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Degrowth initiatives in the urban water sector? A social multi-criteria evaluation of non-conventional water alternatives in Metropolitan Barcelona

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A B S T R A C T

Debates on degrowth have mainly focused on theoretical issues, specially around the unsustainability of the current economic model based on growth. Along those lines some scholars have dealt with the opportunities and barriers to voluntary social action for degrowth at a general level. Notwithstanding the key importance of such debates, we argue that local strategies to move towards degrowth are still to be explored. Departing from the specific case of water, in this paper we interrogate the compatibility of non-conventional centralised and decentralised water supply technologies (desalination, reclaimed water reuse, greywater reuse and rainwater harvesting) with degrowth principles. Taking as a case study the Metropolitan Area of Barcelona (Spain), a social multi-criteria evaluation has been performed to explore the feasibility, desirability and acceptability of both models. The paper aims to explore the pros and cons of the different water alternatives in two different (and hypothetic) societies: one based on growth (business-as-usual) and one based on degrowth. The technical analysis reveals that rainwater harvesting and reclaimed water reuse are the most preferred alternatives from a degrowth perspective while reclaimed water reuse and desalination are the most preferred alternatives from a growth perspective. The social multi-criteria analysis also serves to unveil which social actors may favour or block the adoption of each alternative. Notwithstanding that most social groups see desalination as the least desired option, this is the hegemonic non-conventional source in Spain which evidences the prevalence of growth discourses in water management. Local decision-makers, city council managers and environmental groups clearly opt for the promotion of rainwater harvesting and as a result, they appear as potential allies to promote degrowth in water consumption. The social multi-criteria evaluation helps to elucidate the main challenges that need to be addressed in the pursuit of a more sustainable and equitable water management.

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1. Introduction: the looming water crisis and the changing water paradigms

Industrialised societies have based their development in the escalating production and consumption of goods and services. This production–consumption nexus has resulted in an unsustainable extraction and use of a large variety of natural resources of which water constitutes a prime example. Water crises are meant to be common feature of the world of the 21st century (Gallopin and Rijsberman, 2000; Rijsberman, 2006), and could be further aggravated by climate change (Alcamo et al., 2007; Arnell, 2004). Currently, about one-third of the world population lives in countries with moderate-to-high water stress (UNEP, 2002). By 2030, this figure is expected to increase to about half of the world population (World Water Assessment Programme, 2009). Similar to the concept of "peak oil", the concept of "peak water" (Palaniappan and Gleick, 2008) suggests that water, although renewable, may become a limited resource in certain cases, especially at regional and local scales where water available for consumption may be restrained if demand exceeds renewable resources or water is polluted.

By 2020 water use is expected to rise by 40% with respect to the beginning of the century (World Water Council, 2000). The construction of large and sophisticated infrastructures such as dams or water transfers has been the main strategy followed to meet the growing water demand of urban agglomerations and irrigated agriculture (Saurí and del Moral, 2001; Kallis and Cocossis, 2003). Opposition to these types of megaprojects is, however,

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growing, since these expensive infrastructures produce severe damages on aquatic ecosystems and local populations (McCully, 1996; World Commission on Dams, 2000). Against this situation of growing water use and environmental degradation, and drawing on Schneider et al. (2010), in this paper we attempt to bring the debate on degrowth (introduced by Georgescu-Roegen in the 1970s) (Georgescu-Roegen, 2006) and further developed during the last years (see for instance Latouche, 2006, 2010) to the urban water sphere.

In opposition to supply-side strategies such as the construction of large-scale infrastructures based on economic growth and an increasing water demand rationale, water demand management strategies have increasingly gained recognition, particularly at the local level. However, among the different strategies of Demand Side Management (DSM), economic tools reign supreme as the hegemonic mechanism to allocate water resources. Environmental Economics has dominated this debate, casting water price as a powerful way to manage demand: high prices are believed to lead to low consumptions. However, price mechanisms show some limitations: for basic uses water is price inelastic (meaning that consumption does not decline at the same pace as price rises), and this may bring some issues especially for the less well-off. In addition, there is still an ongoing debate on how to incorporate the environmental externalities on water pricing. All in all, and despite the clear benefits for the environment, as water consumption may drop (together with energy use related to water use) and externalities become better reflected in prices, the application of reductionist economic instruments may change the perception of the resource as well. Thus, water could change from being considered a common resource to being considered a commodity, and thus may cause unintended effects on those having less economic power.

On the other hand, under the umbrella of Ecological Modernisation, technology has been the other strategy of DSM, as it permits to elude political questions and move the solution of water and other environmental problems to the scientific and technocratic field in a process that Swyngedouw and other authors call the post-political condition (BAVO, 2007).

