Quantifying biodiversity

Experiences from five years of using the biotope method, a tool for quantitative biodiversity impact assessment

Bernt Rydgren, Lasse Kyläkorpi, Birgit Bodlund, Anders Ellegård, Eva Grusell and Sofia Miliander

The biotope method was developed to provide biodiversity impact quantification in life-cycle inventory and assessment studies of energy generation. It is based on measurements of land-use induced biotope alterations, which are considered representative of the impact on biodiversity and facilitate measurements of, and comparisons among, different projects. It includes tools necessary for classifying and characterising the areas affected, and results in transparent, quantitative data. During the past five years, the method has been applied on various energy production systems. The results of these applications are analysed and compared, and suggestions for further methodology development are discussed.

Keywords: biodiversity; electricity; energy; life-cycle assessment; environmental product declaration

In the early 1990s, the Vattenfall Group in Sweden decided to start working with life-cycle inventories, as one method to assess and control its environmental impact and performance. In 1997, the time had come to refine this approach further, and work started on what was to become the world’s first third-party-certified environmental product declaration (EPD®), in accordance with ISO standards (what later evolved into ISO TR 14025).

Sweden is, thus far, the only country in which Vattenfall has implemented EPD®s and used the biotope method. Approximately 75% of Vattenfall’s Swedish electricity generation is EPD® certified. This represents just over 12,000 MW of installed capacity and around 66.5 TWh of annual energy generation, just under half of Sweden’s total.

The PSR (product-specific requirements) (Swedish Environmental Management Council, 2004) for electricity generation demand attention to biodiversity, but without specific mention of methodology or approach. However, given the public’s perception of the environmental impact of the power sector, Vattenfall decided that no presentation of environmental performance could be considered complete without both quantitative and qualitative attention to biodiversity impacts.

Unfortunately, a review of available quantitative methods revealed a complete lack of suitable ‘off-the-shelf’ tools for this purpose. It was concluded that, to pay the attention to biodiversity that it deserves, it would be necessary to develop a specific experimental method within the Vattenfall
The biotope method

The method was named the biotope method. Its scientific basis is measurements of habitat alterations resulting from land-use changes caused by the development of one or several power-generating facilities under study. These alterations are used as a measure of the impact on biodiversity. The method includes tools necessary for the classification and characterisation of the areas affected, and results in transparent, replicable and quantitative data. The results are related to the amount of produced good (here electric energy or heat), thus enabling comparisons among different developments, such as power stations or power systems.

The biotope method considers impacts on biodiversity that can be directly related to a specific activity. Indirect or derived impacts, such as fragmentation and barrier effects, are outside the scope of the method.

Biotopes are characterised as follows:

- critical biotope is one that harbours, or has potential to harbour, red-listed species;
- rare biotope is one that deviates from surrounding areas by high species diversity, a profusion of regionally rare species or by an abundance of key features;
- general biotope covers those that cannot be put in any of the other categories;
- biotope loss refers to areas lacking the preconditions for biological production (for instance, paved areas or buildings).

In brief, the method specifies an area assessment and delineation of biotopes/habitats with concomitant classification and characterisation. With the aid of geographic information systems (GIS) or similar analytical methods, supported by surveys and ground-truthing (checking that an interpretation made from aerial photographs or satellite images is correct), the areas are divided into the four basic categories defined above. The categories relate to the identified areas' actual documented or potential ability to harbour red-listed species, or the existence of environmental features particularly favourable to high biodiversity, such as waterfalls and rapids, old trees and wetlands.

This exercise is carried out for both the pre-project and the post-project situations, the before and after situations. A simple subtraction between the after and the before results yields a quantitative measure of impacts on biodiversity. The method allows for several different quality levels to be adopted, depending on the quality and detail of the information available/gathered. Lower quality levels are punished by erring on the side of safety, resulting in much less favourable results.

Figure 1 presents an outline of how the distribution of different biotope categories may be changed by a project (these are arbitrary changes shown for illustrative purposes).

For a detailed description of the method, see Blümer and Kyläkorpi (2001a). The method was presented at IAIA 99 in Glasgow, Scotland (Blümer et al., 1999) and has subsequently undergone several refinements. A new version is expected to be finished in 2005.

After about five years of using the method, the decision has been taken to re-evaluate the results and experiences. An ambitious plan for revision and improvement has been identified, aiming to achieve better accuracy and also a method that can be used as a comprehensive tool in environmental impact assessments (EIAs).

Application to electricity generation

During the past five years, a number of methodological applications and studies for various electricity- and heat-generation technologies (hydropower, nuclear power, wind power, waste incineration and forestry residues for biomass-based electricity generation) have been conducted. In the results presented in Tables 1–7, the full accuracy of the original study is presented in the area columns, while in the columns denoting impact per functional unit (kWh or kg of incinerated waste) for consistency the results are presented rounded off to two value figures.
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**Hydropower**

For hydropower in Sweden, all relevant assessments for the Vattenfall Group are of the post-project type. Most hydropower in Sweden was developed in the period 1950–1980. The system boundaries play a major role in the interpretation of any such assessment, since most Swedish rivers, and all the ones subjected to major hydropower development, were strongly affected by many prior land and water-resource uses. The most prominent was the forestry-related floating of timber down the rivers.

These activities lead to extensive and often almost complete ‘cleaning’ of the utilised rivers, resulting in the removal of many ecologically valuable sections. “Even many smaller streams were affected by the floating; common activities included the construction of small dams, clearing activities as well as the spraying of shorelines with herbicides” (translated quote from Östlund (1997)).

To facilitate the adaptation of the method, a technology-specific guideline was developed for hydropower (Blümer and Kyläkorpi, 2001b). In accordance with the methodology, the impacts of the hydropower activities were analysed with the above mentioned damage as a baseline — the before situation.

Classification of the areas can be rather difficult, primarily in the before case, given that the aerial photos available from the 1940s and 1950s are often of inferior quality. However, many of the hydropower development projects in Sweden were predated by very detailed ecological (mainly floristic) surveys, making the task somewhat easier. In order to deal with poor data in the before case, the best choice has often been the production of area-specific standard charts, lists that detail what category a particular biotope/habitat belongs to in the general setting of the studied area (see Blümer and Kyläkorpi, 2001a).

A special case with hydropower applications is that it is generally (particularly in extensively developed rivers, as in Sweden) wrong to relate the resulting biotope changes to the electricity output of an individual power station. The reason for this is that some dams and reservoirs have huge impacts but also provide a storage function for other plants, enabling the latter to generate much more electricity than would have been possible otherwise. Thus, for hydropower, it is often necessary to study an entire river system, and report impacts relative to functional units based on all power stations located in that system.

Hydropower was the first power source to be studied, and Vattenfall now has two major river systems, the Lule and Ume, analysed with the method. The results are now part of EPD®s (see above), for both rivers and can be viewed in Tables 1 and 2.

**Nuclear power**

Two of Vattenfall’s nuclear power plants have been analysed with the method as part of EPD®s: Forsmark on the east coast, approximately 100 km north...
of Stockholm (see Table 3); and Ringhals on the west coast, approximately 50 km south of Gothenburg (see Table 4).

The PSR for the EPD® work demands attention to the entire fuel cycle, an approach adhered to in the applications of the biotope method. This means that, in these applications, studies have been performed for the uranium supply (mining sites), conversion and enrichment facilities, fuel fabrication, the power plants and the waste-management sites.

Because of the complexity of the fuel cycle, different approaches have been used. As an example, the deep repository for spent nuclear fuel is yet to be built. Here, data from the available feasibility studies have been used to predict the land area needed for the facility. These data have only been used for discussing relative magnitudes of land use, and not as part of the final applications presented. Also, for most of the conversion and enrichment facilities, only data on land use have been available for the study, and they have therefore been left out of the final application.

However, when studying the magnitude of allocated land area, sufficient data on some 97% of the utilised area (the power plants and mining operations clearly dominate) has been available. Hence the conclusion is that the results still give a reasonably good picture of the area-dependent quantitative impact.

A designated application guideline for nuclear power plants (or rather for the nuclear fuel chain), is yet to be developed.

**Wind power**

Regarding wind power, Vattenfall has one EPD®, representative of all the company’s wind-power generation (see Table 5). This was conducted by analysing three typical wind plants and farms, located on the west and east coasts and in the northern mountains. For this purpose, a specific guideline was developed (Kyläkorpi, 2003). Here, a slightly different approach to the before situation is suggested. Most of the wind-power plants are recently constructed, and the land use is normally very limited. Therefore, the study focused on the area immediately adjacent to the plants and access roads and, based on what was found there, the classification and characterisation steps were performed. It is assumed that this approach also gives a relevant picture of the before situation.

The definition of affected area in the case of wind power is one that can cause major discussions. The approach here is to assess and report only those areas with irrevocable land-use changes (not areas located between towers, which clearly have their

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**Table 3. Results for Forsmark nuclear power plant**

<table>
<thead>
<tr>
<th>Category</th>
<th>Baseline – pre</th>
<th>Present – post</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ha m²/kWh</td>
<td>ha m²/kWh</td>
<td>ha m²/kWh</td>
</tr>
<tr>
<td>Biotope loss</td>
<td>0.06 0.026 x 10⁻⁶</td>
<td>11.8 5.1 x 10⁻⁶</td>
<td>+11.8 +5.1 x 10⁻⁶</td>
</tr>
<tr>
<td>Critical biotopes</td>
<td>2.9 1.3 x 10⁻⁶</td>
<td>0</td>
<td>-2.9 -1.3 x 10⁻⁶</td>
</tr>
<tr>
<td>Rare biotopes</td>
<td>2.9 1.3 x 10⁻⁶</td>
<td>0</td>
<td>-2.9 -1.3 x 10⁻⁶</td>
</tr>
<tr>
<td>General biotopes</td>
<td>34.8 15 x 10⁻⁶</td>
<td>29.0 12 x 10⁻⁶</td>
<td>-5.8 -2.5 x 10⁻⁶</td>
</tr>
</tbody>
</table>

**Table 4. Results for Ringhals nuclear power plant**

<table>
<thead>
<tr>
<th>Category</th>
<th>Baseline – pre</th>
<th>Present – post</th>
<th>Difference</th>
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<tr>
<td></td>
<td>ha m²/kWh</td>
<td>ha m²/kWh</td>
<td>ha m²/kWh</td>
</tr>
<tr>
<td>Biotope loss</td>
<td>0.1 0.040 x 10⁻⁶</td>
<td>14.8 5.9 x 10⁻⁶</td>
<td>+14.7 +5.8 x 10⁻⁶</td>
</tr>
<tr>
<td>Critical biotopes</td>
<td>3.8 1.5 x 10⁻⁶</td>
<td>0</td>
<td>-3.8 -1.5 x 10⁻⁶</td>
</tr>
<tr>
<td>Rare biotopes</td>
<td>4.9 1.9 x 10⁻⁶</td>
<td>0.7 0.28 x 10⁻⁶</td>
<td>-4.2 -1.7 x 10⁻⁶</td>
</tr>
<tr>
<td>General biotopes</td>
<td>43.2 17 x 10⁻⁶</td>
<td>36.5 14 x 10⁻⁶</td>
<td>-6.7 -2.7 x 10⁻⁶</td>
</tr>
</tbody>
</table>

**Table 5. Results for Vattenfall’s wind power plants**

<table>
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<tr>
<th>Category</th>
<th>Baseline – pre</th>
<th>Present – post</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m² m²/kWh</td>
<td>m² m²/kWh</td>
<td>m² m²/kWh</td>
</tr>
<tr>
<td>Biotope loss</td>
<td>300 1.1 x 10⁻⁵</td>
<td>15160 56 x 10⁻⁶</td>
<td>+14860 +55 x 10⁻⁶</td>
</tr>
<tr>
<td>Critical biotopes</td>
<td>1800 6.6 x 10⁻⁵</td>
<td>0</td>
<td>-1800 -6.6 x 10⁻⁵</td>
</tr>
<tr>
<td>Rare biotopes</td>
<td>2160 7.9 x 10⁻⁵</td>
<td>0</td>
<td>-2160 -7.9 x 10⁻⁵</td>
</tr>
<tr>
<td>General biotopes</td>
<td>10940 40 x 10⁻⁵</td>
<td>40 0.15 x 10⁻⁶</td>
<td>-10900 -40 x 10⁻⁵</td>
</tr>
</tbody>
</table>
usefulness restricted by the constructions), since this is considered to be in analogy with the system boundaries applied, for instance, for hydropower, where down-stream and other off-site impacts are not assessed.

**Waste incineration**

The method has been applied to Vattenfall’s waste incineration plant in Uppsalan, unit 5 (see Table 6). It is a pre-project assessment on a plant expected to come into service in 2005.

The technology-specific guideline (Grusell, 2003) for this application of the biotope method is truly specific. After discussion with some of Europe’s most experienced LCI/LCA (life-cycle inventory/life-cycle assessment) experts, it was determined that in a waste-incineration plant, in which the heat, a by-product of the incineration, is used in the district-heating grid in the city where the plant is located, the heat is not the primary product, and thus kWh of heat should not be the functional unit. The functional unit is, instead, the amount of waste incinerated. The ‘manufacturing’ of the waste is outside the system boundaries. This approach has also been adopted in the PSR.

The waste-incineration plant shares several functions related to land use with many other installations and activities. When these other actors are energy-generation installations, the electricity-generation capacity of each activity has been used for allocation of impact. For the remaining, non-electricity-generating activities, the share of total utilised area has been the basis for allocation. The ash deposit is considered a biotope loss, given the temporary nature of vegetation colonisation. However, in the future, once the deposit is taken out of operation and rehabilitated, permanent vegetation can be established, or will establish itself, and an environment that is likely to be classified as general biotope will develop.

**Forestry residues/biomass power**

It has not yet been possible to analyse any biomass-fuelled power plant with the method, but in anticipation of this need a technology-specific guideline for this purpose has been developed (Blümer and Kyläköri, 2001c).

**Transmission rights of way**

It has not yet been possible to analyse any transmission rights-of-way (ROWs), for inclusion into a separate EPD®, but the method has been applied to transmission corridors on a number of occasions, for other purposes. A technology-specific guideline for ROWs has been developed (Blümer and Kyläköri, 2001d).

The existing applications have been partly as student theses projects (see Mårs (1999) and Åslund (2000)), or in one case as a commissioned study from the transmission and distribution arm of the Vattenfall Group in Sweden (Kyläköri and Grusell, 2001).

The special conditions of ROWs primarily concern some unexpected effects of their meadow-like management. In Sweden, traditionally managed grazing land harbours a rich biodiversity dependent on their open nature, grazing animals and recurrent cutting/clearing of woody vegetation. Lately, with growing pressure on agriculture for more efficient production, resulting in larger production units and the closure of many small farming enterprises, much of this meadow land has either been planted with ‘productive’ trees for forestry, or simply allowed to revert to bush and, ultimately, natural forest successions. Many of the red-listed species in Sweden are associated with these meadows.

The most interesting biodiversity-relevant findings of the ROWs was that they mimic the ecological function of meadows, and can even act as corridors between the remaining ‘real’ meadow areas. The very high fraction of ROWs that consist of edge zones further enhance their capacity to support a particular type of flora and fauna. For details of these studies, see Kyläköri and Gärdenäs (1997) and Kyläköri and Grusell (2001).

**Comparative results**

The results of the applications on different power- and heat-generating technologies vary quite markedly and, perhaps for some, in a surprising way. If, for example, we compare the impact on critical and rare biotopes, wind power has far worse results than nuclear power. In Table 7, the net impact on the different biotope categories from the tables above (with the same functional unit), is summarised. The results

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**Table 6. Results for the Uppsala unit five waste incineration plant**

<table>
<thead>
<tr>
<th>Category</th>
<th>Baseline – pre</th>
<th>Present – post</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m²</td>
<td>m²/kg</td>
<td>m²</td>
</tr>
<tr>
<td>Biotope loss</td>
<td>73088</td>
<td>1.1 × 10⁻⁶</td>
<td>78564</td>
</tr>
<tr>
<td>Critical biotopes</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rare biotopes</td>
<td>1158</td>
<td>0.17 × 10⁻⁶</td>
<td>1158</td>
</tr>
<tr>
<td>General biotopes</td>
<td>7534</td>
<td>1.1 × 10⁻⁶</td>
<td>2058</td>
</tr>
</tbody>
</table>

*Note: The functional unit here is not kWh, but rather kg of incinerated waste*
Discussion

There are many problems and issues that could and/or should be debated concerning the biotope method. It is, however, of the utmost importance to remember that there seems to be a never-ending call for methods that do deal with quantification of biodiversity in an affordable and reasonably rapid manner, particularly in an EIA context (exemplified by, for instance, de Jong et al (2004), and Stockwell (undated), but also represented by just about every multilateral development bank and bilateral development agency). Somewhat harshly we could say that if we do not at least try quantification, we allow economists to set default (monetary) values of biodiversity to zero. It is this need that the continued development of the biotope method tries to respond to, if only partially.

A few issues, deserving of special attention, are elaborated below.

System boundaries

There are many details surrounding the larger complex of system boundaries that could be discussed. Indeed, from an EIA practitioner’s point of view we might say that it is too limiting, and prone to externalising many important significant impacts. However, even in traditional EIA, there is a distinct element of boundary setting. Rather than attending to all global repercussions of the project under study, practitioners define, for instance, an impact area, a concept that is, in most cases, an over-simplification of the problem at hand. It is in fact the very same simplification as that introduced by system boundaries in an LCA.

There are two really serious problems with the way in which the system boundary concept is currently defined in the biotope method. One is the technically derived length of the life cycle, the other is the focus on the immediate project/installation site.
Another issue that deserves special attention is the choice of indicators. The primary one is red-listed species and a secondary one is key environmental features (as mapped by official conservation bodies in Sweden). Red-listed or, more broadly, threatened species are very questionable as indicators of ecosystem response to change.

A multitude of authors have debated this issue (for instance, Treweek, 1999), but there is no general consensus on what is best for which situation. De Jong et al (2004) discussed the issue in the Swedish context, and pointed out that certain directives of a multinational nature can sometimes even distort the use of red-lists, since the directives do not differentiate between regional and local rarity. Vattenfall aims to address this issue with a comprehensive literature review and may change the approach currently adopted.

**Use in EIA**

Apart from the work carried out on the LCA/EPD applications, Vattenfall also carries out many EIA studies every year. As mentioned above, there is agreement in the research community that quantitative assessment of biodiversity impact is still poorly addressed in most EIAs. Given Vattenfall’s positive experiences from using the biotope method so far, the intention is to try to adapt it for use also in an EIA context.

For this use, several steps will need to be added to achieve an acceptable level of prediction. The method’s strength in this context is its simplicity and strong emphasis on aerial photographs, GIS technology, and so on. This renders it an excellent presentation tool, easy to understand for non-expert readers.

However, the problem is the landscape (or off-site) perspective. The method cannot satisfactorily, in its present form, deal with extremely important biodiversity concepts, such as (but not limited to) fragmentation, barriers, edge effects, cumulative effects, and maybe most importantly, thresholds and ecosystem functionality (the two last are dependent on many of the previously mentioned issues). To address this problem, the intention is to combine a qualitative–quantitative hybrid approach with an application at different levels of resolution of the method. This would then be conceptually similar to a more traditional transect-surveys approach that utilises a higher density of transects in the principal direct-impact areas.

**Conclusions**

When the biotope method was first developed it was, arguably, the first easily applicable biodiversity assessment method for use in LCIs/LCAs.

The main problem with it is the inherent conflict between simplicity and scientific ‘correctness’, that is, some sort of ‘true’ but practically unattainable answer. This is, however, a problem the method has in common with most practically useful assessment methods, for example, the rapid biodiversity assessment approaches. Rapid rural appraisal (RRA), and its ‘successor’ PRA (participatory RA), are other examples of a similar kind, from a different but equally difficult area of comprehensive impact assessment work.

Off-site impacts, and thus actual total project impacts, are not dealt with in depth. This is a result of the LCA-adapted system boundary choices of the method. The method is, therefore, currently not directly suitable for use in EIA, primarily because of problems with application and validity at landscape level. The intention is to address this with methodology development in the near future.

In the context of LCI/LCA, the method is considered quite satisfactory, given the focus on quantitative assessment and actual numbers in technology assessments.

**Notes**

1. Now one of Europe’s largest power utilities with substantial assets in several countries in northern Europe.
2. Biotope, as used here, has the same meaning as habitat. The reason for the use of biotope is linguistic — the method was named in Swedish first, and there the word of choice corresponds to biotope.
3. Fragmentation impacts may occur when a large area/biotope is subdivided into smaller units. This may create a situation in which certain species have insufficiently large continuous areas, even though the total area remains satisfactory.
4. Barrier effects may occur when a physical barrier (such as a railway, transmission line corridor or road) prohibits contact among sub-populations. This may lead to insufficient genetic exchange among sub-populations.

**References**


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Further reading


