to 29. To avoid double counting, some indices had to be merged. For example, the index of global average temperature and greenhouse gas emissions was merged because both dealt with human induced climate change. After this, eight indices were left. These were processed into indicators able to assess fuel systems by adapting their units to different contexts. With these eight indicators identified, they were each related to a criterion. Some indicators, deemed closely related, were grouped together under the same criterion. In total, six criteria were defined, these and their indicators can be seen in Table 2. The criteria were then linked back to the Swedish environmental quality objectives through the indicators in order to clarify which objective(s) each criterion influenced.

3.4. Step 4: Defining the normative scales

Next, the normative scales were defined for each criterion. At first, a draft version was developed by the authors, which was used to stimulate discussions between participants. The final version of the scales was built on consensus discussions between the participants at a workshop and through remissions that were done through email conversations. The scales for each criterion used in the case detailed in the paper can be seen in Table 3.

3.5. Step 5: Assessing the alternatives

In step 5, the indicators were assessed for each of the predefined fuel systems. Data was gathered through a literature study searching for life-cycle emissions and impacts for each respective indicator-fuel system combination. The data was cross-checked with several studies (when there were several studies available) to ensure its validity, but only one or a few sources—the newest or most representative—were selected to be included in the tool for simplicity purposes. This data and their respective sources can be found in the supplementary materials.

The scores for each fuel system in each criterion can be seen in Table 4, providing an overview of how different fuel systems performed in terms of their impact on the Swedish environmental quality objectives. As can be seen in the assessment, biomethane fuel systems tended to perform well. This was mainly due to their inherent multi-dimensionality (Dahlgren, 2019; Hagman, 2018), meaning that they contribute towards fulfilling many environmental objectives. For example, they were the only fuel systems to get a positive effect on the criterion of increased biodiversity and reduced eco-toxicity due to the importance of the digestate (which is co-produced with biomethane in anaerobic digestion) as input into organic farming (Anspatch et al., 2011; Lantz et al., 2007) and its positive impact on agricultural practices (Li et al., 2013; Prade et al., 2017). Furthermore, many biomethane fuel systems were waste-based, contributing to the criteria of increased resource recycling and reuse. In general, it appears that waste-based biofuels align well with the Swedish environmental quality objectives as they performed well in the criteria of reduced greenhouse gas emissions, improved air quality and increased resource recycling and reuse. These fuel systems also had small or negligible adverse effects on acidification and eutrophication. Crop-based biofuels, on the other hand, performed worse; their greenhouse gas emissions tended to be higher than waste-based biofuels, coupled with large negative effects on the criteria of reduced acidification and reduced eutrophication stemming from soil conditioning and fertilization practices. Electric fuel systems performed well within the criterion of improved air quality, but on the criteria of reduced greenhouse gas emissions, reduced acidification and reduced eutrophication, the source of the electricity had a large influence on the results. Here

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### Table 1

<table>
<thead>
<tr>
<th>Fuel System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil diesel</td>
<td>Electricity(^a) based on the Swedish electricity mix</td>
</tr>
<tr>
<td></td>
<td>Coal-fired based electricity(^b)</td>
</tr>
<tr>
<td>Biomethane Swedish mix(^c)</td>
<td>Wastewater treatment-based Swedish biomethane</td>
</tr>
<tr>
<td>Imported biomethane from manure</td>
<td>Swedish wheat-based ethanol</td>
</tr>
<tr>
<td>HVO from Swedish tall oil</td>
<td>RME from Swedish rape seed</td>
</tr>
<tr>
<td>Fossil methane</td>
<td>Electricity(^a) based on the European electricity mix</td>
</tr>
<tr>
<td></td>
<td>Household waste-based Swedish biomethane</td>
</tr>
<tr>
<td></td>
<td>Manure-based Swedish biomethane</td>
</tr>
<tr>
<td></td>
<td>Food industry waste-based Swedish biomethane</td>
</tr>
<tr>
<td></td>
<td>Imported biomethane from crops</td>
</tr>
<tr>
<td></td>
<td>Imported Ethanol mix</td>
</tr>
<tr>
<td></td>
<td>Imported HVO(^d)</td>
</tr>
<tr>
<td></td>
<td>Imported RME</td>
</tr>
</tbody>
</table>

