

**The ecological footprint as a follow-up tool for an  
administration: Application for the Vanoise National  
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► **To cite this version:**

Natacha Gondran. The ecological footprint as a follow-up tool for an administration: Application for the Vanoise National Park. Ecological Indicators, Elsevier, 2012, Volume 16, pp.Pages 157-166. <10.1016/j.ecolind.2011.09.036>. <emse-00636523>

**HAL Id: emse-00636523**

**<https://hal-emse.ccsd.cnrs.fr/emse-00636523>**

Submitted on 3 Nov 2011

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1           **The ecological footprint as a follow-up tool for an administration:**  
2                           **Application for the Vanoise National Park**

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9  
10           ***Keywords:** Environmental Management, Ecological footprint, National park*

11  
12   **Abstract**

13 Ecological footprint calculation methodology is generally well defined on a national scale.  
14 It is also proposed by several authors as a corporate sustainability metric, yet for this scale,  
15 there is no consensus method. The aim of this paper is to identify the consequences of such  
16 methodological liberties within the ecological footprint estimation and its use as a decision  
17 aid tool on the scale of a public organization.

18 The method was developed and validated for the Vanoise National Park which undertook  
19 to reduce its ecological footprint by 10% between 2009 and 2007.

20 The methodological liberties inherent to ecological footprint analysis on an organization  
21 scale generate methodological choices that may influence the results in terms of  
22 environmental impact hierarchy and priority of actions. Therefore, such analysis requires  
23 transparency in the methodological choices behind the calculation and the involvement of  
24 the end-users in these choices.

25  
26   ***Keywords:** Environmental Management, Ecological footprint, National park*

27   **1. Introduction**

28 Ecological footprint is aimed at comparing the demand on ecological services to available  
29 supply on a world scale. Such a metric is needed to make policy makers and people at large  
30 understand the threat of an overshoot of natural resources and to facilitate the emergence of  
31 a consensus over the actions needed to address the ecological risks (Ewing et al., 2008).  
32 First proposed by William Rees (Rees, 1992) (1992) and Mathis Wackernagel  
33 (Wackernagel, 1994)(1994), ecological footprint is mostly calculated and interpreted for  
34 Nations and the calculation methodology is now well documented for this scale (Ewing et  
35 al., 2010)

36 Ecological footprint calculations are also experimented on the scale of sub-national  
37 populations ((Chambers et al., 2002), (Barrett et al., 2003)). For example, the “Resources  
38 and Energy Analysis Programme” (REAP) aims at helping British local governments and  
39 agencies understand the footprints of residents by providing data, maps and reports on  
40 carbon and ecological footprints for local authority areas. In France, some local authorities  
41 have calculated their ecological footprint but only on a one-shot basis. Often, these

42 calculations were made as a means of communication and raising awareness for the  
43 general public (Boutaud, 2009).  
44 Since Barret and Scott proposed it (Barrett and Scott, 2001), numerous experiments have  
45 been conducted to use the ecological footprint (EF) as a corporate sustainability metric.  
46 However, they are generally based on a one-shot analysis and EF is not used as a follow-up  
47 and decision support tool for environmental management.  
48 One of the first applications of ecological footprint for organizations to be published was  
49 conducted by (Chambers, N. and Lewis, K., 2001). These authors proposed a 7-step  
50 methodology: data scoping, data collection, assembling the footprint table, calculating the  
51 ecological footprint, normalization, scenarios and global sustainability assessments,  
52 refining the footprint/sensitivity analysis, Environmental management systems/using the  
53 footprint. The data collection appears to be the “most intense and challenging task”.  
54 Indeed, few companies collate comprehensive data in the required format. Therefore,  
55 numerous assumptions and proxies are necessary. L. Holland (2003) also brings up the  
56 necessity of a clearly developed management information system that records not only  
57 financial data but also consumptions of material and energy, transportation of goods and  
58 persons and waste disposal in physical units. Ecological footprint analysis (EFA)  
59 encourages businesses to develop an environmental information system to provide a  
60 monitoring process and measure improvements. “This is perhaps its greatest strength – to  
61 incorporate hard science and ethical intuition into the assessment of business activity”  
62 (Holland, 2003). Indeed, ecological footprint translates various physical units into a single  
63 “currency”. This currency can be hectare-years (Chambers, N. and Lewis, K., 2001) (1  
64 hectare-year corresponds to the use of one hectare during one year) or hectare (Li et al.,  
65 2008). However, the most usual unit used is the global hectare (gha) ((Lewis et al., 2005),  
66 (Wiedmann, 2008)), (Klein-Banai and Theis, 2011). It is a hectare that has the world  
67 average productivity of biologically productive land and water in a given year.  
68 This aggregation relies on conversion factors that are used to convert different  
69 heterogeneous data, expressed in various units, into a single footprint unit. There is no  
70 consensual database of conversion factors. For example, Best Foot Forward  
71 commercializes the EcoIndex™ Methodology, whose database is proprietary (Chambers,  
72 N. and Lewis, K., 2001). CENSA developed TBL2 UK (Wiedmann and Lenzen, 2006a)  
73 (CenSA, 2008). These methods are based on the “shared responsibility” principle and the  
74 need for capturing impacts across the entire upstream and downstream supply chain  
75 (Wiedmann and Lenzen, 2006b).  
76 These ecological footprint accounting methods were applied to public organizations. For  
77 example, the EF of Waverley Borough Council was calculated for the financial year  
78 2007/2008 (CenSA, 2008). This study distinguished the impacts that are produced directly  
79 by the organization (38% of the total ecological footprint) and the ones associated to the  
80 consumption of goods and services, including electricity. Seven different types of land type  
81 were taken into account: fossil fuel energy footprint is due to the burning of fossil fuels and  
82 represents 84% of this footprint; nuclear energy footprint; crop land; pasture footprint;  
83 built-up land; sea footprint and forest footprint. The uncertainty of the results, expressed in  
84 gha, was estimated at +/- 13% (CenSA, 2008). The method used for this study, TBL2 UK,  
85 is based on an environmentally extended input-output-based LCA method and uses the

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88 financial accounts of the organization under study to provide both carbon and ecological  
89 footprint accounting (Wiedmann and Lenzen, 2006b). Input-output analysis is a top-down  
90 economic technique which is based on monetary transaction data between various  
91 industrial sectors. Thus, the conversion factors are obtained thanks to English macro-  
92 economic data from the ONS National (economic) Accounts, ONS Environmental  
93 Accounts and GFN National Footprint Accounts (NFA).

