Quantitative Biodiversity Impact Assessment: Five Years of Using the Biotope Method

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Abstract

In 1999, a method for biodiversity impact assessment was developed in order to handle biodiversity impacts into quantitative environmental product declarations. The method was named *the Biotope Method* and is based on measurements of land use-induced biotope alterations. These alterations are considered representative of the impact on biodiversity, and facilitate quantitative measurements of and comparisons between different projects, e.g. power developments. The method includes tools necessary for classification and characterisation of the areas affected, and results in transparent and quantitative data. The results are related to the amount of produced good (here: electricity), thus enabling comparisons between different developments such as power stations or power systems.
During the past five years, a number of method applications on various energy production systems, such as hydro, nuclear and wind power, have been conducted. In this paper, the results of these applications are analysed and compared, and suggestions for further methodology development and other possible applications are discussed.

Introduction

In the early 1990s, the Vattenfall Group[1] 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. 75% of Vattenfall's Swedish electricity generation is EPD® certified.

The PSR (Product-Specific Requirements, The Swedish Environmental Management Council, 2001), for electricity generation demand attention to biodiversity, but without specific mention of methodology or even 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 methods revealed a complete lack of suitable

[1] Now one of Europe's largest power utilities with substantial assets in several countries in northern Europe

"off-the-shelf" methods for this purpose. For this reason, Vattenfall decided to develop an experimental method, to be tried out in conjunction with the EPD® work.

The first EPD® was developed for hydropower from a river in northern Sweden, Lule river. Thus, hydropower was the point of departure for our methodology development, but from the outset we were aiming for a method that, with minor adjustments, could be applied to as wide a variety of electricity- and heat-generating technologies as possible.

The Biotope Method

The method was named the ***Biotope Method***[2]. It's scientific basis is measurements of biotope alterations resulting from land use changes caused by the development of one or several power-generating facilities under study. These alterations are used as an indicator 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), thus enabling comparisons between different developments, such as power stations or power systems.

In brief, the method specifies an area assessment and delineation of biotopes/habitats with concomitant classification and characterisation. The areas are divided into fours basic categories: *critical, rare and general biotopes* plus *biotope* loss. 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. This exercise is carried out for both the pre-project and the post-project situations, the *before* and *after* situations in the method. 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 of the study.

For a detailed description of the method, please see Blümer and Kyläkorpi, 2001a. The method was introduced at IAIA 99 in Glasgow, Scotland (Blümer, Kyläkorpi and Rydgren, 1999). It has, however been amended since, and the presently valid methodology guideline is the first reference above.

Application to different electricity-generating technologies

During the past five years, a number of methodological applications to various electricity generation technologies (i.e. hydropower, nuclear power, wind power, waste incineration and forestry residues for biomass-based electricity generation), have been conducted.

Hydropower

In the case of 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 from 1950 to 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 other

[2] *Biotope*, in our use here, has the same meaning as *habitat*

land and resource uses. The most prominent was the forestry-related floating of timber down the rivers. This activity lead to extensive and often almost complete "cleaning" of the utilised rivers. This lead to the almost complete removal of all ecologically valuable sections of the rivers. "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 damages 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 are often of less than stellar quality. However, many of the hydropower development projects in Sweden were predated by very detailed ecological surveys, making the task somewhat easier.

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

The main problem with application of the method to hydropower in Sweden has been the information quality in the *before* case. This means that 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 studied area (see Blümer & Kyläkorpi, 2001).

A special case with hydropower applications is that it is generally (particularly in extensively developed rivers, such as the case is in Sweden), wrong to relate the resulting biotope changes to the electricity output of an individual power station. The reason for this is obvious – some dams and reservoirs have huge impacts but also act as storage for other plants, enabling the latter to generate much more electricity than would have been possible without the storage function carried by other installations. 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.

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 of Sweden (just north of Stockholm), and Ringhals on the west coast, some distance south of Gothenburg.

The PSR demands attention to the entire fuel cycle, and when applying the Biotope Method we have chosen to do the same. This means that in these applications, studies have been performed for the uranium suppliers (mining sites), conversion and enrichment facilities, fuel fabrication, the power plants as well as the waste-management sites.

Because of the complexity of the fuel cycle, different approaches have been used. E.g., the deep repository for spent nuclear fuel is yet to be built. Here we have used data from the available feasibility studies in order to predict the land area needed for the facility. This figure has only been used for discussing relative magnitudes of land use, and not as a part of the final applications. Also, for most of the conversion and enrichment facilities, only figures 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, we have sufficient data on some 97% of the utilised area (the power plants and the mining operations clearly dominate). Hence we claim 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. This was conducted by analysing three typical wind plants and farms, located respectively 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 for the before situation is suggested. Most of the wind-power plants are recently constructed, and the land use is normally very limited. Therefore, we have chosen to study the area immediately adjacent to the plants and access roads, and thereby perform the classification and characterisation steps. We believe that this approach gives a relevant picture also of the before situation.

The definition of affected area in the case of wind power is one which can cause major discussions. We have chosen to assess and report only those areas with irrevocable land use changes (i.e., not areas located between towers, areas which clearly have their usefulness somewhat restricted by the constructions), since we consider this to be in analogy with the system boundaries applied, e.g. 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 Uppsala, unit 5. 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 experts, it was determined that in a waste-incineration plant, where the heat from 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 cannot be the functional unit. The functional unit is, instead, the incinerated amount of waste. The "manufacturing" of the waste is outside of the system boundaries. This approach has been adopted in the PSR as well.

The unit shares several functions related to land use with many other installations and activities. When these other actors are energy generation installations, the capacity has been used for allocation of impact. For other 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. Once the deposit is taken out of operation and rehabilitated, permanent vegetation can establish itself and an environmental that will likely be classified as general biotope will develop.

Forestry residues/Biomass power

We have not yet had the opportunity to analyse any biomass-fuelled power plant with the method, but in anticipation of this need we have developed a technology-specific guideline for this purpose (Blümer and Kyläkorpi, 2001c).

Transmission ROWs

We have not yet had the opportunity to analyse any transmission ROWs for inclusion into a separate EPD®, but the method has been applied to transmission corridors on a number of occasions, for other purposes. There is a technology-specific guideline also for this purpose (Blümer and Kyläkorpi, 2001d).

The existing applications have been partly as student theses projects, or in one case as a special commissioned study from the transmission and distribution arm of the Vattenfall Group.

The special conditions in the case of ROWs primarily concern some unexpected effects of their meadow-like management. In Sweden, traditionally managed grazing land have come to harbour a rich biodiversity dependent on their open nature and recurrent cutting/clearing of woody vegetation. Lately, with growing pressure on agriculture for more efficient production, resulting in larger production units, 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 connected to these meadows. What we found in our studies of the ROWs was that they clearly mimic the function of meadows, and can even function as corridors between the remaining "real" meadow areas. The very high fraction of the ROWs that consist of edge zones further enhance their nature as zones capable of supporting a very particular type of flora and fauna.

Comparative results

Note that the results below in the columns denoting m^2/kWh, are rounded off to two value figures. This means that the sums do not always add up correctly. Note also that the numbers denote changes in area, e.g. that a positive number for Biotope Loss is a negative impact, and the same applies to a negative number for Critical Biotopes.

Hydropower

Lule river:

Category	Baseline – pre		Present – post		Difference	
	ha	m^2/kWh	ha	m^2/kWh	ha	m^2/kWh
Biotope Loss	0	0	6 895.5	150 x 10^{-6}	6900	150 x 10^{-6}
Critical Biotopes	5 797.3	130 x 10^{-6}	0.9	0.020 x 10^{-6}	-5800	-130 x 10^{-6}
Rare Biotopes	983.4	22 x 10^{-6}	1.6	0.036 x 10^{-6}	-980	-22 x 10^{-6}
General Biotopes	3571.4	79 x 10^{-6}	3454.0	77 x 10^{-6}	-117.4	2.6 x 10^{-6}

Ume river:

Category	Baseline – pre		Present – post		Difference	
	ha	m^2/kWh	ha	m^2/kWh	ha	m^2/kWh
Biotope Loss	0	0	9 161.3	330 x 10^{-6}	9 161.3	330 x 10^{-6}
Critical Biotopes	8 658.3	320 x 10^{-6}	331.4	12 x 10^{-6}	-8 326.9	-310 x 10^{-6}
Rare Biotopes	8 410.8	310 x 10^{-6}	26	0.95 x 10^{-6}	8 384.8	-310 x 10^{-6}
General Biotopes	12 442.5	460 x 10^{-6}	19 992.8	740 x 10^{-6}	7 550.3	280 x 10^{-6}

Nuclear power

Forsmark:

Category	Baseline – pre		Present – post		Difference	
	ha	m^2/kWh	ha	m^2/kWh	ha	m^2/kWh
Biotope Loss	0.050	0.021×10^{-6}	3.290	1.4×10^{6}	3.240	1.4×10^{-6}
Critical Biotopes	0.036	0.015×10^{-6}	0	0	-0.036	-0.015×10^{-6}
Rare Biotopes	0.036	0.015×10^{-6}	0	0	-0.036	-0.015×10^{-6}
General Biotopes	31.496	13×10^{-6}	28.328	12×10^{6}	-3.168	-1.4×10^{-6}

Ringhals:

Category	Baseline – pre		Present – post		Difference	
	ha	m^2/kWh	ha	m^2/kWh	ha	m^2/kWh
Biotope Loss	0.1	0.040×10^{-6}	8.848	3.5×10^{6}	8.748	3.5×10^{-6}
Critical Biotopes	1.951	0.77×10^{-6}	0	0	-1.951	$- 0.77 \times 10^{-6}$
Rare Biotopes	3.051	1.2×10^{-6}	0.7	0.28×10^{6}	-2.351	-0.93×10^{-6}
General Biotopes	41.426	16×10^{-6}	36.981	15×10^{6}	-4.445	-1.8×10^{-6}

Wind power

Category	Baseline – pre		Present – post		Difference	
	m^2	m^2/kWh	m^2	m^2/kWh	m^2	m^2/kWh
Biotope Loss	300	1.1×10^{-6}	15 160	56×10^{6}	+14 900	$+55 \times 10^{-6}$
Critical Biotopes	1 800	6.6×10^{-6}	0	0	-1 800	-6.6×10^{-6}
Rare Biotopes	2 160	7.9×10^{-6}	0	0	-2 160	-7.9×10^{-6}
General Biotopes	10 940	40×10^{-6}	40	0.1×10^{6}	-10 900	-40×10^{-6}

Waste incineration

Category	Baseline – pre		Present – post		Difference	
	m^2	m^2/kg	m^2	m^2/kg	m^2	m^2/kg
Biotope Loss	73 088	52×10^{-6}	78 564	53×10^{6}	5 476	0.82×10^{-6}
Critical Biotopes	0	0	0	0	0	0
Rare Biotopes	1 158	0.17×10^{-6}	1 158	0.17×10^{6}	0	0
General Biotopes	7 534	1.1×10^{-6}	2 058	0.31×10^{6}	-5 476	-0.82×10^{-6}

Note that the functional unit here is not kWh, but rather kg of incinerated waste.

Forestry residues/Biomass power

Not applied on a real case yet.

Transmission ROWs

Not applied on a full-scale case yet.

Comparative table

The results of the applications on different power-generating technologies vary quite strongly and, perhaps for some, in a surprising way. If one, for example, compares the impact on critical biotopes, wind power gets a far worse outcome than nuclear power. In the table below the net impact on the different biotope categories from the tables above (with the same functional unit), is condensed.

Category	**Lule river HP** (m^2/kWh)	**Ume river HP** (m^2/kWh)	**Forsmark NP** (m^2/kWh)	**Ringhals NP** (m^2/kWh)	**Vattenfall WP** (m^2/kWh)
Biotope Loss	150×10^{-6}	330×10^{-6}	1.4×10^{-6}	3.5×10^{-6}	$+55 \times 10^{-6}$
Critical Biotopes	-130×10^{-6}	-310×10^{-6}	-0.015×10^{-6}	$- 0.77 \times 10^{-6}$	-6.6×10^{-6}
Rare Biotopes	-22×10^{-6}	-310×10^{-6}	-0.015×10^{-6}	-0.93×10^{-6}	-7.9×10^{-6}
General Biotopes	2.6×10^{-6}	280×10^{-6}	-1.4×10^{-6}	-1.8×10^{-6}	-40×10^{-6}

Problems

- Off-site impacts.
- Not fully compatible with standard EIA.
- The inherent conflict between simple/quick/applicable and "correct".
- Problems in attaining basic information of sufficient quality in some post-project assessments.
- Cumulative impacts.
- Barriers effects, fragmentation and thresholds are not possible to evaluate in pre-project assessments.

Conclusions

- When the method was first developed it was, arguably, the first easily applicable biodiversity assessment method for use in LCIs/LCAs.
- The obvious number 1 problem with the method is the inherent conflict between simplicity and "correctness". This is, however, in our view an unavoidable problem that applies to all practically useful assessment methods.
- Works best in post-project assessments, since then the LCI/LCA requirement for quantitative results can most often be satisfied with a fair degree of accuracy.
- In spite of its limitations, it is user-friendly and it yields a useful measure of changes to biodiversity.
- Off-site impacts and actual total project effects are not dealt with in depth. This is an unavoidable result of the chosen system boundaries of the method.
- In the context of LCI/LCA, we consider the method quite satisfactory, given the focus on quantitative assessment and actual numbers.
- The method is presently not suitable for use in EIA due to, primarily, two things: a) a lack of discussion regarding the application/validity at landscape level; b) the lack of a section dedicated to discussions on prevention and mitigation (to make EIA impact prediction and M&E possible).

The future

Improvements for use in LCI/LCA

- A more comprehensive discussion regarding uncertainties in the choices made and the results arrived at. This could take the form of a scenario approach whereby different assumptions are analysed and presented, leaving the reader to choose which one (s)he finds most probable.

Development for use in EIA

- The system boundaries will obviously have to be extended outside of the "direct impact" area. To a certain extent this is no more difficult than the choices of limitation of assessed areas made in standard ecological assessment methodology, but wrongly adopted would often mean quite resource-heavy assessments, exactly what the method was supposed to avoid.
- Include analyses of possible prevention and mitigation opportiunities.
- Apart from this, the obvious problem areas are shared with traditional EIA and ecological assessment; fragmentation, barrier effects, edge effects, thresholds and the long-term functionality of the various biotopes/habitats.

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