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\(^a\) Battery electric vehicles were assumed to be used.
\(^b\) Based on an average Swedish mix of biomethane, which is 43% imported manure-based biomethane, 24% Swedish biomethane from wastewater treatment, 19% Swedish household waste-based biomethane, 9% Swedish biomethane from food industry waste and 5% Swedish manure-based biomethane, deduced from the Swedish Energy Agency (2019a). 
\(^c\) Based on the way the average imported ethanol to Sweden is produced and sourced, which is ethanol from corn (Swedish Energy Agency, 2019b).
\(^d\) Based on how the largest part of imported HVO to Sweden is produced and sourced, namely, from palm fatty acid distillate (Swedish Energy Agency, 2019b).
Table 2
The criteria and indicators defined based on the Swedish environmental quality objectives.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced greenhouse gas emissions</td>
<td>Emissions of CO₂-equivalents during the life-cycle of the fuel</td>
</tr>
<tr>
<td>Improved air quality</td>
<td>Emissions of particulate matter during the operation of vehicles(^a)</td>
</tr>
<tr>
<td>Increased biodiversity and reduced eco-toxicity</td>
<td>Potential change in farmland able to grow organic crops due to an increased amount of available organically certified manure</td>
</tr>
<tr>
<td>Increased resource recycling and reuse</td>
<td>Potential reduction of pesticide use due to increased use of by-products from fuel generation</td>
</tr>
<tr>
<td>Reduced acidification</td>
<td>Increased amount of recycled or biologically treated waste</td>
</tr>
<tr>
<td>Reduced eutrophication</td>
<td>Emissions of SO₂-equivalents during the life-cycle of the fuel</td>
</tr>
<tr>
<td></td>
<td>Emissions of PO₄-equivalents during the life-cycle of the fuel</td>
</tr>
</tbody>
</table>

\(^a\) Emissions from fuel production and end-of-life treatment of batteries were omitted from this indicator due to those emissions generally occurring in places where air pollutants do less damage to human and ecosystem health, and the emissions being negligible when compared to emissions of particulate matter and nitrogen oxides during vehicle operations.

The assessment results were compiled in an Excel-file, including the data sources, the normative scale, and the criterion results. In addition, the price adjusting function was integrated in this file (see Eqs. (1) and (2)). This Excel-file was shared with all participants as well as all members of the regional cooperative organisation for renewable fuels and the National Biogas Research Center that were originally used to find participants.

3.7. An illustrative example of the tool’s application

This section aims to illustrate how the described tool could be used in practice through a hypothetical case where public organisation A wants to procure 10 buses for its operations. A first defines all the normal demands on the functionality of the vehicle so that the buses will suit its operations. After this, A may either (1) use the procurement tool’s database and assessments to define additional functional or technical criteria and choose the tender with the lowest price that fulfills those criteria or (2) use the procurement tool as a set of price adjusting criteria to adjust the incoming price of tenders and select the tender with the lowest adjusted price.

In the case of (1), the tool may be used to motivate why a certain fuel was chosen over other fuels, which can be specified as a technical criterion, for example, buses must run on ethanol. On the other hand, the tool may be used to motivate certain functional criteria, such as low emissions of particulate matter or greenhouse gases. Since public organisations in Sweden are tasked with working to fulfill the Swedish environmental quality objectives, understanding how fuel use impacts the objectives may provide well-motivated grounds for setting environmental performance criteria, which is important since many public organisations describe the fear of appeals as a barrier to GPP (Bratt et al., 2013).

If the tool is to be used as price adjusting criteria (2), A first needs to decide on the weights for the importance of environmental performance, and the relative importance of each criterion. For the sake of this example, A holds a workshop within the organisation, inviting elected politicians, procurement specialists, vehicle experts, and environmental and sustainability specialists. Together, they decide on the following weights: environmental performance is weighted at 40 percent, reduced greenhouse gas emissions at 1.0, improved air quality at 0.6, increased biodiversity and reduced eco-toxicity at 0.8, increased resource recycling and reuse at 0.5, reduced acidification at 0.4 and reduced eutrophication at 0.4. After the weights are set, the Excel sheet with the scale, scores and price-adjusting function is sent out (together with any minimum compliance criteria that are deemed relevant to the purchase of bus transport services) to any potential bidders so that they may test what fuel system will enable them to give their best offering. The fact that bidders can test their offerings to understand which of their offerings is the most favourable in the procurement enables transparency in the procurement process, something that was highlighted by Bernal et al. (2019) as a possible improvement proposal for future sustainable procurement practices.

In total, A receives three bids on its tender that can meet other minimum compliance criteria. The price and fuel systems are:\(^4\):

1. 5,100,000 € for buses running on ethanol, 10 percent of which can be sourced from Swedish origin
2. 7,000,000 € where eight buses run on electricity (Swedish mix) and two on imported RME
3. 5,500,000 € where five buses run on biomethane from the local sewage plant and five on imported HVO

Assuming that all buses within each tender use an equal amount of fuel during their lifetime (otherwise, the fuel use of each bus must be accounted for in order to find the correct fuel mix for the tender), the following calculations are made (Eqs. (3)–(5)):

The final adjusted price of each tender, in this case, becomes 5,089,820 € for the ethanol buses, 6,264,916 € for the electric and RME buses, and 4,954,955 € for the biomethane and HVO buses. With this, bid number 3—biomethane and HVO buses—wins the bid and is awarded the tender.

\(^4\) The prices and fuel systems are just arbitrarily chosen to show the function of the public procurement tool and in no way represent the actual price of buses with respective fuels.
4. Discussion

The method presented in the paper builds on the idea of integrating national environmental objectives in GPP, something recommended by, for example, Sparrevik et al. (2018), Cheng et al. (2018), and Lundberg et al. (2016) because it enables GPP to contribute towards long-term strategic objectives in a structured way, facilitating regional and local contributions to nationally set ambitions. The use of national environmental objectives also lends legitimacy to the procurement (assuming that the objectives were defined by an authority with high legitimacy). This legitimacy can aid public organisations if they need to motivate their criteria in the face of appeals or criticism. The process of creating tools based on national environmental objectives may be relatively straightforward if well-defined objectives and indices are available. The method requires the objectives to be sufficiently specific so that one may understand how to fulfil each objective. Otherwise, one may have to define how to measure and track progress within the objectives before the objectives can be translated into indicators and procurement criteria. If the objectives are incomplete in some way (for example, do not cover all environmental impact areas relevant to the selected alternatives), one could reconsider the choice of objectives, or add other relevant objectives or indicators. For example, noise pollution was not covered in the Swedish environmental quality objectives, although it is relevant to transportation. To consider noise pollution would be favourable to electric (and potentially gas) vehicles, since these vehicles have a lower noise footprint (see, e.g., Cucurachi et al., 2019; Pallas et al., 2016). We chose not to add a noise criterion, as it could lower the tool’s legitimacy gained from being fully based on the Swedish environmental quality objectives. However, it is of importance to be transparent in cases where there are such relevant gaps.

The aim of the method is to create easy to use and transparent tools, highlighted as a need to increase the uptake and effectiveness of GPP tools (Bernal et al., 2019; Söninchsen and Clement, 2020). Usability can be facilitated via the participatory elements of the method, including potential users in the process of creating the GPP tool. For example, the tool featured in this paper was developed together with stakeholders such as civil servants, procurers, environmental strategists, fuel producers, and transport solution providers, all providing input on the usability of the tool. The transparency, on the other hand, comes from the fact that all information is visible in the same place and that the result of offers is calculated irrespective of other potential offers, enabling bidders to understand how their offer will score prior to the finalization of the procurement. Hence, the tool provides knowledge on the environmental impact of fuel systems to both procurers and potential bidders, as data, references, and assessments are available to all actors. This ensures that the knowledge burden of understanding how products and services impact the environment is not shifted from one actor to another.

Tools developed with the method described in the paper should utilize life-cycle-based environmental performance data (as per recommendations by Cheng et al., 2018; Parikka-Alhola and Nissinen, 2012; Testa et al., 2016). This leads to more comprehensive assessments and thus decreases the risk that environmental impacts are unintentionally shifted from one part of the life-cycle to another part (Korhonen, 2004). However, this requires relevant and valid data, meaning that the data should be regularly revised to match new technologies, practices, and knowledge related to the environmental performance of various fuel systems. In addition, the scales used to score different fuel systems may also need to be updated to ensure that the tool spurs continued improvement.

One crucial part of the procurement process has been left out of the scope of this paper, namely, to follow-up the implementation of the tender. This needs to be done to ensure that what was agreed upon in the procurement is implemented. In the sector targeted by the tool developed in this paper, it would mean ensuring that vehicles procured run on the fuels agreed upon when the tender was awarded. Better monitoring of operations and compliance audits has been highlighted as a need in literature (Testa et al., 2016), however, it falls outside this paper’s scope. Even so, we want to stress the importance of compliance audits.

In the case study, the procurement tool provided relatively comprehensive information on the environmental performance of fuels such as biomethane, fossil diesel, electricity, ethanol, HVO, natural gas, and RME. It structures relevant information based on the Swedish national environmental quality objectives, providing an overview and knowledge about the environmental impact of transportation technologies. Clearly, there are several renewable alternatives on the market with a substantially lower environmental impact than fossil diesel and natural gas, regarding several essential indicators. However, the inclusion of a wide variety of environmental impact categories seems especially important for biomethane fuels systems to comprise the wide array of environmental effects that can be related to them. Their inherent multidimensionality (Dahlgren, 2019; Hagman, 2018) means that they contributed towards fulfilling many of the national Swedish environmental objectives. Other waste-based biofuels also appeared to be well aligned with these objectives. Crop-based alternatives, on the other hand, had a worse performance, although this is dependent on the type of crop and agricultural system behind it. Electric vehicles brought improved air quality in urban areas, but the score of these solutions depended on the source of the electricity, where renewable sources, or other low carbon alternatives, had a good performance. However, the electric fuel systems suffered from poor
<table>
<thead>
<tr>
<th>Large positive effect</th>
<th>Small positive effect</th>
<th>Negligible effect</th>
<th>Small negative effect</th>
<th>Large negative effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced climate change</td>
<td>More than 70% reduction compared to fossil reference</td>
<td>21–70% reduction compared to fossil reference</td>
<td>0–20% reduction or increase compared to fossil reference</td>
<td>21–70% increase compared to fossil reference</td>
</tr>
<tr>
<td>Improved air quality</td>
<td>Significant NOx and Particulate matter emissions reduction (roughly more than 50%) during operation of the vehicles</td>
<td>Significant NOx or Particulate matter emissions reduction (roughly more than 50%) during operation of the vehicles</td>
<td>No or negligible difference in NOx or Particulate matter emissions compared to fossil reference during operation of the vehicles</td>
<td>Significant NOx or Particulate matter emissions increase (roughly more than 50%) during operation of the vehicles</td>
</tr>
<tr>
<td>Increased biodiversity and reduced eco-toxicity</td>
<td>The life-cycle of the fuel system generates by-products that may be used in ecological farming and reduces the need for pesticides</td>
<td>The life-cycle of the fuel system generates by-products that may be used in ecological farming or reduces the need for pesticides</td>
<td>None or negligible impact compared to reference fuel system (fossil diesel)</td>
<td>The life-cycle of the fuel system reduces the possibility of ecological farming and increases the need for pesticides</td>
</tr>
<tr>
<td>Increased resource recycling and reuse</td>
<td>Close to all the input into the production of the fuel and its by-products is done with waste classified material or close to all critical materials required in the fuel system life-cycle is recycled or reused after use</td>
<td>The majority of the input into the production of the fuel and its by-products is done with waste classified material, or the majority of critical materials required in the fuel system life-cycle is recycled or reused after use</td>
<td>Does not meet requirements for small positive or negative impact (nor large positive or negative impact)</td>
<td>The life-cycle of the fuel system requires an increase in the use of critical materials and only a small part (roughly less than 10%) of the critical materials are recycled or reused after use</td>
</tr>
<tr>
<td>Reduced acidification</td>
<td>Significant reduction (roughly more than 50%) of SO2-equivalents during the life-cycle of the fuel system compared to fossil reference</td>
<td>Reduction (roughly between 10 and 50%) of SO2-equivalents during the life-cycle of the fuel system compared to fossil reference</td>
<td>None or negligible increase or reduction of SO2-equivalents compared to fossil reference</td>
<td>Increase (roughly between 10 and 50%) of SO2-equivalents during the life-cycle of the fuel system compared to fossil reference</td>
</tr>
<tr>
<td>Reduced eutrophication</td>
<td>Significant reduction (roughly more than 50%) of PO4-equivalents during the life-cycle of the fuel system compared to fossil reference</td>
<td>Reduction (roughly between 10 and 50%) of PO4-equivalents during the life-cycle of the fuel system compared to fossil reference</td>
<td>None or negligible increase or reduction of PO4-equivalents compared to fossil reference</td>
<td>Increase (roughly between 10 and 50%) of PO4-equivalents during the life-cycle of the fuel system compared to fossil reference</td>
</tr>
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* Compared to material required in the reference fuel system.
recycling infrastructure for batteries (Gradin et al., 2018; Mayyas et al., 2019).

5. Conclusions

This paper has described a method for the development of GPP tools that enable the assessment of different tenders with respect to...
their contribution to the fulfilment of national environmental objectives. This offers a tangible way for local and regional public authorities to work towards the fulfilment of national environmental objectives, enabling procurement processes to contribute systematically towards nations’ long-term strategic environmental work. This paper contributes to the, so far sparse, literature on dedicated GPP tools for criteria identification and formulation. The method presented has been applied to develop a public procurement tool that is able to assess public transportation tenders based on the Swedish environmental quality objectives, providing knowledge and guidance to Swedish public organisations that aim to procure more environmentally friendly transportation services. The tool can be used either as a body of knowledge to support formulation of minimum compliance criteria (either functional or technical criteria) or as a set of award criteria that adjust the price of incoming tenders. In the exemplifying case, 18 different fuel systems were evaluated in relation to six criteria (and eight indicators), where each fuel system was defined as a mix of different input materials, fuel types and geographical origins. Hence, allowing for procurement that contributes towards the Swedish environmental quality objectives in a cost-effective way without locking public transport buyers into one particular fuel. The developed tool contributes to broad environmental assessments (and procurements), which is essential to better cover all relevant environmental impacts and more fairly judge alternative technologies when compared to a narrow assessment. For example, biomethane solutions may be linked to a wide array of positive environmental effects that one fails to account for using a narrower climate-focused approach, which has been the main approach of Swedish transport procurement so far.

In the future the method should be applied to other geographical, political, and technical context to verify the extent of its transferability. Future studies may want to investigate to what extent the method must be adapted to fit different contexts and how flexible it is in its adaption. In addition, investigation into the application and use of the tools created with the method may provide insights into how to improve the method in order to further refine the usability and relevance of the tools that are created using it. When it comes to dedicated GPP tools in general, many interesting avenues remain unexplored. For example, studies critically reviewing current available GPP tools and guidelines could offer support to the development of new tools and the refinement of existing ones. Moreover, studies focusing on the impact of using GPP tools in procurement processes are needed. These studies should preferably focus on the quality of environmental criteria used and the outcome of these tenders, that is, did the use of GPP tools lead to an increase of green technologies being purchased and if so, in what way do these green technologies reduce environmental impact?

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Appendix A. Supplementary data

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References


CRediT authorship contribution statement

Axel Lindfors: Conceptualization, Methodology, Software, Investigation, Writing - original draft, Writing - review & editing.

Jonas Ammenberg: Conceptualization, Methodology, Supervision, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.