94 This macroeconomic-based approach is not the one that was adopted by the French  
95 national agency for environment and energy efficiency (ADEME). Indeed, to estimate the  
96 carbon footprint of French companies, the ADEME developed its “Bilan Carbone<sup>TM</sup>”,  
97 aimed at calculating greenhouse gas emissions using consumption data and assessing the  
98 direct or indirect emissions produced by an activity (ADEME (Agence de l'Environnement et de la  
99 Maîtrise de l'Energie) - Mission Interministérielle de l'Effet de Serre, 2007), 2007) from physical and  
100 monetary data relating to the organization under study. This method is compatible with  
101 standard ISO 14064, the GHG Protocol initiative and the terms of the "permit" Directive  
102 No. 2003/87/CE relating to the CO<sub>2</sub> quota trading system. Contrary to the carbon uptake  
103 footprint of the National Footprint Account, which only considers CO<sub>2</sub> emissions, the  
104 “Bilan Carbone<sup>TM</sup>” takes the 6 main greenhouse gases covered by the Kyoto protocol and  
105 aggregates them via their 100 year global warming potential. Thus, it defines GHG  
106 emission factors which are based on LCA for the most frequent consumption products and  
107 services.

108

109 To come back to the main equation of ecological footprint:

110  $EF_c = EF_p + EF_I - EF_E$  (Ewing et al., 2008) where  $EF_p$  is the Ecological Footprint of  
111 production, and  $EF_I$  and  $EF_E$  are the Footprints embodied in imported and exported  
112 commodity flows, respectively.

113 For a public organization like a National Park whose main mission is to provide services,  
114  $EF_p$  and  $EF_E$  can be considered equal to 0. Thus, the ecological footprint is equal to the sum  
115 of the ecological footprints of all the products that it bought during a given year. “The  
116 usefulness of EF as a stand-alone indicator for environmental impact is limited for product  
117 life cycles with relatively high mineral consumption and process-specific metal and dust  
118 emissions”(Huijbregts et al., 2008). However, EF is valuable for biological products. For  
119 example, the conventional production of wines was found to have a Footprint value almost  
120 double that of organic production, mainly due to the agricultural and packing phases  
121 (Niccolucci et al., 2008). It would appear to be interesting to consider not only a one-year  
122 field operation but also the whole lifetime of the system under study (Cerutti et al., 2010).

123

124 There are several methods of calculation of ecological footprint at the various possible  
125 scales of study. To ensure that Footprint assessments are produced consistently and to  
126 suggest community-proposed best practices, *Ecological Footprint Standards 2009* (Global  
127 Footprint Network (GFN), 2009) were defined for sub-national population, product, and  
128 organization Footprint analysis and communication. However, these standards are not very  
129 directive as to the calculation methodology and the conversion factors. The aim of this  
130 paper is to identify the consequences of such methodological liberties within the ecological  
131 footprint estimation and its use as a decision aid tool for environmental management. What

132 are the different possible methodological choices when estimating the ecological footprint  
133 of a public institution? Do these choices have an influence on the various options for action  
134 and the use of EF as a follow-up tool?

135 For a one-shot-analysis, public or private institutions may rely on commercial software that  
136 does not encourage them to question the hypothesis and conversion factors on which the  
137 tool is based. However, our assumption is that in the context of a decision-making support  
138 and follow-up tool, the understanding of these choices is essential. If the end-user cannot  
139 verify and control conversion factors, it may not trust commercial software and use it as a  
140 decision support and follow-up tool.

141  
142 This study estimates the ecological footprint of the administration of the Vanoise National  
143 Park (VNP), in the Alps, France. This public institution is in charge of preserving the  
144 Vanoise Massif (Northern French Alps), obtaining knowledge of its natural and cultural  
145 heritage and making the public aware of the need to protect it. Thanks to its director's  
146 willingness, this public institution is involved in the environmental management of its  
147 activities and facilities. In its 2007-2009 Contract of objectives with the French  
148 Government, the VNP undertook to reduce its ecological footprint by 10% between 2009  
149 and 2007 (Parc National de la Vanoise, 2007). Therefore, it needed an EF monitoring tool  
150 to identify actions in order to reach this ambitious objective and to verify its achievement.  
151 With the aim of using it as a follow-up tool, the VNP needed a calculator that it could  
152 easily make its own: easy to handle and understand, with open and transparent assumptions  
153 and corresponding to the French production patterns in terms of agricultural and forest  
154 yields and greenhouse gas emission factors and in particular consistent with the "Bilan  
155 Carbone" method (ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) -  
156 Mission Interministérielle de l'Effet de Serre, 2007). The methodological liberties of  
157 ecological footprint calculation made it possible to draw up such a custom-made tool.

158 In this context, a partnership was set up with the Ecole Nationale Supérieure des Mines de  
159 Saint-Etienne and Aurélien Boutaud Conseil to carry out the three-year (2007 to 2009)  
160 follow-up of the ecological footprint of the Vanoise National Park. A steering committee,  
161 regularly bringing together the main stakeholders of the Vanoise National Park, discussed  
162 and validated the methodological choices of the EF analysis tool.

## 163 **2. Methods**

164  
165 The Ecological Footprint aims at evaluating the human appropriation of ecosystem  
166 products and services in terms of the amount of bioproductive land and sea area needed to  
167 supply these services. The Ecological Footprint accounts cover six land use types:  
168 cropland, grazing land, fishing ground, forest land, built-up land and carbon uptake land  
169 (Ewing et al., 2010). For each component, the ecological footprint is obtained through the  
170 consumption of a harvested product (or amount of CO<sub>2</sub> emission) divided by the yield for  
171 these ecological services. This value is then converted into "global hectares" thanks to  
172 yield and equivalence factors (Ewing and al., 2008b).

173 These principles were considered to estimate the ecological footprint of the Park. The  
174 calculations were based on a component-based method that consists in inventorying every  
175 product and service consumed by the organization for the year under study and then  
176 applying various conversion factors for each type of land, corresponding to a certain unit  
177 of product or service ((Barrett et al., 2003), (Chambers, N. and Lewis, K., 2001)). To take  
178 into account the national production patterns, these conversion factors were calculated for  
179 the French situation (agricultural yields and emission factors, for instance) and for the year  
180 2007 that is the reference year of the environmental management system of the Vanoise  
181 National park.

182  
183 As the aim was to obtain a follow-up tool that the end-user could easily make its own and  
184 modify and that could be easily adapted to other national or regional parks, the EF tool was  
185 developed with commonly used computer applications such as MS Excel files that are  
186 linked together by Visual Basic for Application macros.

187 A five-step approach was followed to estimate the ecological footprint of the Park.

188

### 189 **1.1. Definition of the scope of the activity**

190 The first step was to **define the scope of the activity** under study (GFN, 2009). The  
191 activities for which the institution was a direct decision-maker were taken into account. In  
192 order to achieve its missions, the National Park is simultaneously:

- 193 - An owner of office buildings and park rangers' dwellings that use built-up areas,  
194 energy and water
- 195 - An employer of staff which travel from home to work and for their professional  
196 missions and get reimbursed for some meals during business trips
- 197 - A purchaser of goods and services
- 198 - A producer of waste that can be incinerated with or without energy recovery  
199 brought to landfills or recycled depending on the various places where the offices are  
200 located.

201 For all these activities, all the input and output fluxes were taken into account wherever the  
202 ecological footprint was generated.

203 75 items of consumptions which are listed in the first column of table 1, were taken into  
204 account. To facilitate the interpretation of the results, these items were grouped into  
205 categories that were inspired from (Chambers, N. and Lewis, K., 2001) and consistent with  
206 the actual information system of the Park. The buildings category rounds up built-up land,  
207 energy and water consumptions. Mobility includes home-to-work employee travel,  
208 business trips and freight. Food estimates the food products that were consumed by the  
209 employees during their business trips when they received meal expenses, and the lunches  
210 the Park organizes for special events. Manufactured goods account for the depreciation of  
211 durable goods (vehicles, computers, furniture, etc.), the manufacture of the consumer  
212 goods (office paper and furniture, for example) and the production of communication  
213 material as well as the waste generated by the staff of the Park.

214

215 **Proposed place for Table 1**

216

217 Initially, it was planned to account for all the operations for which the Park has operational  
218 control (Russell et al., 2010). In particular, it was intended to include the ecological  
219 footprint of the mountain refuges that are owned by the Park but managed by private  
220 refuge caretakers. However, the information on the relative energy consumption and the  
221 food served to the tourists was difficult to obtain and the Park could hardly impose  
222 ecological requirements on the food served preferring to promote a voluntary-based  
223 approach in favor of organic food consumption. This ecological footprint of the refuges is  
224 significant (about 25 % of the total ecological footprint of the Vanoise National Park),  
225 however, it could not be monitored accurately.

226 Thus, a control/operational hybrid approach was preferred: the organization accounts for  
227 100 percent of the ecological footprint from operations for which it has direct control  
228 (Russell et al., 2010) and for the energy used by Park-owned but employee-operated  
229 dwellings. The ecological footprint of the VNP-owned refuges was only estimated and  
230 presented separately from the Park ecological footprint.

231

232 **1.2. Identification and collection of consumption data**

233 The second step was to **identify and collect the inventory and consumption data of the**  
234 **organization** for years 2007, 2008 and 2009. Data had to be collected for 30 different  
235 consumption sites (headquarters, local offices, mountain refuges and huts, warden houses).  
236 This was a long and fastidious phase as the data required was rarely immediately available  
237 and likely to come from several information sources. The main sources of information  
238 were the financial accounts and the analysis of the numerous bills to obtain physical values  
239 (kWh, km, litres, tons, etc.) that were preferred over monetary data when available, on-site  
240 data, employee survey and building energy audits.

241 In the case of a follow-up tool, it was important to record information sources to facilitate  
242 subsequent data collection. When collecting the information during the second and third  
243 years of study, some information collected the first year appeared to be incomplete or false.  
244 Therefore, unlike a one-shot study, this phase was consolidated thanks to the monitoring  
245 over several years. Furthermore, analyzing the evolution of the main ecological footprint  
246 components appeared to be a good management practice in order to identify evolution  
247 trends.

248

249 **1.3. Calculation of the footprint**

250 One of the main interests of EF is “to provide a partial solution to the sustainability  
251 aggregation problem by expressing environmental impacts in a single measurement unit”  
252 (Mamouni Linnios et al., 2009). Therefore, the third step consisted in **organizing the**  
253 **information and calculating the conversion factors** into global hectares.

254 The first challenge when organizing the information was to develop a tool that was both  
255 simple and complete. In particular, it was necessary to keep a record of the various

256 consumptions of several categories of consumption (physical characteristics of buildings  
257 and the related water, electricity and other energy consumptions, transportation, freight,  
258 inventory of equipment depreciation, consumption of consumables, services and food) for  
259 several sites. Indeed, in order to foster the use of the footprint follow-up calculator, it was  
260 designed with several uses in mind: complete calculation of ecological footprint but also  
261 recording of the yearly consumptions of the various sites as an environmental management  
262 tool. The challenge of the EF calculation method was to be simple enough in order to be  
263 understood and appropriated by non-“ecological footprint experts”.

264 In the literature, conversion factors are often picked up from previous studies (generally  
265 (Chambers, N. and Lewis, K., 2001) or (Barrett et al., 2003)). They are generally  
266 calculated or chosen by experts and not supposed to be discussed by the end-users of the  
267 EF calculator. However, some arbitrary choices are unavoidable in this step. Therefore, in  
268 order to weight the various items with coefficient both as similar as possible to the ones  
269 used by the National Footprint account so as to be coherent with EF national calculations  
270 and standards, and easily understood by the end-users of the tools, conversion factors were  
271 calculated with data issued from official statistical databases and then explained and  
272 discussed to the steering committee involving the main stakeholders of the Vanoise  
273 National Park.

274 For forest, cropland, fishing ground, grazing land, and built-up footprint, the classic  
275 equations of EF were used. For example, for cropland:

$$276 \quad EF_{cropland} = C_i * P_i * EF_f / Y_c$$

277  $C_i$ : consumption of the item  $i$  (in tons/year)

278  $P_i$ : industrial productivity for the harvested product that is necessary for item  $i$

279  $Y_c$ : Yield per hectare for the type of crop that is necessary for item  $i$  (tons/ha)

280  $EF_c$ : equivalence factor for cropland (2.64 gha/ha according to (Ewing and al.,  
281 2008))

282 The same equation was used for fishing ground and grazing land respectively.

283 To be consistent with NFA, the FAOSTAT database was used to identify crop yields of  
284 primary products for year 2007. This official database provides statistically reliable yields  
285 of primary products. However, various sources (professional federations, for example)  
286 were used to estimate industrial productivities between primary and secondary products.  
287 These yields are less reliable and vary according to various studies. As the Vanoise  
288 National Park gives priority to local products, the steering committee wanted the tool to  
289 take into account the ecological advantages of a local food supply. Therefore, the French  
290 yields, higher than the world yields, were taken into account for the food products that can  
291 grow in France. For the other products (bananas, for example), world yields were  
292 considered. The same approach was used for forest land. The yields that were taken into  
293 account aimed at representing the real yields that can be recorded for the different types of  
294 products consumed. Sources of data were AGRESTE (2010), UNECE Timber Committee  
295 and the FAO European Forestry Commission (2010). If the world yield of forest products  
296 had been considered, the consumption of wood logs for heating buildings would have  
297 represented more than 35% of the Park ecological footprint. In the Vanoise mountain  
298 context, wood log heating contributes in a positive manner to the forest management and is



299 considered as a renewable energy. Giving such ecological weight to this practice was  
300 considered by the steering committee as counter-productive from an environmental  
301 management point of view. Local yields were therefore chosen.

302

303 Table 2 groups the yield and equivalence factors.

304

305 **Proposed place for Table 2**

306

307 • **Carbon uptake land**

308

309 The main originality of the method presented in this paper is the calculation of the carbon  
310 uptake land based on the 6 GES greenhouse gases considered by the Kyoto protocol (CO<sub>2</sub>,  
311 CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub>) as opposed to the national footprint accounts that only  
312 consider CO<sub>2</sub> emissions. French businesses, local authorities and public institutions are  
313 indeed encouraged to measure their carbon footprint with the “Bilan Carbone” method. A  
314 private or public organization will rarely analyze both its carbon and an Ecological  
315 footprint if the two methods are not consistent. Hence, the carbon uptake land of this study  
316 was based on the “Bilan Carbone » method (ADEME (Agence de l'Environnement et de la  
317 Maîtrise de l'Energie) - Mission Interministérielle de l'Effet de Serre, 2007), 2007). The  
318 100-year global warming potentials (GWP), the most commonly suggested method, was  
319 used to include CH<sub>4</sub>, N<sub>2</sub>O, HFCs, PFCs and SF<sub>6</sub> in ecological footprint analysis ((Lenzen  
320 and Murray, 2001);(Barrett et al., 2003)). The GWP reflect the radiative forcing and  
321 atmospheric lifetime of each gas (IPCC 2001) and convert each gas into its carbon dioxide  
322 equivalent based on its ability to absorb and re-release radiation in the atmosphere over its  
323 projected atmospheric lifetime. (Kitzes et al., 2009).

324

325 The following equation was used:

326

$$327 \quad EF_{carbon} = CI * Fi * 0,001 * (1 - S_{oceans}) * EF_c / CSF$$

328

329 where

330  $C_i$ : consumption of the item i (in tons/year)

331  $F_i$ : greenhouse gas emission factor (GWP<sub>100</sub>) for item i (kg Ceq/ton of item i)

332  $S_{oceans}$ : percentage of anthropogenic emissions sequestered by oceans in a given  
333 year: 26 % according to (Ewing and al., 2008)

334  $EF_c$ : equivalence factor for forest (1.33 gha/ha according to (Ewing and al., 2008))

335  $Y_c$ : annual rate of carbon uptake per hectare of world average forest land (0.97  
336 tCeq/ha/year deduced from (Ewing and al., 2008)).

337 When available, the greenhouse gas emission factors were obtained from the Bilan  
338 Carbone® method (ADEME, 2007). When there were not available, they were obtained  
339 from the Ecoinvent database (CML 2001 methodology) (Swiss centre for Life cycle  
340 inventories, 2010) or with LCA studies that were found in academic literature.

341

342 Prior to 2008, the ecological footprint method treated nuclear power in the same manner as  
343 coal power. Since 2008, the Global Footprint Network no longer includes nuclear energy  
344 in NFA. As 78% of the French electricity is generated with nuclear power, the steering  
345 committee considered that this component could not be neglected considering the French  
346 electricity mix. Indeed, as ecological footprint was used as an aggregation tool to prioritize  
347 the various environmental aspects of the VNP, these risks and environmental impacts  
348 associated with nuclear technology could not be neglected. Using the low greenhouse gas  
349 emission factor of the French mix ( $23\text{gC}_{\text{eq}}/\text{kWh}$ ) would give very little importance to the  
350 impacts associated with electricity consumptions. Given that the European electricity  
351 network is increasingly interconnected, the steering committee chose to consider the  
352 European electricity mix ( $96\text{gC}_{\text{eq}}/\text{kWh}$ ) instead of the French one. This corresponds to  
353  $9.7 \cdot 10^{-5}$ gha of carbon uptake land/GWh/yr and  $4.7 \cdot 10^{-7}$ gha of built-up area/GWh/yr.  
354 However, one of the Vanoise villages, Bonneval, is exclusively supplied with  
355 hydroelectricity. For the Bonneval buildings, the hydroelectricity mix was taken into  
356 account ( $3.96 \cdot 10^{-6}$ gha of built-up area/GWh/yr).

357

358 Carbon footprint is correlated to the annual rate of carbon uptake. To be consistent with the  
359 GFN calculation, the same rate of carbon uptake as Hails (2008) was retained:  
360  $3.56\text{tCO}_{2\text{eq}}/\text{ha}/\text{yr}$ . From a physical point of view, this data is rather uncertain and subject to  
361 changes with the varying carbon uptake capacities of forests. On the other hand, although  
362 the real figure is uncertain, the order of magnitude is confirmed by other studies. For  
363 example, the range of carbon uptake for Galician forest was estimated between 3.81 to  
364  $4.58\text{ t CO}_2/\text{ha}/\text{yr}$  (Herva et al., 2010). This range is slightly higher than the global value  
365 used in the Living Planet Reports ( $3.67\text{ t CO}_2/\text{ha}/\text{yr}$  in 2003 and 3.56 in 2005), but the  
366 Galician forests may have higher carbon uptake capacities than the world average and the  
367 greatest difference is less than 30%.

368 Another factor that strongly influences carbon footprint is the percentage of anthropogenic  
369 emissions sequestered by oceans in a given year. It was fixed at 26% (Ewing and al.,  
370 2008). However, this percentage may significantly decrease over a long period of time  
371 because of the risk of saturation of the absorption capacities of the biosphere (Canadell,  
372 Pataki, on 2007). This would considerably increase the carbon footprint.

373

374 When using ecological footprint as a decision support tool, conversion factors that are  
375 based on natural resource productivity (for example, greenhouse gas emissions and crop  
376 production) are used to weight and aggregate different types of environmental impacts.  
377 The identification of conversion factors requires some inevitable choices to be made by the  
378 researcher defining the calculation method. To make the analysis as transparent as  
379 possible, these choices must be formalized clearly and should be discussed with experts in  
380 the various thematic fields concerned (forestry, agriculture, greenhouse gas, etc.). Table 1  
381 groups the conversion factors chosen for this study.

382

383 The consumption data specific to the organization under study are then multiplied with the  
384 generic conversion factors to **calculate the organization's ecological footprint**. The results

385 must then be verified by cross-checking and verification of the order of magnitude of the  
386 results of the various components.  
387

#### 388 **1.4. Analysis of results, scenario building and communication**

389 The fourth step is the **synthesis and interpretation of the results** in order to identify the  
390 main components of the ecological footprint. To interpret more easily the meaning and the  
391 evolution of the ecological footprint, EF results can be normalized according to the  
392 activity. However, as a public service provider, the activities of a National Park are  
393 multiple and hard to quantify: patrolling services to protect the natural area and its  
394 biodiversity, renovation of the built and natural heritage, monitoring of the state of the  
395 environment, work with local authorities, production of publications, etc. It could have  
396 been valuable to structure the EF calculation for each of these different final outputs.  
397 However, as there is no internal analytical accounting for the different resources used for  
398 each activity, only a global EF calculation was possible.

399 From an accounting perspective, the National Park's contribution to wealth could have  
400 been determined as the sum of staff cost and equipment depreciation. However, this  
401 monetary indicator may not represent the real contribution of a National Park very clearly.  
402 Indeed, the roles of public services are quite diverse and difficult to quantify. Besides, this  
403 accounting approach was not the one adopted by the Vanoise national Park (nor by the  
404 French administrations in general). Its most usual activity indicator is the number of Full-  
405 time equivalents. A FTE of 1.0 is equivalent to a full-time worker for one year and  
406 accounts for seasonal workers proportionally to their work period. For example, a  
407 receptionist that works during the two summer months is accounted for as 0.17 FTE.  
408 Therefore, the results were presented in gha per FTE. This expression was well understood  
409 by the staff.

410 The aim of this ecological footprint analysis was not only to present an overview of the  
411 situation and its evolution but also to identify and quantify ways of action. Thus, the results  
412 and scenarios were presented and discussed with the Park management, its governing body  
413 and its staff (during its general assembly).

### 414 **3. Results**

415  
416 The ecological footprint of the administration of the Vanoise National Park was estimated  
417 at 186gha/yr (2.25gha/yr/FTE) in 2007 and 190gha/yr (2.02gha/yr/FTE) in 2009. Figure 1  
418 shows that although the absolute ecological footprint of the institution increased by 2%  
419 from 2007 to 2009, the ecological footprint per FTE decreased by 10% between 2007 and  
420 2009. Thus the Park did reach its EF reduction commitment.

421  
422 Proposed place for Figure 1

423  
424 The main source of improvement is due to the choice, since 2008, of recycled paper for the  
425 publications distributed by the Park. The reduction of ecological footprint is visible in  
426 Figure 1 (reduction of the forest land). However, this representation does not take into

427 account the potential impacts of recycling paper on water effluents (Terasaki et al., 2008),  
428 nor the complete system boundary of the local waste management scheme (Merrild et al.,  
429 2008).

430 In 2007, 77% of the Park's ecological footprint was made up of carbon footprint. However,  
431 forest land (18%) and cropland (3%) were significant. The main sources of ecological  
432 footprint are respectively buildings (in particular their energy consumption) (34%),  
433 mobility (especially employee and committee travel) (26%), manufactured goods (mainly  
434 communication products) (26%), services (about 10%) and food services (4%).

435  
436 From a decision support point of view, it was more relevant to identify the bigger  
437 contributors and to follow their evolution. Therefore, the various components were ranked  
438 according to their ecological footprint.

439

#### 440 **Proposed place for Figure 2**

441

442 This figure underlines the main items that need to be improved. The ecological footprint  
443 hierarchy of items is different to that of the carbon footprint. For example, the consumption  
444 of wood heating energy represents a small carbon footprint. Because of the quantification  
445 of the forest land to grow the trees, it was the highest ecological footprint component. This  
446 conclusion was difficult to accept by the Park staff because it is considered as a renewable  
447 energy that should be promoted. Thanks to this representation, the evolution over the years  
448 of the various components was monitored in order to identify both the consequences of the  
449 environmental management practices and the unwanted evolutions.

450

#### 451 **Proposed place for Figure 3**

452

453 Figure 3 shows, for example, the results of the thermal insulation building actions and  
454 investments into wood pellet boilers (reduction of the ecological footprints of wood log  
455 energy and fuel). On the other hand, it also shows that some attention should be drawn to  
456 the use of service providers and consumption of office and small consumables whose  
457 spendings are increasing. However, the ecological footprint of these three components are  
458 based on a ratio of ton of CO<sub>2</sub> equivalent that are emitted per euro spent, based on the French  
459 average of carbon emissions of these activity sectors. Using this ratio is pragmatic as it is  
460 impossible to identify the real GHG emissions that are generated by each service provider.  
461 However, it is relatively inaccurate. Indeed, if the cost of a service or furniture increases,  
462 its ecological footprint will also increase even if the material and energy flows that are  
463 generated stay the same.

464

465 Ecological Footprint was also used as a prospective tool to estimate the ecological  
466 footprint reduction that could be generated by several possible environmental management  
467 actions. To define the scenarios, the "Negawatt approach" (Salomon et al., 2005), initially  
468 proposed for energy issues, was adapted to ecological footprint issues. The Negawatt  
469 approach first tackles the issue of 'how to consume better' before answering 'how to  
470 produce more'.

471 It is based on three steps:

- 472 • “Sufficiency” (or consumption efficiency) consists of reducing wastefulness by  
473 rational individual behavior, organizational and societal choices: “consuming less”
- 474 • “Efficiency” means reducing as much as possible the losses of energy or matter for  
475 a certain use. It is often obtained by technological changes: “consuming better”
- 476 • “Renewable”: “actions of sufficiency and efficiency can reduce our energy needs at  
477 their source. What still needs to be produced shall be provided by renewable  
478 energies, coming from amongst others our only true natural and everlasting source  
479 of energy: the sun” (Salomon et al., 2005)

480 For each type of action, two levels of ambition were considered: level 1 can be achieved  
481 rapidly and easily while level 2 is more ambitious and over the long term.

482 For example, electricity consumptions can be reduced by various complementary actions:

- 483 - Sufficiency: reduction of electricity demand through appropriate behavior and energy  
484 saving equipments can reduce the ecological footprint from 0.6 (level 1) to 1.3gha  
485 (level 2)
- 486 - Efficiency: refurbishment of the buildings where electricity is used as additional  
487 heating can reduce the ecological footprint from 0.8 (level 1) to 2.4 gha (level 2)
- 488 - Renewable energy: selecting electricity suppliers which use renewable energy  
489 sources can reduce the ecological footprint from 3.6 (level 1) to 10.2 gha (level 2).

490

491 Proposed place for Figure 4

492

493 Figure 4 represents the total EF improvements that can be obtained thanks to the various  
494 scenarios that were proposed.

#### 495 **4. Discussion**

496

497 Table 3 shows that Ecological Footprint Analysis (EFA) methodology ranks building as  
498 the main contributor of EF while GHG emission analysis ranks mobility as the greatest  
499 contributor. Then, similarly to what was noticed by (Klein-Banai and Theis, 2011), the  
500 hierarchies of impacts evaluated by EFA methodology and GHG emission analysis are  
501 different as EFA gives more weight to the consumption of natural resources such as wood  
502 and food. Thus, EFA encompasses more environmental impacts than a GHG inventory.  
503 Therefore, it might be more relevant as an environmental management decision-aid tool.

504

505 Proposed place for Table 3

506

507 87 components had to be informed to fulfill a complete ecological footprint analysis. As  
508 each component is itself a combination of one to 30 raw data (bills, for example), the  
509 process of gathering information may be long and costly (about two persons-months for an  
510 administration with about 85 employees). Not all public organizations can afford to spend  
511 so many hours monitoring their environmental pressures. However, as only 22 components  
512 contributed to 90% of the 2007 ecological footprint, the process of updating the data could

513 be shortened if only these components were updated. Nonetheless, 10% of the Ecological  
514 footprint would remain uncertain and this uncertainty margin exceeds the reduction  
515 commitment of 5 percent each year. Fuzzy logic could be used as a way of dealing with  
516 uncertainty in the input data and reducing the need of environmental data (González et al.,  
517 2002), (Beynon and Munday, 2008).

518

519 Ecological footprint was used as an internal metric to prioritize impacts and to quantify  
520 environmental abatement options, as proposed by (Baboulet and Lenzen, 2010). It  
521 aggregates various types of impacts into a common unit. The choice of conversion factors  
522 (forest and crop yields, annual rate of carbon uptake, greenhouse gas emission factors, for  
523 example) has a strong influence on the final hierarchy of results. Although these  
524 coefficients are based on scientific studies or official statistical databases, they must be  
525 questioned. They are in fact subject to variations. For example, forest yields may vary  
526 considerably according to the various forest products. For instance, timber productivity for  
527 paper products or heating firewood is higher than for wooden furniture. Climatic  
528 conditions may affect crop and forest yields. The different industrial processes that can be  
529 used to produce the same type of manufactured products may generate very different  
530 amounts of greenhouse gas emissions. The choice of these conversion factors may affect  
531 the final results substantially, and thus the hierarchy of ecological footprint components...  
532 and the actions to be considered in priority.

533 Therefore, when drawing up the ecological footprint calculator, some choices are  
534 unavoidable. The understanding of these assumptions by the organization's decision-  
535 makers is indispensable. The bottom-up methodology that was used in this study makes it  
536 possible to clarify each methodological choice and to jointly define the conversion factor  
537 the most suited to each product or service used. It appears to be more flexible than a  
538 compound approach, where the same environmental factor is used for any monetary  
539 exchange between two given activity sectors, whatever the specificity of the product  
540 exchanged.

541

542 Another issue was the choice of crop yield factors. In actual fact, the Vanoise National  
543 Park promotes the use of organic farming in its territory and purchasing policy (for food,  
544 textiles, etc.). Therefore, it wanted to highlight the benefits of organic farming against  
545 intensive agriculture. However, organic farming generates a lower yield per unit of land  
546 and thus requires larger areas than intensively cultivated land to produce a similar quantity  
547 of products, so it has a larger crop and grazing EF (Mozner and Tabi, 2010). However,  
548 intensive agriculture uses more manufactured products (fertilizers, insecticides, herbicides,  
549 etc.) and generates more greenhouse gas emissions than organic farming. Thus, smaller  
550 greenhouse gas emission factors should be used to estimate the ecological footprint of  
551 organic products (Niccolucci et al., 2008), but larger cropland yield factors than for  
552 intensive agriculture. However, considering the negative impacts of intensive agriculture  
553 on soils (erosion, depletion of soil nutrients, etc.), it was not acceptable for a decision-  
554 maker wishing to promote organic farming to introduce into its follow-up tools, crop yields  
555 that would favor, on the cropland footprint side, intensive farming rather than organic.  
556 Therefore, the same crop yields were used regardless of the origin of the products.

557 However, it may be interesting to take into account “sustainable yields” to calculate the  
558 cropland footprint. The cropland footprint could be considered as the area required to  
559 sustainably cultivate the crops that are used by a given organization or population,  
560 whatever their real mode of production, thereby increasing the cropland footprint. This  
561 methodological choice could also be used for sub-national or national footprint accounts  
562 (NFA). Indeed, in the actual NFA, biocapacity and cropland ecological footprint are  
563 constructed as equal: no cropland overshoot can be observed whereas the over-exploitation  
564 of farmland is a well-known and worrying issue. If the crop biocapacity remains calculated  
565 with the actual yields whereas the crop footprint takes into account “sustainable yields”,  
566 the crop footprint would appear larger than the biocapacity. This could clearly highlight the  
567 over-exploitation of farmland. This difference between the natural capacity of farmland  
568 (the so-called “sustainable yields”) and artificial and unsustainable yields that are currently  
569 recorded could be explained by the use of industrial products to overharvest farmland.  
570 Such a methodological change within the national ecological footprint accounts would  
571 appear urgent in order to promote the use of ecological footprint as a decision aid tool. The  
572 current method does in fact put organic farming at a disadvantage. This issue was  
573 emphasized by the French Commissariat général au développement durable - Service de  
574 l’observation et des statistiques (CGDD–SOeS – general commissariat for sustainable  
575 development – Department for Observation and Statistics) during its expert examination of  
576 the Ecological Footprint where it tested a switch to organic farming, ‘other things being  
577 equal’ (Tregouet, 2010) and concluded that “The exercise revealed the limits, and even the  
578 dangers, of a purely mechanical approach”. Indeed, with the current method, if a country  
579 switches broadly to organic farming, its carbon footprint may decrease, but its cropland  
580 footprint may, on the contrary, increase.

581

582 To aggregate greenhouse gas emissions, the 100-years GWP (Global Warming Potential) is  
583 generally used by regulators and environmental databases like Ecoinvent (Swiss centre for  
584 Life cycle inventories, 2010). This GWP method can be interpreted as indicating the  
585 amount of additional carbon dioxide that would need to be sequestered to balance the  
586 equivalent of other greenhouse gas emissions. Therefore, it was the method that was  
587 chosen in this study. However, “the warming potential of a greenhouse gas is arguably  
588 unrelated to the biosphere's regenerative capacity for these materials. A global warming  
589 potential method will become more difficult to justify as these other gases begin to form a  
590 larger, non-marginal fraction of total warming potential”. (Kitzes et al., 2009) Besides,  
591 while CO<sub>2</sub> can persist in the atmosphere for several centuries, methane disappears in a few  
592 decades. Therefore, its impact varies largely over time: over twenty years its warming  
593 power is seventy times that of CO<sub>2</sub>; over a hundred years, only twenty-four times.  
594 Methane's contribution to warming is therefore much greater in the short term than is  
595 expressed by the 100-year GWP (Dessus et al., 2008). In the context of our study, methane  
596 emissions are neglectable, so this is not an important issue. However, in the case of  
597 organizations that generate methane emissions (landfill, livestock farming, for example),  
598 this aggregation method should be used carefully as the hierarchy of environmental impacts  
599 – and consequently the priority of actions to implement – obtained with a 100-year GWP  
600 may be very different from the one that would be get with a 20-year GWP.

601  
602 Another difficulty with using ecological footprint as a follow-up tool is linked to the yearly  
603 actualization of conversion factors. Indeed, when rigorously calculating the ecological  
604 footprint of a new year, conversion factors should be updated to take into account the  
605 annual yields (of harvested products, for example) of the new year under study. However,  
606 if such a method is chosen, the variations of ecological footprint over the years can be  
607 explained by two factors: changes in the consumptions of the organization and/or changes  
608 to conversion factors. The latter are linked to variations of productivity of national or even  
609 world-wide productivity and are independent from the decisions of the organization under  
610 study. From a decision support point of view, this is not satisfactory: the organization  
611 wants to monitor only the changes it is responsible for. Therefore, it only wants to track  
612 changes that are linked to the evolution of its own consumptions. So, the “constant global  
613 hectare” Method was chosen (Kitzes et al., 2007) and the 2007 conversion factors were  
614 used for the three years under study.

## 615 **5. Conclusion**

616  
617 Although the analysis of ecological footprint for a National Park raises several  
618 methodological and conceptual questions, this study shows that it has some obvious  
619 benefits as a decision support tool for environmental management. It contributed to making  
620 the employees and stakeholders more aware of the pressures that are generated on  
621 biological resources (for example, wood consumption for paper, heating, etc). It also raised  
622 awareness of the issues that were ignored because they were not directly visible to the end-  
623 users (for example, the end-user of a tee-shirt has no idea of the surface area required to  
624 grow the cotton of this tee-shirt). The component-based approach chosen for this study led  
625 to the implementation of an internal information system based on physical flow data (kWh,  
626 tons of fuel, tons of wood, etc.) and flows that are not directly paid by the administration  
627 but that are generated by its activity or facilities (home-to-work travel, energy consumption  
628 of employees living in the organization’s accommodation, for example). This has given the  
629 institution a greater overview of its impacts and has generated interesting discussions  
630 among the steering committee and the staff as to its responsibility as an employer, a service  
631 and goods purchaser, but also a housing service provider. Monitoring these data over three  
632 years underlined their evolution trends and enabled to inform decision-makers of the  
633 reductions or increases in these various consumptions. Thanks to this study, environmental  
634 actions could be identified as well as goals of improvement and the progress or distance  
635 towards these goals to be tracked.

636  
637 Ecological Footprint aggregates various types of environmental pressures on the basis of  
638 conversion factors stemming from biophysical data. Multi-criteria analysis methods may  
639 also aggregate such pressures but their weighting is often obscure and based on the point of  
640 view of experts rather than biophysical data. Besides, contrary to monetary indicators that  
641 aim to internalize ecological externalities, ecological footprint does not rely on the



642 hypothesis that natural resources could be substituted by human capital (money, culture,  
643 knowledge, facilities, etc.) (Boutaud and Gondran, 2009).

644

645 However, ecological footprint on the scale of an organization should be used with care.  
646 First of all, its analysis is time and cost-consuming for the collection of data and  
647 calculations. Besides, methodological liberties that are inherent to ecological footprint  
648 analysis generate methodological choices that may influence the results in terms of  
649 environmental impact hierarchy, and thus the priority of actions that arise from the study.  
650 Indeed, numerous conversion factors are hidden behind the simplicity of results with a  
651 single unit. Thus, some pressures that could have been emphasized with different  
652 conversion factor choices may be under-estimated. Therefore, the choice of conversion  
653 factors must be discussed and presented clearly to the end-user of the tool.

654 To conclude, although the ecological footprint of an organization can definitely be  
655 estimated and used as a decision support tool for environmental management, it does  
656 require efforts in order to make the end-users understand the methodological choices  
657 behind the calculation. Therefore, the simpler the method, the more satisfactory it is as a  
658 decision support tool for environmental management.

659

660

#### 661 **Acknowledgements**

662 Special thanks to the Vanoise National Park (and especially to P. Traub, its Director, J.L.  
663 Gosselin and L. Ougier) and to A. Boutaud.

664 Several students of the Ecole Nationale Supérieure des Mines de Saint-Etienne contributed  
665 to this study (C. Rigal, A. Cikankowitz, L. Autixier, H. Tiersonnier, E. Plancher, D.  
666 Barbachou and F. Alvares Leite). Deirdre McArdle-Epinat edited the English language of  
667 this paper. I wish to thank them all.

668 I would like to thank the two unknown reviewers for their constructive comments.

669

#### 670 **References**

671 ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) - Mission  
672 Interministérielle de l'Effet de Serre, 2007, 2007. Guide des facteurs d'émissions, Version  
673 5.0, Calcul des facteurs d'émissions et sources bibliographiques utilisées. , 240 p.

674 Baboulet, O., Lenzen, M., 2010. Evaluating the environmental performance of a university.  
675 J. Clean. Prod. 18, 1134-1141.

676 Barrett, J., Scott, A., 2001. The Ecological Footprint: A Metric for Corporate  
677 Sustainability. Corporate Environmental Strategy 8, 316-325.

678 Barrett, J., Vallack, H., Jones, A., et al., 2003. A Material Flow Analysis and Ecological  
679 Footprint of York. , 1-9.

680 Beynon, M.J., Munday, M., 2008. Considering the effects of imprecision and uncertainty  
681 in ecological footprint estimation: An approach in a fuzzy environment. Ecol. Econ. 67,  
682 373-383.

683 Boutaud, A., 2009. Les agendas 21 locaux - Bilan et perspectives en Europe et en France.

- 684 Boutaud, A., Gondran, N., 2009. L'Empreinte Écologique, Collection Repères ed. La  
685 Découverte, Paris.
- 686 Canadell, J.G., Pataki, D., Pitelka, L., 2007. Terrestrial Ecosystems in a Changing World,  
687 The IGBP Series ed. Springer-Verlag, Berlin Heidelberg.
- 688 CenSA, 2008. An Ecological Footprint Analysis of Waverley Borough Council. 08-03, 1-  
689 19.
- 690 Cerutti, A.K., Bagliani, M., Beccaro, G.L., Bounous, G., 2010. Application of Ecological  
691 Footprint Analysis on nectarine production: methodological issues and results from a case  
692 study in Italy. *J. Clean. Prod.* 18, 771-776.
- 693 Chambers, N. and Lewis, K., 2001. Ecological Footprint Analysis: Towards a  
694 Sustainability Indicator for Business. 65.
- 695 Chambers, N., Heap, R., Jenkin, N., Lewis, K., Simmons, C., Tamai, B., Vergoulas, G.,  
696 Vernon, P., 2002. A Resource Flow and Ecological Footprint Analysis of Greater London.
- 697 Dessus, B., Laponche, B., Le Treut, H., 2008. Effet de serre : n'oublions pas le méthane ! .  
698 *La Recherche* n° 417.
- 699 Ewing, B., Goldfinger, S., Wackernagel, M., Stechbart, M., Rizk, S.M., Reed, A., Kitzes,  
700 J., 2008. The Ecological Footprint Atlas 2008.
- 701 Ewing, B., Moore, D., Goldfinger, S., Oursler, A., Reed, A., Wackernagel, M., 2010. The  
702 Ecological Footprint Atlas 2010.
- 703 Ewing, B., Reed, A., Rizk, S.M., Galli, A., Wackernagel, M., Kitzes, J., 2008. Calculation  
704 Methodology for the National Footprint Accounts, 2008 Edition.
- 705 Global Footprint Network (GFN), 2009. Ecological Footprint Standards 2009.
- 706 González, B., Adenso-Díaz, B., González-Torre, P.L., 2002. A fuzzy logic approach for  
707 the impact assessment in LCA. *Resour. Conserv. Recycling* 37, 61-79.
- 708 HAILS, C. (ed.), 2008. Living Planet Report 2008. WWF International, Gland,  
709 [http://wwf.panda.org/about\\_our\\_earth/all\\_publications/living\\_planet\\_report/living\\_planet\\_](http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/living_planet_report_timeline/lpr_2008/)  
710 [report\\_timeline/lpr\\_2008/](http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/living_planet_report_timeline/lpr_2008/)
- 711 Herva, M., Hernando, R., Carrasco, E.F., Roca, E., 2010. Methodological advances in  
712 Ecological Footprinting, Footprint forum 2010.
- 713 Holland, L., 2003. Can the principle of the ecological footprint be applied to measure the  
714 environmental sustainability of business? *Corporate Social Responsibility and*  
715 *Environmental Management* 10, 224-232.
- 716 Huijbregts, M.A.J., Hellweg, S., Frischknecht, R., Hungerbühler, K., Hendriks, A.J., 2008.  
717 Ecological footprint accounting in the life cycle assessment of products. *Ecol. Econ.* 64,  
718 798-807.
- 719 Kitzes, J., Galli, A., Wackernagel, M., Goldfinger, S., Bastianoni, S., 2007. A "Constant  
720 Global Hectare" Method for Representing Ecological Footprint Time Trends. *International*  
721 *Ecological Footprint Conference* .
- 722 Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., Ede, S., Erb, K., Giljum, S., Haberl,  
723 H., Hails, C., Jolia-Ferrier, L., Jungwirth, S., Lenzen, M., Lewis, K., Loh, J., Marchettini,  
724 N., Messinger, H., Milne, K., Moles, R., Monfreda, C., Moran, D., Nakano, K., Pyhälä, A.,

725 Rees, W., Simmons, C., Wackernagel, M., Wada, Y., Walsh, C., Wiedmann, T., 2009. A  
726 research agenda for improving national Ecological Footprint accounts. *Ecol. Econ.* 68,  
727 1991-2007.

728 Klein-Banai, C., Theis, T.L., 2011. An urban university's ecological footprint and the  
729 effect of climate change. *Ecol. Ind.* 11, 857-860.

730 Lenzen, M., Murray, S.A., 2001. A modified ecological footprint method and its  
731 application to Australia. *Ecol. Econ.* 37, 229-255.

732 Lewis, K., Vergoulas, G., Jenkin, N., 2005. An Ecological Footprint Analysis of the  
733 Countryside Council for Wales.

734 Li, G.J., Wang, Q., Gu, X.W., Liu, J.X., Ding, Y., Liang, G.Y., 2008. Application of the  
735 componential method for ecological footprint calculation of a Chinese university campus.  
736 *Ecol. Ind.* 8, 75-78.

737 Mamouni Limnios, E.A., Ghadouani, A., Schilizzi, S.G.M., Mazzarol, T., 2009. Giving the  
738 consumer the choice: A methodology for Product Ecological Footprint calculation. *Ecol.*  
739 *Econ.* 68, 2525-2534.

740 Merrild, H., Damgaard, A., Christensen, T.H., 2008. Life cycle assessment of waste paper  
741 management: The importance of technology data and system boundaries in assessing  
742 recycling and incineration. *Resour. Conserv. Recycling* 52, 1391-1398.

743 Mózner, Z., Tabi, A., 2010. Comparing the environmental impacts of intensive and  
744 extensive agricultural practices. *Footprint forum 2010*, Colle di Val d'Elsa and Siena, June  
745 7-12, 2010.

746 Niccolucci, V., Galli, A., Kitzes, J., Pulselli, R.M., Borsa, S., Marchettini, N., 2008.  
747 Ecological Footprint analysis applied to the production of two Italian wines. *Agric. ,*  
748 *Ecosyst. Environ.* 128, 162-166.

749 Parc National de la Vanoise, 2007. Contrat d'objectifs Etat-Etablissement public du Parc  
750 National de la Vanoise 2007 – 2009.

751 Rees, W.E., 1992. Ecological Footprints and appropriated carrying capacity: what urban  
752 economics leaves out. *Environment and Urbanization* 4, 121-130.

753 Russell, S., Sotos, M., Bostock, V., Canes, M., Dzuray, E., Hardison, H., Jonassen, R.,  
754 Kalloz, J., Poche, S., 2010. The Greenhouse Gas Protocol for the U.S. Public Sector:  
755 Interpreting the Corporate Standard for U.S. Public Sector Organizations .

756 Salomon, T., Couturier, C., Jedliczka, M., Letz, T., Lebot, B., 2005. A negawatt scenario  
757 for 2005-2050. ECEEE.

758 Swiss centre for Life cycle inventories, 2010. Ecoinvent database. v2.2.

759 Terasaki, M., Fukazawa, H., Tani, Y., Makino, M., 2008. Organic pollutants in paper-  
760 recycling process water discharge areas: First detection and emission in aquatic  
761 environment. *Environmental Pollution* 151, 53-59.

762 Tregouet B. (dir.), 2010. An expert examination of the Ecological Footprint. Observation  
763 et statistiques. n°16, [http://www.statistiques.developpement-](http://www.statistiques.developpement-durable.gouv.fr/fileadmin/documents/Produits_editoriaux/Publications/Etudes_et_documents/2010/An_expert_examination_of_the_Ecological_Footprint_03.pdf)  
764 [durable.gouv.fr/fileadmin/documents/Produits\\_editoriaux/Publications/Etudes\\_et\\_docume](http://www.statistiques.developpement-durable.gouv.fr/fileadmin/documents/Produits_editoriaux/Publications/Etudes_et_documents/2010/An_expert_examination_of_the_Ecological_Footprint_03.pdf)  
765 [nts/2010/An\\_expert\\_examination\\_of\\_the\\_Ecological\\_Footprint\\_03.pdf](http://www.statistiques.developpement-durable.gouv.fr/fileadmin/documents/Produits_editoriaux/Publications/Etudes_et_documents/2010/An_expert_examination_of_the_Ecological_Footprint_03.pdf)

766 Wackernagel, M., 1994. Ecological Footprint and Appropriated Carrying Capacity: A Tool  
767 for Planning Toward Sustainability.

768 Wiedmann, T., 2008. The Carbon Footprint and Ecological Footprint of the Scottish  
769 Parliament. 08-01, 1-14.

770 Wiedmann, T., Lenzen, M., 2006a. Sharing Responsibility along Supply Chains - A New  
771 Life-Cycle Approach and Software Tool for Triple-Bottom-Line Accounting. The  
772 Corporate Responsibility Research Conference 2006.

773 Wiedmann, T., Lenzen, M., 2006b. Triple-Bottom-Line Accounting of Social, Economic  
774 and Environmental Indicators - A New Life-Cycle Software Tool for UK Businesses.  
775 Third Annual International Sustainable Development Conference "Sustainability –  
776 Creating the Culture".

777