In recent times, the use of new water sources, different from the more traditional surface water withdrawals or underground water extraction, is growing in order to cope with the challenges that water management faces all over the world. However, new sources such as desalinated water, reclaimed water (i.e. wastewater treated to a high degree to be reused in secondary uses), greywater or rainwater present very different characteristics.

These non-conventional techniques generate different water qualities and thus may be used for different water purposes. Notwithstanding this, they may serve to alleviate water stress by both reducing the quantity of water demanded from conventional sources and by providing more resilience to the water supply system of a given place. In general terms, they can be divided according to two different management models: centralised and decentralised. Desalination and water reclamation usually share the features of centralised models since water is usually treated in large facilities and transported through long networks before being consumed. Decentralised systems such as rainwater harvesting and greywater reuse rely on local water sources that may be "produced" on-site, at the house or building scale. Another distinctive feature of these two models is their dominant form of governance. Centralised systems serve many users and are governed by either public or private water companies while decentralised systems serve few people and are usually governed by the users themselves. It is acknowledged that both models are not totally exclusive and can indeed be complementary in some circumstances but at the same time, public policies usually tend to favour one of the two models. For instance, in some municipalities of the Metropolitan Area of Barcelona (MAB), public policies are starting to stimulate the use of decentralised water supply systems in new buildings while at the national level public policies usually favour the use of centralised systems.

2. Objectives of the paper

Debates on degrowth (see for example the different contributions in this issue) have mainly focused on theoretical questions, and especially on the unsustainability of current trends (Alcott, 2010; D'Alessandro et al., 2010; Hueting, 2010; Kerschner, 2010; Spangenberg, 2010). The overall rationale of these contributions has been one of breaking the myth of growth (see for instance Van den Bergh, 2010), or highlighting the opportunities and barriers to voluntary social action for degrowth (Hamilton, 2010; Matthey, 2010). While acknowledging the key importance of such debates, we argue that local strategies are to be explored in order to move towards degrowth, as said by Research and Degrowth (2010) in the Degrowth Declaration of the Paris 2008 conference. In this sense, we find relevant the contributions of Lietaert (2010) and Cattaneo and Gavaldà (2010) around degrowth and new forms of understanding our way of living.

Taking as a case study the MAB and by means of a social multicriteria evaluation (SMCE), this paper attempts to compare four non-conventional water sources (desalinated seawater, reclaimed water, rainwater and greywater) in order to gain knowledge about their real and perceived socioenvironmental performance. Furthermore, and drawing on the principles of a growth and degrowth paradigm, the paper attempts to contribute to the debate on the desirability and feasibility of these non-conventional water sources in these two contexts. Finally, the paper also intends to unveil the main social actors behind each water alternative.

The following premise constitutes the starting point of this research: in urban settings the use of desalinated seawater, reclaimed water, rainwater and greywater is increasing but these sources receive different levels of public support due to their differing characteristics (Brown et al., 2009; Dolnicar and Schäfer, 2009).

3. The use of non-conventional water resources in Metropolitan Barcelona

The equilibrium between water supply and demand in the Metropolitan Area of Barcelona (MAB), one of the most important urban conurbations of Southern Europe with more than three million people in 2010, has been historically fragile (Saurí, 2003). Several episodes of water scarcity have taken place during the 1990s and the early 21st century and climate change is expected to worsen this situation (Llebot, 2005). Water scarcity in the MAB became especially evident in 2008 when the area suffered an acute drought episode resulting in water restrictions for a number of uses. The area was just days away from possible domestic cuts and water had to be shipped by sea tankers from different locations of the Mediterranean coast. At the same time, this crisis opened an interesting debate around the needs of water of Barcelona's social metabolism and whether the region water scarcity responded to physical or social factors. Water demand management was central during drought management. Awareness campaigns were launched asking for a reduction of water consumption and for citizen's contribution to confront the drought. Furthermore, outdoor water uses such as gardening watering and swimming pool filling-up were forbidden during the drought. Technological devices such as aerators were also distributed to reduce water consumption. While the urgent needs of more water were repeated like a mantra, there was an intense debate on how to provide the

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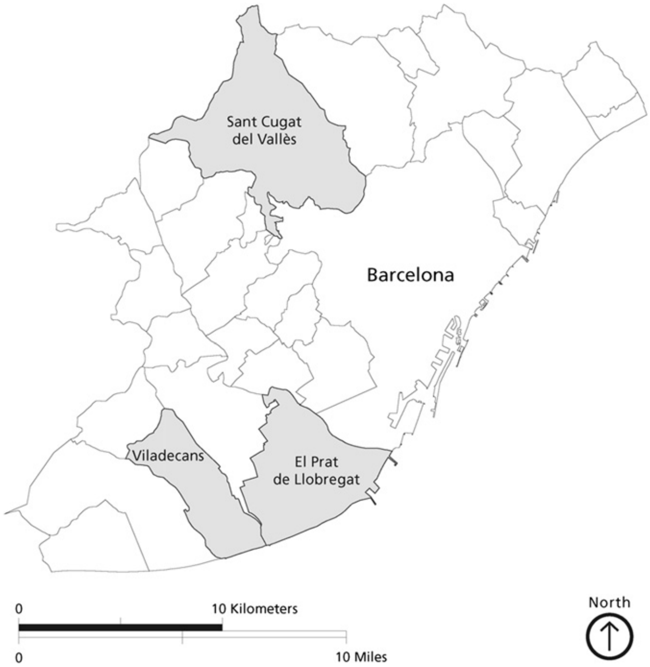

Fig. 1. Map of the Metropolitan Area of Barcelona and reference municipalities.

extra flows needed as in recent years the deployment of 20th century water technologies, dams and transfers, had been severely criticised.

To face this challenge, on the one hand the Spanish (State) and the Catalan (Regional) governments promote desalination plants along the Mediterranean coast and consider the use of reclaimed water from wastewater treatment plants (ACA, 2009). In contrast, at the local level, several municipalities promote greywater reuse and rainwater harvesting systems through local regulations (Sant Cugat del Vallès City Council, 2008).

In order to facilitate the analysis of the non-conventional sources under scrutiny, four case studies from the MAB with relevant experience on the management of these sources have been selected (Fig. 1). The case studies are described below:

- *Seawater desalination plant in the Llobregat river basin* (Departament de Medi Ambient i Habitatge et al., 2009). The plant, located in the municipality of El Prat del Llobregat, was inaugurated in July 2009. It has an average flow capacity of 180,000 m^3/day and may supply water to all the entire MAB. It is one of the largest desalination plants in the Mediterranean.
- *Water reclamation project in Viladecans* (Almudéver, pers. com., 2009). The installation of a tertiary treatment stage in the wastewater treatment plant of Gavà-Viladecans and the construction of a dual distribution network in the municipality of Viladecans will make possible the distribution of reclaimed water for irrigating public and private parks and for street cleaning. The dual network also distributes groundwater extracted from wells in the municipality. The infrastructure was expected to work at full capacity in the spring of 2010.
- *Greywater reuse in Sant Cugat del Vallès* (Domènech and Saurí, 2010). Since 2002 all new buildings in this affluent suburb of Barcelona with more than eight apartments or shower consumption over 400 m^3/year must install a greywater reuse system that recycles shower water for toilet flushing. By 2009, 4699 flats had already been included in the regulation. A standard system serving 20 flats has served as a reference to make the pertinent calculations.
- *Rooftop rainwater harvesting in Sant Cugat del Vallès*. (Domènech and Saurí, 2011). Since 2002 all new buildings in this municipality with more than 300 m^2 of garden must install a rainwater harvesting system. By 2009, 1640 flats had been included in the regulation. Several households also received subsidies from the municipality to install rainwater-harvesting systems. A rainwater harvesting system (storage capacity of 10 m^3, water used for toilet flushing and garden irrigation) installed in a single family detached house has been taken as a reference model.

4. Social multi-criteria evaluation: a tool to appraise non-conventional water sources feasibility and desirability

Multi-criteria evaluation is designed to take into account a wide variety of factors in decision-making and not only profit maximisation, as would be the case in more conventional tools such as Cost-Benefit Analysis (CBA) (Martínez-Alier et al., 1998). In that sense, multi-criteria decision theory appears to be a promising tool to perform empirical evaluations of potential degrowth initiatives, as it seeks to modulate the influence of economic factors considering other aspects such as environmental conservation or social equity. In the water field, efforts to assess different water alternatives by using a multi-criteria decision framework can be found in White et al., (2006) and Paneque Salgado et al. (2009).

Testing the feasibility and desirability of different water supply alternatives involves confronting high degrees of complexity and uncertainty arising from the need to consider different dimensions (economic, social, environmental, technical) and the preferences and values of different social actors. One important result of these uncertainties and indeterminacies is that, in any policy problem, one has to choose an operational definition of "value" taking into account that social actors with different stakes, cultural identities and goals may have different definitions of "value" (Funtowicz and Ravetz, 1993). In order to obtain a ranking of policy options, the use of multi-criteria evaluation implies the need for deciding about

Table 1
Social actors influencing and shaping water management and governance in the MAB that responded to the on-line questionnaire.

Social actor	Scope	Number of respondents	Description
Catalan water agency	Regional	4	Public entity responsible for planning and managing the integrated water cycle in the inner basins of Catalonia where the MAB is located
City council managers	Local	19	Professionals working in the environmental departments of municipalities
Local decision-makers	Local	13	Elected members of the municipal governments in charge of the environmental department of the municipalities
Water supply companies	Local/Regional	8	Public and private water supply companies responsible for supplying retailed water to consumers
Water technology related firms	Regional	4	Regional companies selling domestic water treatment technologies
Scientists	Regional	7	Researchers and experts of the water sector
Neighbourhood associations	Local	4	Group of citizens defending the interests of the residents living in one neighbourhood
Environmental groups	Regional	4	NGOs defending the conservation of the natural environment

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Table 2
Evaluation criteria.

Dimension	Criteria	Type of evaluation	Description	Initial list	Final list
Financial	Capital cost of the system	Quantitative	Capital cost of the system per cubic metre of water. An amortisation period of 20 years is assumed.	✓	✓
	Operation and maintenance cost	Quantitative	Operation and maintenance cost of the system per cubic metre of water.	✓	✓
Social	Level of public acceptability	Qualitative	Level of public acceptability of the users towards non-conventional water sources.	✓	✓
	Health risk	Qualitative	Risk for human health of every source according to the quality of the treated water.	✓	✓
	Empowerment of local government bodies	Qualitative	Degree of involvement of local institutions and citizens in the management of water sources.	✓	
Environmental	Energy consumption	Quantitative	Energy consumed per cubic metre of water, including catchments, treatment and transportation. Energy consumed to pump water within the household is not included in the analysis, as it is assumed that it is equivalent for all non-conventional water sources.	✓	✓
	Other environmental impacts	Qualitative	Environmental impacts caused by every non-conventional water source, except energy consumption.	✓	✓
Technological	Simplicity	Qualitative	Degree of dependence on state-of-the-art technology.		✓
	Reliability	Qualitative	Availability of the non-conventional water source throughout time.		✓
	Time of implementation	Quantitative	Time taken to complete the installation of the non-conventional water supply system	✓	

"*what is important* for different social actors as well as *what is relevant* for the representation of a real-world entity" (Munda, 2006:p. 91). In order to ensure a transparent SMCE "the way a given policy problem is structured and thus the assumptions used, the ethical positions taken, and the interests and values considered have to be made clear" (Munda, 2003:p. 8).

In this framework, mathematical models still play a very important role in order to guarantee consistency between the assumptions used and the results obtained. In this case, we use two different models: the Condorcet–Kemeny–Young–Levenglick (C–K–Y–L) ranking procedure (Munda, 2005) and the NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) method (Munda, 1995). The C–K–Y–L is used to conduct a technical analysis (Section 4.1.) while NAIADE is used to conduct an institutional analysis (Section 4.2.)

In this paper we use a social multi-criteria evaluation framework to analyse the feasibility and desirability of the four non-conventional water sources in incipient use in the MAB. The main social actors influencing and shaping urban water management and governance in the MAB were identified and included in the analysis (see Table 1). An on-line survey was used to capture the views and opinions of the social actors identified. This technique has the advantage that it allows for the participation of a large number of respondents and for the collection of structured information. In total 63 individuals belonging to eight different social groups answered the survey. The individuals were selected according to their relevant experience on the field and/or their availability to answer the survey. The questionnaire[1] included seven different questions:

1. With the objective of increasing the volume of water available for domestic consumption in Catalonia, indicate the degree of suitability (from totally appropriate to extremely inappropriate) that you would assign to the following alternatives: seawater desalination, reclaimed water reuse, greywater reuse, rainwater harvesting
2. Apart from the four alternatives mentioned above to increase the volume of water available for domestic uses, do you think that it would be important to include some other alternative to the multi-criteria analysis?
3. Below we present those criteria that we have considered relevant for the evaluation of the suitability of the presented alternatives in the current context. Indicate the importance of the following criteria according to your opinion (from very important to very insignificant)

   Capital cost of the system; operation and maintenance cost; empowerment of local government bodies; level of public acceptability; health risk; energy consumption (CO_2 emissions); other environmental impacts; time of implementation

4. Would you like to include some other criteria to evaluate the suitability of the selected alternatives? Which one?
5. To what extent you agree with the following statement (from very much agree to very much disagree): "Public institutions should incentive the installation of descentralised water systems (greywater reuse and rainwater harvesting systems)".
6. To what extent you agree with the following statement (from very much agree to very much disagree): "Citizens should assume more responsibilities in the urban water cycle, for example assuming the management of decentralised water systems (greywater reuse and rainwater harvesting systems)"
7. Below we present a series of available mechanisms to incentive greywater reuse and rainwater harvesting. Please indicate to what extent you agree with their implementation (from very much agree to very much disagree)

   Regulations (obligatory); subsidies; partial exemption of the Canon de l'Aigua (water tax); price increase of conventional water sources; awareness campaigns; others

4.1. *Technical analysis*

The technical analysis is performed to evaluate a series of alternatives (in this case the various non-conventional water sources in emergent use in the MAB) against a series of criteria set. We compare the performance of these non-conventional sources in two different scenarios: one based on growth (i.e. business-as-usual) and one based on degrowth. This type of analysis enables a better understanding of the advantages and limitations of the different alternatives in each scenario.

4.1.1. *Selection of alternatives and evaluation criteria*

The alternatives under study were proposed by the research team (after an extended review of the literature) and, as said,

[1] The questionnaire (in Catalan) is accessible in this website: http://icta.uab.es/recursoshidrics/index.php.

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Table 3
Weights given to the evaluation criteria for the growth and degrowth scenarios.

Dimension	Criteria	Weight growth	Weight degrowth
Financial	Capital cost	$x = 0.171$	$x/2 = 0.071$
	O&M cost	$x = 0.171$	$x = 0.143$
Social	Public acceptability	$x/2 = 0.086$	$x = 0.143$
	Health risk	$x = 0.171$	$x = 0.143$
Environmental	Energy consumption	$x/2 = 0.086$	$x = 0.143$
	Other environmental impacts	$x/2 = 0.086$	$x = 0.143$
Technological	Technological simplicity	$x/3 = 0.057$	$x = 0.143$
	Reliable water supply	$x = 0.171$	$x/2 = 0.071$

included four non-conventional water resources: desalination, reclaimed water reuse, greywater reuse and rainwater harvesting.

Eight criteria were proposed by the research team to evaluate technically every alternative: capital cost of the system, operation and maintenance cost, level of public acceptability, health risk, empowerment of local government bodies, energy consumption, other environmental impacts, and time of implementation. In order to select the most relevant criteria, respondents were asked to give their views on their importance. Empowerment of local bodies and time of implementation were the criteria considered by respondents as the least important and, accordingly, were excluded from the final list of criteria. Respondents were also given the option to propose other relevant criteria for analysis. Two new criteria – water security and technological simplicity – were suggested by several respondents and thus, they were incorporated in the final list. This final list for the technical multi-criteria evaluation consists of eight criteria which are presented in Table 2.

Every alternative has been evaluated against the criteria set taking as a reference one of the case studies presented above and one of the scenarios presented in the following section. When data required to fulfil the impact matrix was not available in a selected case study, the information was obtained from grey and academic literature. Whenever possible criteria were expressed in quantitative terms, however, in various instances they had to be expressed in qualitative terms either due to difficulties to find a suitable unit to quantify the criteria or because of the lack of available data. For the qualitative criteria we have used a ranking score with ordinal meaning of a Condorcet type. The main assumptions made for the design of the multi-criteria impact matrix are explained in the results section.

It is important to bear in mind that uncertainties are an inherent feature of complex systems and that ethical and subjective judgements may influence the assessment process. However, if the problem is well-structured, assumptions are well explained and the awareness and expertise of participants is ensured, the quality of the overall process should be guaranteed (Munda, 2004).

4.1.2. Growth and degrowth scenarios

We have created two different scenarios – growth and degrowth – in order to examine the pros and cons of every water alternative in both contexts. The criteria used in both scenarios are the same, although they have been given different weights (importance coefficients) depending on the relevance of the criteria for each scenario.

In the degrowth scenario the criteria capital cost and reliability are considered less important than the rest of criteria and consequently, have been given half of the standard weight ($x/2$). The capital cost of the system is less relevant in the degrowth scenario since in this case the weight of economic indicators is reduced while the importance of social and environmental indicators is accentuated. Regarding the reliability of the system, in a degrowth context users are more willing to get adapted to the unreliability of the water supply system as trade-offs for environmental benefits can be accomplished.

In the growth scenario economic criteria reign supreme in the selection of the most feasible alternative. Social and environmental aspects such as the level of public acceptability, energy consumption and other environmental impacts are less considered in this scenario and as a result, we have given half of the standard weight ($x/2$) to these three indicators. Technological simplicity would be the least relevant criteria in a society based on growth. In this way, this latter criterion has been assigned one-third of the standard weight ($x/3$) for the growth scenario.

Weights given to the different criteria in each scenario are shown in Table 3.

4.1.3. The C–K–Y–L ranking procedure

The multi-criteria impact matrix shown in Table 4 is used to run the technical multi-criteria evaluation. Since we are giving weights as importance coefficients we have to use a Condorcet approach, which is a non-compensatory approach (conversely, the Borda's approach would be adopted when weights are used in the form of trade-offs). This method presents a lower probability of rank reversal in comparison to other scoring methods. One of the main problems of the Condorcet's approach is the presence of cycles i.e. cases where $a\mathbf{P}b$, $b\mathbf{P}c$ and $c\mathbf{P}a$ may be found (Munda, 2009).

Kemeny (1959) and Young and Levenglick (1978) solved the cycle issue by fully understanding and axiomatising the Condorcet's approach. The resulting approach is called Condorcet–Kemeny–Young–Levenglick (C–K–Y–L) ranking procedure (Munda, 2009).

The C–K–Y–L ranking procedure was the method selected for finding the preferred ranking of alternatives for the two scenarios considered. The Condorcet approach is based on a pair-wise comparison between alternatives j and k according to M individual criteria. The pair-wise comparison is based on Eq. (1) (Munda, 2005) and is used to build the outranking matrixes

Table 4
Multi-criteria impact matrix.

Dimension	Criteria	Centralised water supply systems		Decentralised water supply systems	
		Seawater desalination	Reclaimed water reuse	Greywater reuse	Rainwater harvesting
Financial	Capital cost	0.23 €/m^3	0.42 €/m^3	0.82 €/m^3	7.90 €/m^3
	O&M cost	0.40 €/m^3	0.21 €/m^3	1.64 €/m^3	1.23 €/m^3
Social	Public acceptability	4	3	2	1
	Health risk	1	3	4	2
Environmental	Energy consumption	4.00 kWh m^{-3}	1.24 kWh m^{-3} [a]	1.25 kWh m^{-3} [b]	0 kWh m^{-3}
	Other environmental impacts	4	3	2	1
Technological	Technological simplicity	4	3	2	1
	Reliable water supply	1	2	3	4

[a] Borràs and Sala, 2006.
[b] Hansgrohe. Pontos-Aquacycle 2500.

Table 5
Outranking matrix for the growth scenario.

	A	B	C	D
A	0.000	0.429	0.600	0.686
B	0.571	0.000	0.771	0.514
C	0.400	0.229	0.000	0.343
D	0.314	0.486	0.657	0.000

presented in Tables 5 and 6 for the growth and degrowth scenarios respectively:

$$e_{jk} = \sum_{m=1}^{M} \left(w_m \left(P_{jk} \right) + \frac{1}{2} w_m \left(I_{jk} \right) \right) \quad (1)$$

where M is the evaluation criteria, w_m (P_{jk}) and w_m (I_{jk}) are the weight of the evaluation criteria presenting a preference and an indifference relation respectively.

The main methodological foundation of the C–K–Y–L ranking procedure is the maximum likelihood principle which selects as a final ranking the one with the maximum pair-wise support, i.e. the ranking supported by the maximum number of criteria for each pair-wise comparison, summed over all pairs of alternatives. The final ranking (r^*) is the one which maximises the following equation (Munda, 2005):

$$r^* \Leftrightarrow \varphi_* = \max \sum e_{jk}$$

When the number of possible combinations grows there is need to use numerical algorithms. The results of the algorithm applied are shown in Tables 7 and 8. The rankings with the higher coefficient (φ) are the rankings more probable or stronger.

4.2. Institutional analysis

By means of the institutional analysis we aim to compare the judgement of the main social actors of the water sector regarding the different non-conventional water sources included in the study. In this way, we attempt to envisage which social actors may be supporting or blocking its future implementation.

NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) is the multi-criteria evaluation method selected to conduct the institutional analysis, i.e. the analysis of the proximity and distance of the positions of the different social actors (Joint Research Centre, 1996). NAIADE is also a well-known multi-criteria evaluation method used to conduct the technical analysis exposed in the previous section. However, in this study NAIADE could not be used for that purpose because it does not allow giving weights to the evaluation criteria.

The first question of the questionnaire (Section 4) enabled to obtain the preferences of the social actors regarding the different alternatives proposed. The answers obtained are summarised in the equity matrix shown in Table 9. This data was used to plot a dendrogram of coalition formation (Fig. 2) which shows the coincidence and distance between the different social actors' interests and perceptions based on the intensity of their preferences for the various alternatives presented. In this way, the dendrogram of coalition formation enables to analyse the alliances and tensions of the different interest groups in relation to the alternatives examined. The similarity index shown on the left of the graph expresses the similarities between the actor's judgements (Fig. 2).

Table 6
Outranking matrix for the degrowth scenario.

	A	B	C	D
A	0.000	0.250	0.393	0.429
B	0.750	0.000	0.571	0.286
C	0.607	0.429	0.000	0.143
D	0.571	0.714	0.857	0.000

Table 7
Possible rankings with the higher coefficients for the growth scenario.

Alternatives (A = desalination; B = reclaimed water; C = greywater; D = rainwater)				Coefficient
B	A	D	C	3.886
B	A	C	D	3.571
A	B	D	C	3.571
A	D	B	C	3.543
B	D	A	C	3.514
D	B	A	C	3.486

5. Results

5.1. Non-conventional water resources: technical analysis

In the following sections we compare the four alternatives selected according to the four dimensions defined (financial, social, environmental and technological) and the criteria set. The main aims of this section are to obtain a better understanding of the existing differences between the various non-conventional water resources available in the MAB and to start picturing the desirability and the compatibility of the various alternatives with the two scenarios presented before: growth and degrowth.

5.1.1. Financial considerations

Seawater desalination and reclaimed water reuse enjoy lower amortisation costs due to the effects of economies of scale. The desalination plant in the Llobregat river basin produces a maximum of 60 Mm^3/year (million cubic metres per year) and the reclamation project in Viladecans can recycle a maximum of 370,000 m^3/year.

Because of their intrinsic characteristics, decentralised systems such as rainwater harvesting and greywater reuse systems generate much lower volumes of water per system. A standard greywater reuse system for 20 flats produces 670 m^3/year while a rainwater harvesting system of 10 m^3 collects on average around 41 m^3/year. As a result, the capital cost per unit of water is extremely high for rainwater harvesting and relatively high for greywater.

Desalinated water is transported through the conventional drinking water network while all the other alternatives require the construction of dual distribution networks as these flows cannot be used for drinking purposes. Thus, desalinated water shows the lowest capital cost because of the high water production capacity and the low investment required in the distribution network. The cost of the distribution network is particularly significant in water reclamation projects. In Viladecans the cost of the dual network accounts for 47% of the total cost of the project.

Operation and maintenance (O&M) costs are also affected by economies of scale. Decentralised water supply systems are fairly

Table 8
Possible rankings with the higher coefficients for the degrowth scenario.

Alternatives (A = desalination; B = reclaimed water; C = greywater; D = rainwater)				Coefficient
D	B	C	A	4.225
D	C	B	A	4.125
D	B	A	C	3.975
B	D	C	A	3.725
D	C	A	B	3.525
B	D	A	C	3.475

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Table 9
Equity matrix.

Social actor	Seawater desalination	Reclaimed water	Greywater reuse	Rainwater harvesting
Catalan water agency	Very good	Good	Good	Very good
Neighbourhood associations	Moderate	Good	Good	Very good
Environmental groups	Moderate	Very good	Very good	Perfect
City council managers	More or less good	Good	Very good	Very good
Local decision-makers	Good	Good	Very good	Perfect
Water technology related firms	More or less good	More or less good	More or less good	Perfect
Water supply companies	Good	Very good	Good	Good
Scientists	Good	Good	Very good	Very good

simple and therefore, maintenance requirements in absolute terms are small. However, maintenance costs per cubic metre of water are higher than in centralised water supply systems due to the small volume of water produced in relation to the staff and technical means appointed to maintain the system.

Operation costs are also influenced by the amount of energy consumed and the cost of electricity. Even though energy is currently still fairly inexpensive, in the near future energy prices are expected to rise due to a reduced availability of fossil fuels and climate change constraints. In 2007 in Catalonia, only 9.2% of the electricity produced came from renewable resources (ICE, 2007). Be the case energy prices continue to soar, the operation cost of desalination is expected to rise importantly due to its high energy consumption. As a result, the rest of non-conventional water sources could become more competitive, both in a growth (business-as-usual) and degrowth scenarios. In the case energy prices do not rocket, in a business-as-usual scenario, i.e. growth-led, the most cost effective solutions, i.e. seawater desalination and reclaimed water reuse, would be the preferred alternatives (in part due to the fact that not all costs are internalised).

5.1.2. *Social considerations*

It is broadly recognised that the lack of public acceptability represents a potential impediment for the widespread installation of non-conventional water supply systems (Menegaki et al., 2007; Hurlimann et al., 2008; Dolnicar and Schäfer, 2009). Two face-to-face surveys, carried out among the residents of the MAB, have been used to measure public acceptability. The results of a survey conducted among 520 people of Sabadell (Romeu, 2008), one of the largest cities of the Metropolitan Region of Barcelona, revealed that the preferred source of water to expand the volume of water available in the region was rainwater harvesting, followed by reclaimed water reuse and lastly, desalination. Environmental concerns probably explain the lower preference for desalination technologies. Unfortunately, greywater reuse was not included in this survey.

Public acceptability towards greywater reuse is deduced from another survey conducted among 120 households of Sant Cugat del Vallès, in the MAB (Domènech and Saurí, 2010). The households interviewed used treated greywater to flush their toilets. Respondents were asked to make a hypothetical choice: whether they would prefer to use greywater or reclaimed water to flush their toilets. Both alternatives registered a fairly high number of supporters. Greywater reuse was preferred by 46.7% of the respondents while the use of reclaimed water from a wastewater treatment plant was chosen by 32.5% of the respondents. Thus, the degree of public acceptability was considered higher for greywater reuse than for water reclamation. The preference over decentralised models is attributed to the higher sense of control associated with on-site treatment technologies.

Health risks, either real or perceived, constitute another important area of concern that may affect community attitudes (Toze, 2006; Hurlimann et al., 2008). In this paper, the criterion called "health risk" refers to an objective (real) measurement of the risk associated with the use of non-conventional water sources. Three elements are used to define the level of risk (Toze, 2006): occurrence of chemical and microbial contamination in the original water source (seawater, sewage water, domestic greywater, rainwater run-off); the water treatment process applied (reverse osmosis, Membrane Bioreactor (MBR), filtration, disinfection), and the end use of water (drinking, toilet flushing, landscape irrigation, etc.). In order to simplify the health risk analysis, it is assumed that

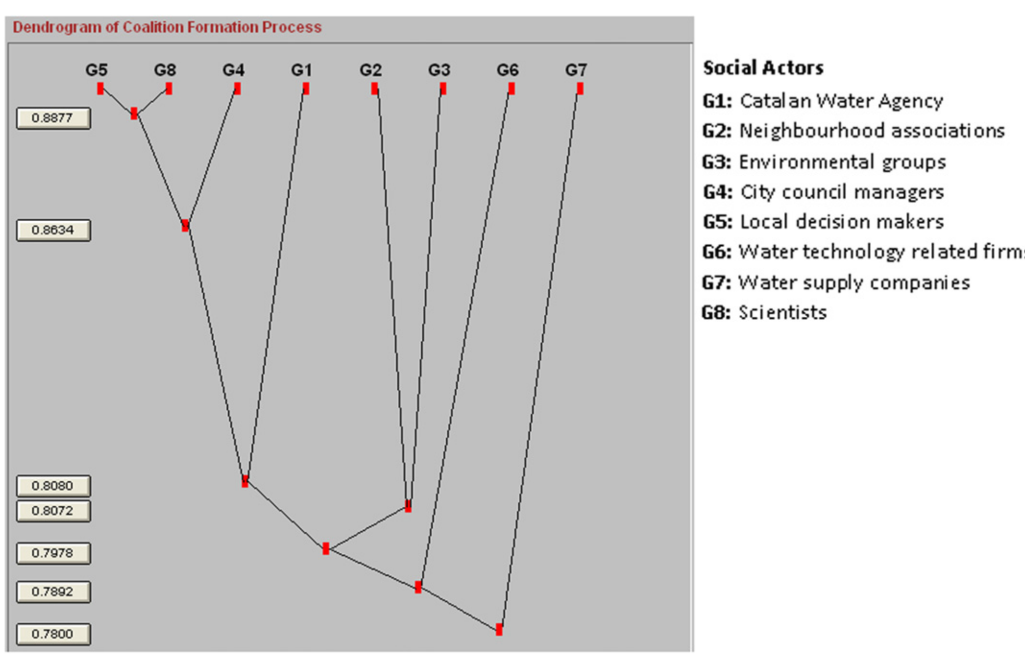

Fig. 2. Coalition formation dendrogram.

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all non-conventional sources are only employed for uses that do not require high quality standards such as toilet flushing and garden watering. The number of individuals that could theoretically be affected by an outbreak of disease is not incorporated in the analysis.

Sewage effluents contain high faecal and chemical loads and, as such, reclaimed water is at origin the most contaminated of the non-conventional sources studied. However, advanced treatments such as MBR processes reduce health risks to acceptable levels. Domestic greywater is less likely to contain hazardous compounds but simple treatment and control processes may lead to relatively higher health risks. Similarly, in rooftop rainwater run-off faecal and chemical contamination is a priori low and therefore, if adequate maintenance practices are followed health risks remain relatively low. Finally, advanced technologies enable to obtain very good quality water from seawater. Reverse osmosis is the technology that offers the highest degree of water purification and as a result, the level of health risk associated with desalinated water is considered the lowest.

Health risks are considered critical in both scenarios, although public acceptability may be more important in a degrowth scenario where bottom-up and inclusive decision-making processes are critical.

5.1.3. Environmental considerations

The environmental impacts associated with the use of non-conventional sources are divided into two criteria: energy consumption and other environmental impacts. The consumption of energy by the treatment and distribution of water can be easily quantified. This criterion is directly related with CO_2 emissions and global warming effects.

To convert one cubic metre of seawater into freshwater implies in total around 4 kWh. Desalination is the most energy intensive water source as the required treatment (reverse osmosis in our case) is very energy demanding. Furthermore, desalinated water needs to be transported and distributed from the desalination plant located by the sea to all the MAB. Reclaimed water demands 1.24 kWh m^{-3} of energy for the operation of the tertiary treatment and for its distribution within an area of few kilometres (Borràs and Sala, 2006). Unlike centralised systems, decentralised water supply systems “produce” water on-site and therefore do not spend much energy in transportation. