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## What is policy analytics? An exploration of 5 years of environmental management applications

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### ► To cite this version:

Yves Meinard, Olivier Barreteau, Christophe Boschet, Katherine Daniell, Nils Ferrand, et al.. What is policy analytics? An exploration of 5 years of environmental management applications. *Environmental Management*, 2021, 67 (5), pp.886-900. 10.1007/s00267-020-01408-z . hal-03122779

**HAL Id: hal-03122779**

**<https://hal.inrae.fr/hal-03122779>**

Submitted on 17 Dec 2021

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1 What is policy analytics? An exploration of 5 years of environmental management applications

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27

28 Abstract

29 Our digital age is characterized by both a generalized access to data and an increased call for  
30 participation of the public and other stakeholders and communities in policy design and decision-  
31 making. This context raises new challenges for political decision-makers and analysts in  
32 providing these actors with new means and moral duties for decision support, including in the  
33 area of environmental policy. The concept of “policy analytics” was introduced in 2013 as an  
34 attempt to develop a framework, tools and methods to address these challenges. This conceptual  
35 initiative prompted numerous research teams to develop empirical applications of this framework  
36 and to reflect on their own decision-support practice at the science-policy interface in various  
37 environmental domains around the world. During a workshop in Paris in 2018, participants

38 shared and discussed their experiences of these applications and practices. In this article we  
39 present and analyze a set of applications to identify a series of key properties that underpin a  
40 policy analytics approach, in order to provide the conceptual foundation for policy analytics to  
41 address current policy design and decision-making challenges. The induced properties are  
42 demand orientedness, performativity, normative transparency and data meaningfulness. We show  
43 how these properties materialized through these six case-studies, and we explain why we  
44 consider them key to effective policy analytics applications, particularly in environmental policy  
45 design and decision making on environmental issues. This clarification of the policy analytics  
46 concept eventually enables us to highlight research frontiers to further improve the concept.

47 Keywords: decision support; environmental policies; legitimacy; data; policy analytics

48

49

## 50 1. Introduction

51 The digital age has provided access to multiple sources of data and information for an increasing  
52 part of the world's population and has accelerated opportunities for their analysis, including  
53 through increased computational capacity. At the same time, the demand for opening policy-  
54 making processes to stakeholders, communities and the general public has evolved into a  
55 generalized call for more inclusive and extensive participation, in some cases becoming  
56 entrenched in national or supra-national regulations. This has often generated conflicting  
57 understandings of problems, driven by multiple bodies of expertise and knowledge on the same  
58 issues, which are embodied by diverse actors in society (see for example Arts et al. 2017). Since  
59 the expansion of environmental movements in the 1970s and 1980s around conservation and

60 environmental protection, the environmental policy domain has long been a prominent arena for  
61 the tension between these two trends (increased information availability and calls for  
62 participation) (e.g. O'Donnell et al., 2019; Long, 2019). However, the current digital age has  
63 rapidly exacerbated the availability of multiple, and at times contradictory, bodies of  
64 information.

65 This context raises new challenges and opportunities for innovatively engaging citizens in  
66 decision-making, and improving policy makers' capacities to intervene effectively in complex  
67 problems. In recent years, Government actors have more actively sought to address both the  
68 opportunities and challenges of new demands and capabilities driven by technological change, as  
69 highlighted by the proliferation of various dedicated policy and legislative instruments, such as  
70 the General Data Privacy Regulation (GDPR) in Europe, and high-level strategies developed by  
71 the US, China, France, Germany, and Australia (e.g. DISS 2018, Federal Data Strategy 2019,  
72 FMEAE 2018, The White House 2019, Villani 2018, Webster et al. 2019).

73 Parallel to, and in support of these shifts, academic research is also seeking to formalize new  
74 models of decision support to environmental policies, to enable a productive interplay between  
75 the use of new information technologies and the enhanced public participation. Among these  
76 initiatives, policy analytics, as formalized in Tsoukias et al. (2013) and Daniell et al. (2015),  
77 provides a framework, tools and methods fit for purpose. The term 'analytics', has historically  
78 been used for decision support within individual sectors, with previous research focusing on  
79 areas such as 'business analytics', 'health analytics' and 'learning analytics'. Across these  
80 applications, the term 'analytics' is understood as an umbrella term describing a variety of  
81 analytical methods and approaches with a sophistication that can match the complexity of the  
82 data types (both qualitative and quantitative), processing and analysis demands of the digital age

83 (Tsoukias *et al.*, 2013). Tsoukias *et al.* (2013) wanted to promote the use of such ‘analytics’ tools  
84 to address the public policy issues for which they may be relevant. However, Tsoukias *et al.*  
85 (2013) also stressed the relative difficulty of applying ‘analytics’ within the public realm, mainly  
86 due to the unique constraints associated with decision support of public policies; in particular,  
87 the use of public money and the associated need for transparency, the prevalence of participatory  
88 and deliberative processes, and the non-monetary and multifaceted nature of policy goals. To  
89 capture this two-fold ambition, they defined “policy analytics” as a project to “*support policy*  
90 *makers in a way that is meaningful (in a sense of being relevant and adding value to the*  
91 *process), operational (in a sense of being practically feasible) and legitimating (in the sense of*  
92 *ensuring transparency and accountability), [by drawing] on a wide range of existing data and*  
93 *knowledge (including factual information, scientific knowledge, and expert knowledge in its*  
94 *many forms) and [combining] this with a constructive approach to surfacing, modelling and*  
95 *understanding the opinions, values and judgements of the range of relevant stakeholders”.*

96 This concept of “policy analytics” has aroused interest among many researchers in the  
97 environmental policy domain in recent years, with numerous discussions about its utility and  
98 possible improvements, and several applications in the field being held in different places around  
99 the world. This article aims to draw on these discussions and applications to clarify the policy  
100 analytics concept so that its use and relevance can be clarified and expanded. To that end, we  
101 analyze a series of examples of concrete applications of the policy analytics framework to  
102 environmental policies. We first outline our methodological approach for clarifying the concept  
103 (section 2). We then implement this approach (section 3). We present our series of case studies  
104 (subsection 3.1). We then articulate four normative properties that emerged from the discussions  
105 and comparisons of these case studies (subsection 3.2). These properties constitute the core of

106 our proposed improved definition of policy analytics. Lastly, section 4 outlines avenues for  
107 future research on and around policy analytics.

108

109 2. A methodology to rethink “policy analytics” as an approach to support environmental  
110 decision makers

111 In their context of launching a research dynamic, Tsoukias et al. (2013) proposed a deliberately  
112 wide definition of policy analytics in order to encourage discussions with a diverse and inter-  
113 disciplinary group of researchers, policy officials and data industry collaborators. This strategy  
114 proved effective, and a series of research projects were launched and developed, as part of an  
115 effort to develop and gain traction for the policy analytics concept and its application. However,  
116 this type of approach, which uses a more general definition to avoid excluding useful  
117 contributions, also has its limits, especially once the concept is mature enough to be compared  
118 with alternative frameworks.

119 As it happens, numerous other frameworks also attempt to address the challenges associated with  
120 developing public policy in a highly data driven age, including “policy informatics” (Johnston,  
121 2015), “computational social sciences” (Lazer et al., 2009), “big data in public affairs” (Mergel  
122 et al., 2016), and “utilization-focused” and “systemic evaluation” of public policies (Midley  
123 2006; Boyd et al. 2007; Patton 2008). Shared amongst these various frameworks is the  
124 acknowledgement that our current information, communication and technological environment is  
125 undergoing rapid changes, and consequently there is both a need and an opportunity for public  
126 policy to utilize the capabilities of changing information and communication technologies.  
127 Furthermore, these approaches also agree on the issues that will emerge from increased usage of

128 data in both public and private settings, including questions around privacy, legitimacy, and  
129 accountability, and the need for new regulatory approaches that mandate certain standards in  
130 relation to these governance attributes.

131 As various research teams began to attempt real-world applications of the policy analytics  
132 concept, the lack of specificity in the definition prompted discussions on the definition itself, and  
133 on what made policy analytics unique from the alternative frameworks highlighted earlier.  
134 Various papers have proposed alternative definitions based on proposed clarifications of one or  
135 several of the criteria mentioned in Tsoukias et al. (2013). Jeanmougin et al. (2017) proposed to  
136 formalize Tsoukias et al. (2013)'s definition, using policy analytics as an evaluation framework  
137 applied to a conservation policy, by singling out four elementary criteria, associated with  
138 concrete examples. As compared with Tsoukias et al. (2013), this formulation retains the  
139 operability and legitimacy criteria, but replaces the "meaningfulness" requirement, which they  
140 considered to be too vague, by two criteria referring, respectively, to a "scientificity"  
141 requirement and a requirement to bring in a demonstrable contribution. However, this  
142 clarification focused on a specific usage of the policy analytics framework (as an evaluation tool)  
143 and applied to a specific context (i.e. conservation policies). Jeanmougin et al. (2017) also  
144 highlighted the difficulty substantiating the "legitimacy" requirement at the core of the policy  
145 analytics framework. Meinard (2017) attempted to clarify this requirement by proposing an  
146 open-ended list of legitimacy criteria, but here again this attempt was focused on the specific  
147 context of conservation policies. Interestingly, some of the criteria proposed referred to the  
148 scientific credentials of the policies whose legitimacy was being evaluated, highlighting that the  
149 four criteria proposed by Jeanmougin et al. (2017) are not completely independent. Although this  
150 interdependency between some of the criteria constituting the definition is not necessarily a fatal



151 flaw, a definition based on independent criteria would certainly be clearer. In the same vein,  
152 Choulak et al. (2019) briefly discussed the vagueness of the operability criterion.

153 The need to clarify the definition and the risks associated with too rigid definitions were  
154 discussed in numerous internal seminars among researchers in the group, based on applications  
155 of various versions of the framework based on a broader variety of policy issues, including the  
156 above mentioned environmental issues but also public health problems (Richard et al. 2018) and  
157 public management issues (Touret et al. 2019). In the wake of theoretical work clarifying the  
158 difference between tools, methods and approaches in decision support theories and practices  
159 (Meinard & Tsoukias 2019), these discussions pointed to the conclusion that policy analytics is  
160 neither a field (such as, for example, policy analysis) nor a tool nor a methodology (such as, for  
161 example, focus groups or other participatory tools), but rather an “approach” to decision support  
162 intended for actors in public policy decision making. Following Meinard & Tsoukias (2019), we  
163 use the term “approach” here to refer to “a way by which [an analyst] conducts a [decision  
164 support] process”. A given approach can be applied to different issues, which can belong to  
165 different academic fields, and it can make use of a variety of methodologies, which can  
166 themselves be used by different approaches. In this understanding, which is anchored in  
167 Habermas’s epistemological views (Habermas 1985, 1990), “approaches” are defined by  
168 normative properties that specify key aspects of the way analysts should use available tools and  
169 methods.

170 This view of policy analytics as an approach embodying normative properties opens avenues to  
171 complement the top-down definitional approach used in these previous works by identifying,  
172 through a bottom-up procedure, normative properties, to some extent shared by exemplary case  
173 studies, which could be considered to provide an addition to the definition of policy analytics.

174 Because the case studies explored below were performed with policy analytics in mind, they can  
175 be seen as partial but complementary attempts to clarify an underlying ambition shared by all the  
176 researchers who decided to gather under the banner of “policy analytics”.

177 In this dynamic, during a workshop in Paris in 2018, a series of examples of policy analytics  
178 applications to environmental policies have been shared and discussed by participants. These  
179 applications provided the empirical material to venture a formulation of key properties, in an  
180 abductive approach (Peirce 1966). This formulation was then used in a reconstructive approach  
181 to rationalize some key aspects of the applications. The results of this reconstruction are  
182 presented in the next section.

183 We should emphasize at the outset that efforts to clarify the definition in this way are not  
184 doomed to constrain the potential of the concept, as Tsoukias et al. (2013) feared. As long as the  
185 definition remains open-ended and open to discussion and improvements, attempts to refine it  
186 can usefully clarify the underlying ambitions of different policy analytics research programs and  
187 provide directions for future investigations.

188

### 189 3. Conceptualizing policy analytics: lessons from 5 years of applications

190 Using the methodology delineated above, in the present section, we start by describing the 6 case  
191 studies that were discussed in the 2018 workshop (3.1). The descriptions are all organized in the  
192 same way: We start by explaining the context (what is the policy at issue, what are the processes  
193 engaged) (1). We then explain the reasons why the researchers involved conceived of their works  
194 as applications of the policy analytics concept. Because, as explained in previous section, the  
195 original definition of policy analytics was quite open, these reasons were disparate and, very  
196 often, focused on quite different interpretations of the concept (2). We then describe the data

197 produced and/or analyzed (3). We finish by summarizing the outcome of each policy analytics  
198 application (4).

199 Following this description of the case studies, we articulate the four normative properties that  
200 emerged from the discussions and comparisons of case studies, which we propose as candidates  
201 to structure an improved definition of policy analytics (3.2).

202

### 203 3.1. Examples of applications

#### 204 3.1.1. Case 1: Elaboration of a wetland prioritization platform

205 (1) The first case involved the elaboration of an operational wetland prioritization platform in  
206 Bourgogne-France-Comté (Choulak et al. 2019) that would be seen as legitimate by its key  
207 stakeholders. Wetlands are ecosystems whose functioning is largely determined by water,  
208 such as swamps, alluvial forests, bogs, etc. These ecosystems are the target of numerous  
209 conservation policies around the world, including the RAMSAR convention, and dedicated  
210 legislation in France. Wetland prioritization is a crucial step in most action plans devoted to  
211 conserving or restoring wetlands in line with these policies. It consists of using available  
212 data on wetlands (e.g. ecological features, hydraulic functions) and the context (e.g.  
213 urbanization dynamics, land use) to decide on which wetlands managers should prioritize. In  
214 2017, the “wetland taskforce” (“Pôle Milieux Humides”) of the Bourgogne-Franche-Comté  
215 region (France)—a team within a non-profit environmental organization (Conservatoire  
216 Espaces Naturels)—was entrusted to elaborate a spatialized database on wetlands by a  
217 consortium of regional to national scale institutions funding environmental actions. It was to  
218 focus on the whole regional scale based on a new prioritization methodology that would also  
219 need to be elaborated.

220 (2) Relevant databases available for prioritizing wetlands are large and heterogeneous, and very  
221 often standard practices tend to conflate very different kinds of data indiscriminately. Some  
222 of the databases house quantitative scientific data such as the results of hydrological models  
223 or data on the abundance of a given species. Others have political aspects and may include  
224 different forms of qualitative and quantitative information, such as zoning maps produced  
225 through political processes. Tsoukias et al. (2013) emphasized the importance of taking into  
226 account the nature and design of data to provide relevant and legitimate decision support.  
227 The researchers involved in this case study therefore saw standard practices in wetland  
228 prioritization as an example domain in which policy analytics could make a difference, by  
229 developing methods that give importance to the nature of the data they use and their design.

230 (3) The data used were the contents of the spatialized database elaborated by the wetland  
231 taskforce, and all the metadata corresponding to the methodologies used to capture these  
232 data, which we used to develop rules to aggregate parts of the information in the database  
233 using a rule-based approach (Azibi & Vanderpooten 2002). An example of a rule in this  
234 context was “if there is no indicator in the database testifying that a given wetland plays a  
235 role in flood mitigation, then this wetland is assigned to the category “*No information in the*  
236 *database suggesting that it is suitable, even poorly, to pursue this objective to conserve*  
237 *wetlands performing a flood regulation function.*” A rule-based approach consists in  
238 identifying a consistent set of such rules allowing information in the database to be  
239 aggregated. To design these rules, we worked with representatives of wetland manager  
240 groups, who collectively identified a series of management objectives that they deemed they  
241 had political legitimacy to choose. We then used a rule-based aggregation method and MR-

242 Sort, a non-compensatory aggregation method (Leroy et al. 2011), to produce a framework  
243 that the wetland taskforce will be able to use autonomously.

244 (4) The concrete outcome is a platform with which the wetland taskforce will be able to prioritize  
245 wetlands for managers, in a legitimate and fine-tuned way, thereby fulfilling the promise to  
246 add value and strengthen legitimacy by paying particular attention to the nature and design  
247 of data. The increased legitimacy stems from the fact that, whereas standard practices in  
248 wetland prioritization indiscriminately conflate technical choices (concerning, for example,  
249 the reliability of this or that indicator) and political choices (for example, choices of  
250 objectives to pursue), this platform makes a point not to preempt the latter (see Choulak et  
251 al. 2019 for more details). The platform has been applied to several projects over the past  
252 few months (Melanie Paris, personal communication), and regional-scale funding  
253 institutions are interested in applying this new method at a larger scale. From a theoretical  
254 point of view, our main contribution is the notion of “meta-decision analysis.” This notion  
255 stresses that, while researchers in decision sciences can provide decision support to decision  
256 makers in some contexts, many other actors, such as consultants, experts, stakeholders, and  
257 so on, can play the role of “decision support providers.” Instead of providing decision  
258 support to a particular decision maker facing a particular problem, a researcher involved in  
259 “Meta-decision analysis” will strive to identify and help legitimate “decision support  
260 providers” to help decision-makers (see Choulak et al. 2019, section 2). Meta decision  
261 support is, in our view, a corollary of the emphasis on legitimacy championed by authors in  
262 the policy analytics space.

263

264 3.1.2. Case 2: Facilitating dialogue over a marine pollution dispute

265 (1) The second case study relates to the “red mud” conflict in the Calanques National Park  
266 (South France). In Marseille, there is an enduring dispute about waste disposal in the  
267 Mediterranean Sea, which is supposedly forbidden by the Barcelona convention of 1992. A  
268 factory has had a long-term special dispensation allowing it to dispose of massive quantities  
269 of residuals of the transformation of bauxite—the so called “red mud”. This pollution is  
270 considered illegitimate by a part of the population and creates a strong political conflict,  
271 although most people also acknowledge that the jobs provided by this factory are vital for the  
272 area. Despite public worries, the administration believes that all has been done to improve  
273 practices – but there is no communication among opposing worlds and thus no reduction of  
274 political conflict, and as a result the main argumentative discussions take place in judicial  
275 courts.

276 (2) In this context, the data available on past and current disputes are numerous (e.g. reports by  
277 experts and consultants, surveys by journalists, scientific studies, data from monitoring  
278 programs). However, in this deeply conflictual context, some of these data can be easily  
279 manipulated, and tracing back the biases that might have plagued them is hazardous. This is  
280 why the researcher involved in this case study saw it as an especially potent illustration of the  
281 idea, stressed in Tsoukias et al. (2013), that in such a complex context, sui generis processes  
282 are required to generate reliable data.

283 (3) A role-playing game was co-produced with local inhabitants, environmental associations,  
284 political decision makers and representatives of the factory to represent a range of points of  
285 view and values in a single format. Based on long interviews, cognitive maps that brought  
286 together definition of problems, actors, and possible actions were produced. Lastly, three  
287 participatory techniques were used to help structure debates: a serious game, participatory

288 theatre and the co-construction of a research project between researchers and activists. The  
289 serious game initially aimed to create debate but was transformed into an education game  
290 because the field study itself created too much tension. It has been used in diverse contexts in  
291 the region since then, but never with a group of people in serious conflict. Artists then  
292 developed a theater play to organize discussion forums where opponents to the factory,  
293 involved scientists, and the general public met and generated new discussions about the  
294 problem and the possibilities for solving it. Eventually 50 interested people were invited to  
295 co-construct a new research project about the multiplicity of forms of pollution and their  
296 circulation in the area, so as to raise awareness of the red mud issue and evaluate the  
297 vulnerability of the territory.

298 (4) The outcomes of this case study confirm the fruitfulness of developing *sui generis* tools  
299 generating entirely new data, in a context in which analyzing existing data would be  
300 methodologically questionable. The continued adaptation of the choice of participatory  
301 techniques and their implementation in this case helped to better understand the diversity of  
302 points of view. Contradictory normative views concerning social priorities could be  
303 characterized and discussed, which facilitated communication among opposing worlds. The  
304 co-constructed knowledge production has strengthened links between scientists and  
305 associations, who in parallel have found representatives able to interact regularly with the  
306 administration. Public trust in the administration was thereby strengthened and the  
307 administration renewed their interest in creating arenas of dialog. However, the political  
308 problem lingers on.

309

310 3.1.3. Case 3: Facilitating reflection on a collaborative water management network

311 (1) The third case focuses on the construction of collaborative environmental networks in the  
312 Gironde estuary (New Aquitaine, South West France) (Boschet & Rambonilaza 2017). In  
313 the context of the Water Framework Directive (WFD) and its implementation at the local  
314 river basin scale, as well as the Birds and Habitat Directives (Natura 2000 sites), several  
315 participatory mechanisms have been introduced. At the same time, local decision-makers  
316 have expressed their wishes to orient the future development of the riparian municipalities  
317 around the preservation and enhancement of natural and heritage resources, in an area that  
318 has historically had vocation as an industrial port. The major challenges were the lack of  
319 links between the two shores of the estuary, and a lack of visibility for the group of  
320 stakeholders who deal with the environmental issues of the estuary.

321 (2) One of the most important ideas emphasized by Tsoukias et al. (2013) in their introductory  
322 definition of policy analytics is that public policy contexts make it particularly difficult to  
323 use the sophisticated techniques typically associated with so-called ‘analytics.’ This is due  
324 to the fact that these sophisticated techniques are difficult for stakeholders and decision  
325 makers to understand, whereas in public policy contexts, transparency, participation and  
326 deliberation play a key role. The researchers involved in the present case study saw this  
327 context as an opportunity to test if it is possible to meet both policy analytics ambitions, by  
328 putting some sophisticated analytic techniques—in this case network analysis and statistical  
329 models—to use to help actors understand their interactions and to coproduce new  
330 interactions.

331 (3) The case study involved an ex-post analysis of the functioning of collaborative  
332 environmental governance and the main factors explaining how collaboration relationships  
333 form, and an assessment of the heterogeneity and representativeness of the stakeholders



334 involved, as recommended by WFD (Art. 14). Data collection used documentary sources to  
335 identify representatives of organizations and count their participation in four policy  
336 processes in the Gironde estuary (514 individuals representing 386 organizations). A two-  
337 mode network methodology and preliminary field survey was used to define the population  
338 of interest (“the actors who act”). Then a final survey of this population produced data  
339 covering their exchanges of information, expertise and resources, as well as the names of the  
340 people who are members of their network, who were themselves interviewed afterwards.  
341 The interviewees were asked to name the network members who are the most important in  
342 the estuary’s environmental management, then in a second step to name their actual  
343 partners, leading them to distinguish their understanding of the whole network and their  
344 personal network of collaboration. The survey, which followed a snowball sample  
345 methodology, was halted when no new names were mentioned by the respondents. These  
346 questions were integrated into a broader interview grid, which highlighted the interviewees'  
347 perceptions of opportunities and barriers to working with potential partners. The use of data  
348 (the actors involved and their relationships) first provided the current state of the  
349 collaborative network: the actors and their links, their position in the network, and the  
350 diversity of exchanges (financial, informational, contractual, informal...). A second step,  
351 which used statistical models of networks, consisted of assessing the factors facilitating or  
352 enabling collaboration links. In particular, the distance between the actors was  
353 systematically analyzed. By “distance”, we mean not only physical distance, but also  
354 institutional distance (the positioning of stakeholders in relation to the rules governing the  
355 management of environmental issues); organizational distance (the principles that dictate the  
356 involvement of stakeholders within participation devices); and finally statutory distance (the

357 specificity introduced by the roles devolved to the political and administrative apparatus via  
358 the statutes of the actors, elected or bureaucrat). The outcome was a visualization of the  
359 collaborative network.

360 (4) This work makes several contributions, illustrating how analytics tools can be put to use in a  
361 public policy context, despite the prima facie contradiction between the complexity of these  
362 tools and the requirements of participation. It provides a robust representation of the current  
363 state of the group of actors involved and a factual proof of the separation between the two  
364 shores in terms of collaboration, and cognitive support to the actors involved in terms of  
365 their social working environment. It also helped the Gironde and Charente local  
366 administration (“Conseils Départementaux”), and the “Syndicat Mixte” of the Gironde  
367 Estuary, to rebuild the collaborative network of actors mobilized around environmental  
368 stakes in the estuary. It is also a renewal of the political economy analysis of the  
369 implementation of environmental policies at the local level. This work also forced some  
370 actors to acknowledge the inertia of some networks of interaction, and its adverse  
371 implications. This eventually enticed them to encourage the arrival of new entrants,  
372 particularly economic players who have developed activities related to the estuary's heritage.

373

#### 374 3.1.4. Case 4: Water management policy design

375 (1) This case study deals with water management in the agricultural system of the Apulia Region  
376 (Italy), characterized by policy resistance that hampers the implementation of a water  
377 protection policy. Due to the limited availability of water resources, the agricultural  
378 activities are characterized by the combined use of both surface water and groundwater.  
379 Groundwater overexploitation depletes water quantity and quality, leading to long term

380 social and environmental problems, including restrictive groundwater measures according to  
381 the Water Framework Directive (Portoghese et al., 2013). The policies implemented in the  
382 area aim either to improve the efficiency of groundwater use through innovative irrigation  
383 techniques or to restrict groundwater use through policies and a tight control of Farmers'  
384 activities (Giordano et al. 2015). Based on a traditional policy making approach, this policy  
385 was developed without considering the potential impacts on the stakeholders, creating  
386 strong conflict between stakeholders. This case study hence represents an emblematic  
387 example of the complexity of water management, where decision-makers with competing  
388 objectives and values need to share the same resource. A limited understanding of the  
389 different problem framings can be a source of conflict, hampering the implementation of  
390 and/or reducing the effectiveness of environmental policies (Giordano et al. 2017).  
391 Stakeholders act as if the decision space was as simple as they presume it to be (i.e. ignoring  
392 the role of some of the other actors and/or making assumptions about their decisional  
393 processes). A detailed description of the case study and the analysis of the ambiguity in  
394 problem framing can be found in Giordano et al. (2017) and Pluchinotta et al. 2018.

395 (2) By highlighting the distinctive challenges involved in trying to use 'analytics' tools in public  
396 policy contexts, publications on policy analytics provide a partial explanation of the fact that  
397 sophisticated decision support methods tend to be poorly used at least in some public policy  
398 contexts. It occurred to the authors involved in this case study that their context of defective  
399 water management policies illustrated this idea. They therefore took this context as an  
400 opportunity to try to fulfil the corresponding promise of policy analytics, which is to put  
401 state-of-the-art decision support tools to use in a complex and conflictual public policy  
402 context.

403 (3) The data generating work focused on the policy design process (i.e. design of policy  
404 alternatives), using an innovative participatory approach. Mainstream policy tends to neglect  
405 the generation of novel policy alternatives and is more concerned with evaluating known  
406 alternatives (Ferretti et al. 2018, Pluchinotta et al. 2019). The experiences carried out in the  
407 Apulia case study supported the application of the Policy-KCP participatory tool for the  
408 design of policy alternatives, integrating Decision science and Design theory. Policy-KCP  
409 (P-KCP) is a Concept–Knowledge theory driven tool (i.e. one of the available design  
410 theories), adapted to the design of abstract objects such as public policies. The P-KCP aims  
411 to formalize the innovative design of policy alternatives within a public decision-making  
412 process. The P-KCP supports the creation of a shared artefact (Ostanello and Tsoukiàs  
413 1993), further motivating stakeholders’ engagement and commitment to a participative  
414 policy making process. The steps of the P-KCP participatory tool are described in  
415 Pluchinotta et al. (2019). The P-KCP participatory tool assisted policy makers and  
416 stakeholders to work together to the generate policy alternatives and overcome the  
417 difficulties of traditional approaches. The phase of knowledge elicitation and alignment (P–  
418 K phase) represents the starting point for building a shared concern, toward a generative  
419 phase (P–C phase). The P–K phase supported identification of the state of common  
420 knowledge on groundwater protection and surface water management problems, including  
421 the quali-quantitative state of aquifers and the analysis of the different stakeholders’  
422 problem framing (Giordano et al 2017). The knowledge elicitation activities were carried  
423 out by integrating scientific and technical pieces of evidence available in literature with  
424 expert and local knowledge according to participatory work principles. The results of semi-  
425 structured interviews structured in mental models were combined with the outputs of the

426 stakeholders' analysis and scientific literature studies, available data, emerging  
427 technologies, best practices and current policies.

428 (4) The main outcome of this study was the pilot application of an original approach for the  
429 innovative design of policy alternatives, illustrating how a state-of-the-art decision support  
430 tool can be implemented in a complex and conflictual public policy setting. The proposed  
431 methodology (P-KCP), integrating Decision Science and Design theory, formalized the  
432 policy design process and supported the generation of previously unimaginable policy  
433 alternatives. It connected local and expert knowledge within the whole design process  
434 thanks to the construction of a collective problem understanding (i.e. a shared concern). It  
435 brought together stakeholders, experts, institutional and non-institutional actors aiding them  
436 to find new ways of working together efficiently, generating innovative possible alternatives  
437 and encouraging longer term thinking. As a result, we observed that policy design can be a  
438 generative process for the creation of a new dimension of values, through the creation of  
439 new variables and/or the elimination of variables having little value for the process. For  
440 example, within the case study, we were able to introduce new alternatives in order to  
441 modify the value structures in a successful policy making.

442

#### 443 3.1.5. Case 5: Decision support for catchment management

444 (1) This study deals with a collection of decision support processes involving modelling for  
445 integrated catchment management and the stakeholders of these catchments, carried out by a  
446 team of researchers at The Integrated Catchment Assessment and Management Centre  
447 (iCAM) at the Australian National University over the past few decades (see Merritt et al.  
448 (2017) for an overview of some applications). Integrated Water Resources Management is a

449 widely recognised paradigm for making more inclusive policy decisions regulating the  
450 many, often competing, users of water; however, without effective decision support or  
451 ‘policy analytics’ the promise of the paradigm is hard to realise. Focusing on a typical  
452 situation, a project is developed in partnership with water management authorities in  
453 Australia through co-creation of a research topic, informed by both opportunities identified  
454 by the university and available resources and priorities of the agency. To ensure legitimacy  
455 of the decision-support processes and models, a steering committee is used to provide  
456 feedback, in addition to having close involvement from government personnel and  
457 landholders.

458 (2) While some of the collection of work in this case study pre-dates discussion of the  
459 expression “policy analytics”, the researchers involved consider the use of analytical tools to  
460 support policy decision making eminently aligned with policy analytics, notably through the  
461 use of participatory techniques combined with integrated modelling; the projects typically  
462 satisfy all four normative principles defining policy analytics, as listed in the next section.

463 (3) A typical project merges data and information from stakeholders and science through  
464 participatory processes and integrated modelling. Modelling provides a natural means for  
465 organizing and integrating economic, ecological, hydrological data, qualitative stakeholder  
466 input and interviews. An iterative process is adopted (Jakeman et al. 2006), recognising that  
467 design of both participatory processes and integrated models needs to be purpose and  
468 context-driven, but that new information arises over time that require changes to the project  
469 plan (Lahtinen et al. 2017). Data used in the construction of models and that from their  
470 resulting outputs play an important role in water management in understanding biophysical  
471 processes and anticipating impact of policy or management measures. Integrated modelling

472 then helps to tie economic and ecological outcomes with hydrological processes and  
473 intervention measures. Workshops to gain a common understanding of the system are  
474 supplemented by interviews targeting sector-specific understanding of agriculture and  
475 ecological outcomes. A pragmatic model building approach is used, involving representing  
476 systems at the required level of complexity and mixing methods for different model  
477 components in order to best integrate knowledge of decision makers, multiple expert  
478 disciplines, and on-the-ground stakeholders. A spatially semi-distributed hydrological model  
479 provides information at key points and aggregate regions, reducing the risk of information  
480 overload for users, and allowing for interactive use of the model. Uncertainty in outcomes is  
481 dealt with using scenarios and Bayesian Networks (Kelly et al. 2013; Maier et al. 2016),  
482 which have typically received positive feedback from users. The result is inherently  
483 interdisciplinary, such that communication within the project plays an important role.

484 (4) Project outcomes are delivered both through the stakeholder engagement process and  
485 produced model and decision support tool. The stakeholder engagement process facilitates  
486 social learning and shared problem framing, as well as building trust in the model. The  
487 model provides cross-sectoral estimates of the impact of various water policies and  
488 management interventions, in a transparent, traceable manner that the stakeholders can  
489 critique and discuss. Both the engagement process and produced tool then influence  
490 regulatory and agricultural decision making processes. Importantly, there is no ex ante  
491 expectation that the model or outputs are directly *referenced* in decision making. The project  
492 is understood to be one of many sources of information that decision makers draw on.  
493 Shaping understanding of the situation is the main priority, along with adjusting different  
494 stakeholders' views of how the world operates and their relationships to each other, which

495 makes evaluation of this type of policy analytics project particularly challenging (Hamilton  
496 et al. 2019).

497

### 498 3.1.6. Case 6: participatory revision of a water management plan

499 (1) This study focuses on the participatory process used to revise a water management plan in  
500 the Drôme river valley, located in southeastern France. The river is managed by a basin  
501 institution and a local water committee. The basin institution is in charge of coordinating  
502 stakeholders, facilitating the local water committee and carrying out construction and  
503 maintenance work. The local water committee is in charge of developing, revising and  
504 monitoring the implementation of the river management plan. The first river management  
505 plan in the Drôme was established in the mid 90's (the Drôme was the first river basin in  
506 France to establish a river management plan). This plan was revised for the first time  
507 between 2007 and 2013. For the second revision, starting in 2018, policy-makers were  
508 willing to use an innovative approach, by enabling citizens to make concrete proposals that  
509 would then be examined by the local water committee for inclusion in the revised river  
510 management plan. This participatory process was supported by a European project, SPARE  
511 (Strategic Planning for Alpine River Ecosystems, co-financed by the European Union via  
512 Interreg Alpine Space), and by international researchers. As a result, between November  
513 2016 and October 2018, 344 citizens were involved in the: i) launching of the process, ii)  
514 design of the process, iii) participatory diagnosis of the river basin, iv) identification of main  
515 stakes of the river basin and proposing of actions and v) synthesis of the results. In total, 62  
516 participatory events were organized over 2 years.



517 (2) The researchers involved saw this context as an opportunity to explore an aspect of the  
518 ambition heralded by policy analytics: how a large amount of data could be gathered and  
519 analyzed in a participatory context, in such a way as to improve the decisions made by  
520 policy makers by anchoring them in new data, while monitoring the involvement of  
521 participants in the process.

522 (3) The various steps of the process produced a large amount of data, including 85 initial  
523 questionnaires about citizens' perceptions of the river and of participation, 630 contributions  
524 to the citizen diagnosis, 189 propositions of actions, 3 action plans, 1 final report, 5 thematic  
525 syntheses sent to the local water committee and answers to 78 questions asked by citizens.  
526 In addition, the participatory process itself was monitored and evaluated to provide data  
527 about: the composition of the participants' group, its representativeness, the retention level  
528 of participants (whether participants stayed throughout the whole process or left part way  
529 through), etc. Data were collected by researchers, facilitators and participants themselves. A  
530 group of 16 citizen volunteers contributed to data framing and collection. Data analyses  
531 were made by researchers and policy makers while the process was underway.

532 (4) The project facilitated a better understanding of the opinions, values and judgements of  
533 participants: for example, the 85 initial questionnaires provided data about citizens'  
534 perceptions of the river and of participation (see results in Ferrand, Girard, & Hassenforder,  
535 2018 and <http://www.alpine-space.eu/projects/spare/en/pilot-case-studies/drome/charts>).  
536 The participatory diagnosis outlined what participants liked or disliked in the river basin,  
537 what they considered needed to be conserved or modified, what data they lacked and what  
538 questions they had. The results were also used to support policy makers, at two levels. First,  
539 data produced by participants fueled the revision of the water management plan. It

540 highlighted issues that were important to citizens and that had been to date left out by policy  
541 makers, a number of which were subjective, such as the importance of the landscape, and  
542 attachment to the territory. It also allowed an analysis of who was present during the process  
543 and those who were absent. For instance, since the process attracted mainly people over 65  
544 in its initial phases, an online participatory tool was set up for the action proposal phase so  
545 that working people and parents could participate as well. As a result, 52 additional  
546 participants contributed. Adapting the process in real time illustrated how data gathering and  
547 analysis can be included in the participatory process, rather than being postponed to the end  
548 the participatory phase. Following a similar adaptive logic, the analysis of the participants'  
549 group composition also fueled the reflexivity of the group of participants who wondered  
550 whether they were legitimate to make decisions about the river if they were not  
551 representative of the population. Finally, the project strengthened the policy process in the  
552 sense that all the data produced was proof-read by participants and then put online, thereby  
553 improving the overall transparency of the policy-making process (results were presented  
554 during participatory events and available online on a forum that was set up purposefully:  
555 <https://sites.google.com/site/dromenjeu/>). As a result, newcomers could see what had been  
556 produced by the group when they joined the process, and participants could promote and  
557 share their productions.

558

### 559 3.2. Properties of applications of policy analytics

560 As detailed in section 2, discussions and reflections on the above case studies (and additional  
561 ones which are not detailed here, such as Kana et al. 2014, Merritt et al. 2017 and Raboun et al.

562 2019), led to the collective identification of normative properties that, we claim, should  
563 accompany applications of policy analytics. The case studies explored above do not specifically  
564 embody all these properties since they were not designed with these properties in mind. Rather,  
565 they were motivated by publications and discussions on policy analytics or by ideas that featured  
566 prominently in such discussions. The properties in this section were thus identified *ex post* from  
567 the collective analysis of these studies. Future works embodying our four normative properties  
568 will demonstrate what we now consider to be important attributes for policy analytics  
569 approaches. The first two properties are concerned with capturing the specific aspects of policy  
570 analytics associated with its anchoring in decision analysis. The other two are meant to outline  
571 policy analytics features associated with its application to public policies.

572 We do not claim that each one of these properties is entirely novel for public policy studies.  
573 Many studies could rightfully claim that they satisfy one of these properties, and there might  
574 even be applications which satisfy several of them. Our claim is that a study that satisfies them  
575 all materializes the ambition underlying the policy analytics research program.

576

577 P1: Demand-orientedness. Our experiences in the different case studies above showed us that, in  
578 most cases, the fact that our academic initiatives could easily respond to a demand voiced by  
579 actors in the field was key to fulfill the ambition of co-producing solutions with decision makers.  
580 In the various cases in which the project was directly and explicitly requested by an institution or  
581 an actor (the wetland taskforce and, ultimately, the consortium of water related institutions in  
582 case 3.1.1, the local regional administration in case 3.1.3, various water management authorities  
583 in case 3.1.5, the basin institution in case 3.1.6), this strengthened the involvement of various

584 actors in the decision process, including of course the one issuing the request but with others as  
585 well. In the other cases (3.1.2 and 3.1.4), although the project stemmed from an initially  
586 academic questioning point of view, the fact that they were addressing problems that actors  
587 deemed important played a key role, which was demonstrated by the fact that various actors  
588 ultimately endorsed the questioning as their own. This suggests the importance of endorsing the  
589 normative idea that the justification of, and motivation for, an application of policy analytics  
590 should not be purely academic, and should be anchored in a real demand, voiced by actors,  
591 groups or institutions in the field. This does not always mean that the demand should pre-exist  
592 and be voiced by an actor or institution already enjoying a form of authority: it can be created as  
593 the research project unfolds, which can take time. But in that case the created demand will  
594 qualify as a demand properly speaking, and the study will qualify as demand-oriented, if and  
595 only if there are actors or groups or institutions who end-up endorsing this demand and making  
596 use of the approach and its outcomes. This theoretically disqualifies academic studies that do not  
597 respond to an actual use case, even if they claim to respond to a generic “societal demand”. We  
598 note that there will be much useful academic work required that may be pre-cursory to being able  
599 to apply policy analytics approaches in a demand-orientated manner, such as algorithm  
600 development and other methodological developments; and that in such situations the distinctions  
601 between good theory development and praxis in any application-focussed academic endeavor are  
602 inherently fuzzy.

603

604 P2: Performativity. By promoting operationalisation and the importance of co-production, policy  
605 analytics stresses that decision support interventions should not be purely academic, and should  
606 rather feed concrete applications, leading to improvements of the situation they study. This idea

607 played a key role in all of our case studies: in case 3.1.1, the outcome was a new prioritization  
608 tool that the decision aiding provider will use on a daily basis in its interactions with wetland  
609 managers, which will inevitably lead to concrete changes in their conservation strategies and in  
610 the concrete restoration actions they will implement. In case 3.1.2, the project deployment led to  
611 the construction of an active debate arena, enabling discussions among concerned populations to  
612 be reorganized. The analytical results in case 3.1.3 helped to guide future actions of decision-  
613 makers in association with the actors of the collaborative network, leading to the emergence of a  
614 new "policy trajectory". In case 3.1.4, the study designed new policy alternatives, which will be  
615 included in and enrich existing policy making processes. In case 3.1.5, water managers in  
616 numerous settings used the results of the modelling exercise to inform and make planning  
617 decisions. In case 3.1.6, the intervention led to process adaptations as illustrated by the online  
618 participatory tool set up for the action proposal phase. In all cases, this direct link with  
619 applications played a key role in ensuring the relevance and operability of the approach. This  
620 suggests the following normative property: the aim of applications of policy analytics should not  
621 simply be to describe or analyze states of affairs or processes; it should be to support actions  
622 which will encourage improvements of these states of affairs and processes, ideally in new and  
623 positive directions. This application-focused aspect is what we call "performativity". This  
624 excludes purely descriptive approaches. However, it does not exclude integration of descriptive  
625 sub-studies within a policy analytics project.

626

627 P3: Normative transparency. Our various case studies show that, when trying to fulfil particular  
628 aspect of the initial policy analytics' ambition, we were all led to work out our own normative  
629 assumptions and forced to clarify and display them. This involves amongst others: reflexively

630 identifying or choosing the role that analysts have in their interactions with decision-makers  
631 (illustrated in particular in case 3.1.1); analyzing and improving existing decision aiding  
632 structures (3.1.3); analyzing and modifying when needed the set of stakeholders, concerned  
633 citizens, and various experts that are involved in the decision process (3.1.6); analyzing the  
634 broader significance of the results of the study, and its chosen boundaries, to identify if and how  
635 they can support more generalized conclusions (3.1.1, 3.1.3, 3.1.4, 3.1.5, 3.1.6). This  
636 requirement was present from the start in case 3.1.1, since the data was specifically selected and  
637 aggregated in such a way as to prevent any risk that some actors might think that the method  
638 used preempted legitimate political or other value-laden choices. In case 3.1.2, normative  
639 considerations did not take center stage at the beginning of the project, but because the first  
640 results unveiled clashes of normative frameworks among the actors concerned, the need to be  
641 transparent with respect to the normative underpinning of the methods used ended-up playing a  
642 key role. In cases 3.1.3 to 3.1.6, the participatory aspects of the study similarly led to the  
643 emergence of a diversity of value frames, which had to be taken into account on an equal  
644 footing, thereby forcing our own interventions to be transparent with respect to their normative  
645 anchorage. With the benefit of hindsight, this idea appears crucial, since it conditions our ability  
646 to support decision makers in their own attempts to be transparent and accountable, in particular  
647 in their interactions with decision support providers (be they researchers, consultants or in-house  
648 policy analysts). This suggests the following normative property: applications of policy analytics  
649 should clarify, display and account for their normative underpinnings, both in terms of the points  
650 of view taken into account and in terms of how interactions between analysts, decision-makers  
651 and stakeholders unfold. This property excludes, for example, welfarist economic, public

652 management approaches and others that do not make explicit their ethics and values-based  
653 assumptions.

654

655 P4: Data meaningfulness. The term “analytics”, in “policy analytics”, was purposefully chosen to  
656 emphasize that one of the most important (if not the most important) ambitions of policy  
657 analytics is to reinforce the importance of reflecting on the nature and meaning of data used to  
658 support policies. The general availability of numerous and sometimes large datasets that  
659 characterizes our digital age means that large quantities of data can be easily accessed and  
660 computed. But information on the context that has led to the emergence of these data, the  
661 protocols used, their intrinsic limits, the paradigms that should accompany their interpretation;  
662 rather than being forgotten in this process. Devictor & Bensaude-Vincent (2016) and Jaric et al.  
663 (2019) provide detailed examples of the problems that this can create for environmental policies,  
664 as data are computed and interpreted in questionable ways. Several of our case studies were  
665 motivated by attempts to master the whole process of data generation and analysis needed to  
666 overcome such problems. In case 3.1.1, data were specifically selected and aggregated in  
667 different ways depending on how stakeholders understand them. The choice of aggregation  
668 methods was then dictated by the interpretation of the data shared among acknowledged experts,  
669 and known or suspected associated uncertainties and knowledge-gaps, which involved avoiding  
670 commonly used, more mechanistic weighted-sum methods which silence these features of data.  
671 In case 3.1.2, the methods used guided the data collection rather than the other way around. In  
672 case 3.1.3, the data were constructed with the actors with a continuing attention to how various  
673 actors or groups understood them. In case 3.1.4, the Policy-KCP participatory tool (Pluchinotta  
674 et al. 2019, Giordano et al. 2020) assisted collaboration between policy makers and stakeholders,

675 connecting local and expert knowledge within the whole design process thanks to the  
676 construction of a collective problem understanding (i.e. a shared concern). Similarly, in cases  
677 3.1.5 and 3.1.6, participants were encouraged to contribute to data framing and collection (P3).  
678 In all the cases, the data meaningfulness issue hence appears crucial, and the *ex post* analysis  
679 even suggests that it could have played a more central role. This is why we champion the  
680 following normative property: the analysis of the nature and meaning of data, determined by  
681 their context of emergence, protocols used, intrinsic uncertainties and limits, and associated  
682 paradigm, should all play a key role in any application of policy analytics. Notice that this  
683 requirement does not prevent including, and even advocating for, gathering experience on the go,  
684 for example through using real-time sensor feeds or logbooks. These tools are meaningful for  
685 both reflexive *ex post* analysis and formative tracking of system impacts, providing some  
686 immediate reflexivity or ‘feedback’ to be used in the policy process itself, for example to identify  
687 a particular threshold that may be crossed.

688

689 The four properties articulated here can thus be seen to provide a concrete shape to the promise  
690 of policy analytics approaches, including to allow them to tackle a number of challenges  
691 associated with digital age and participation, as spelled out in the introduction. Data  
692 meaningfulness (P4) aims to reduce the risk of policy makers feeling overwhelmed by data,  
693 whose analysis can end-up being entirely beyond their control, as well as to allow them to  
694 benefit from messy or unstructured data produced through participatory processes. Normative  
695 transparency (P3) can similarly be seen as a safeguard to prevent decision processes from being  
696 captured by blackbox models and policy processes that obfuscate the actors and their stakes or  
697 interests in them. These two properties can be seen as two constraints on decision support



698 activities that, in what might seem to be paradox at first glance, are at the same time all the more  
699 important and all the more difficult to abide by in the digital age. The importance and difficulty  
700 of the challenge justifies the need for not just incremental improvements in policy analytics  
701 practice, but also major, disruptive innovations in policy making. These can only be delivered by  
702 ambitious research activities rethinking the very structure of decision support science and  
703 practice. This is epitomized again by the emphasis on learning in P3 (normative transparency),  
704 while emphasizing that the innovations produced should have impacts in real life (P2,  
705 performativity) and fulfill real needs or demands rather than emerging from purely theoretical  
706 whims (P1, demand-orientedness).

707 Based on this analysis, we claim that these four normative properties should be understood as a  
708 definition for a *bone fide* application of policy analytics. Our case studies were not elaborated  
709 with these four normative properties in mind. Rather, as explained in our methodology, they  
710 were elaborated with the ambition articulated by policy analytics in mind. Specifically, the  
711 properties were ventured *ex post*, through a structured collaboration process of discussion and  
712 case study analysis, so as to strengthen applications of policy analytics in the future. The six case  
713 studies therefore do not all materialize the four properties to the same degree. The four  
714 properties, however, arguably account for important aspects of all six case studies, and point to  
715 areas where each could have been ideally improved to lead to greater policy impact.

716

#### 717 4. Agenda for further policy analytics research

718 As the above account illustrates, we conceive of the development of policy analytics as a  
719 dynamic project. It was launched as a conceptual contribution, but its contours are being refined  
720 as more and more practical applications have been uncovered from past practice, recently

721 implemented with the policy analytics concept in mind, and subsequently stimulated reflection  
722 and prompted adjustments to both policy analytics theory and praxis. This article attempted to  
723 capture the core ideas and motivations underlying recent applications and developments of the  
724 concept. However, the resulting picture should not be seen as a final description, but rather as a  
725 step in a continuing dynamic, whereby we hope to further improve the framework in the years to  
726 come through new applications to what we see as emergent, challenging and pressing issues. In  
727 this final section, we would like to emphasize a handful of the major issues which could structure  
728 a useful research agenda for the policy analytics community in the near future to support it to  
729 achieve its ambitions. The connection of each research frontier to the properties spelled out  
730 above (P1-4) is also briefly discussed.

731 Our examples above highlighted the importance of participatory approaches in demand-  
732 orientedness (P1). Accordingly, fully implementing this property raised challenges pertaining to  
733 stakeholder selection issues, which have been an important research topic for a long time for  
734 researchers concerned with engineering participatory processes and participation in policy  
735 decisions (e.g. Daniell, 2012; Nabatchi, 2016). The works developed by policy analytics  
736 researchers allowed important advances in the design of participatory processes and continuous  
737 diffusion of data and information through these processes so as to ensure transparency,  
738 relevance, and informed decision-making. However, as the process unfolds, the boundaries of the  
739 issues tackled and problem formulations can evolve. Due to this evolution, the group of  
740 stakeholders initially selected can become incomplete or partly irrelevant at a given stage of a  
741 policy-support process. Similarly, a choice made initially concerning the process design, e.g. the  
742 participatory methods selected or the roles assigned to some participants, may no longer be  
743 relevant later given this evolution. There is therefore a need to identify technologies or

744 procedures to (1) facilitate co-evolution of the participants involved and of the process design,  
745 while (2) keeping a memory of previous dialogues, achievements and evolutions. This is a major  
746 research frontier for which policy analytics' distinctive interest in data analysis and meaning-  
747 giving provide value through collection and use of data generated throughout these participatory  
748 processes.

749 We have also seen above that participatory aspects of policy analytics projects play an important  
750 role in fulfilling the requirements associated with data meaningfulness (P4). Accordingly,  
751 another research frontier for the design of participatory processes is to elaborate means of  
752 identifying the data and information that the various participants need to meaningfully participate  
753 in the decision. Thinking more fundamentally about the notion of data, how data are created,  
754 modified, circulated and re-used out of initially designed contexts is also an important challenge,  
755 echoing the importance that policy analytics grants to data meaningfulness (P4). This reflection  
756 also has aspects concerning data sovereignty and ownership, and what this means for policy  
757 analytics under different jurisdictions. Particularly, policy analytics could integrate reflections  
758 about issues of power linked to ownership and diffusion of data, or lack thereof. There are also  
759 links to issues of data privacy and accessing environmental-related data about people, and how  
760 the use of this should be managed. Likewise the challenges of what streams of data can be  
761 meaningfully and ethically integrated to provide full (but perhaps too full) a picture of people,  
762 their values, interests and preferences is highly topical as governments and corporations look at  
763 their data assets and their perceived underuse (e.g. Löfgren and Webster, 2020). More generally  
764 speaking on the area of participation linked to policy analytics, and already reported in the  
765 literature (Mazri et al. 2019, Daniell et al., 2010), the design of participation structures is itself a  
766 topic of participation, requiring design methodologies where participation is pragmatically

767 considered. Data, when used within complex and long decision processes, are generally subject  
768 to several manipulation processes. Assuring the quality and meaningfulness of the entire data  
769 pipeline is today a major challenge for the whole area of data science (Christophides et al. 2019).  
770 An additional critical issue concerning the policy analytics topic is how to introduce innovation  
771 within public policies, for example to conceive of currently inconceivable policies. The most  
772 promising ideas come from joining analytics with formal design tools, allowing the emergence of  
773 “out of the box” designs (Howlett, 2011; Pluchinotta et al. 2019), and in some cases a healthy  
774 dose of considering science fiction and the cutting edge of artistic inspiration as an options set  
775 worthy of formal investigation (Johnson, 2011; Wenger et al., 2020).

776 Important research frontiers also concern how to implement normative transparency (P3) in a  
777 formalized, rigorous fashion. In this area, formal argumentation theory in artificial intelligence  
778 (Rahwan & Simari 2009) holds important promise to help improve discussions around policy  
779 analytics interventions. However, the possibility to use these approaches in this setting raises  
780 important epistemological and methodological questions that they do not yet tackle. In particular,  
781 if these approaches are used in real-life collective decision processes, they will have to answer  
782 questions such as: who has the legitimacy to decide which arguments should be seen as good  
783 arguments, and which ones should be considered spurious, and how transparency can be  
784 guaranteed in argumentation processes? Cailloux & Meinard (2019) proposed a preliminary  
785 formulation of a framework designed to overcome this (and other) limitation of such approaches.  
786 Important challenges also lie in a proper integration of such tools in the proceedings of  
787 discussions among people or groups, and the reflection of individuals involved, which remain the  
788 core of what normative transparency refers to.

789 An associated issue, having to do with next generation algorithms (e.g. AI), is related to what  
790 metrics are considered relevant when used as part of policy analytics. For example, perhaps  
791 explicability of analytical processes and models is less relevant than legibility (Scott, 1998) and  
792 trust. This is particularly important in automated/autonomous systems where decision and policy  
793 makers may need to understand the different algorithms, data streams and sensors, and hence  
794 trust each layer in the supply chain. What would useful policy analytics look like in such  
795 systems?

796 Lastly, a major concern for future research that has to do with performativity (P2), is the long  
797 term sustainability of the policy analytics interventions. Policy analytics activities should  
798 arguably have long term benefits and co-benefits. Hence a future research avenue is to identify  
799 what makes policy analytics approaches more salient for long-term policy support and  
800 interventions in a variety of contexts.

801 Our six case study examples illustrate how the notion of policy analytics, in its original  
802 conceptualization, proved useful to explore important environmental issues and support  
803 environmental decision-makers for important decisions in the field. However, this agenda for  
804 future research in turn shows how developing the concept in a bottom-up approach, far from  
805 closing debates with a final definition, can help to structure future studies and open new research  
806 avenues to further strengthen environmental decision support and the application of policy  
807 analytics approaches more broadly.

808

809 Acknowledgements

810 This collaborative research was supported by a grant from the ANU Global Research  
811 Partnerships Scheme, and two EU Erasmus+ Jean Monnet projects, the ‘Europa Policy Labs’ and  
812 the ‘Water Policy Innovation Hub’.

813

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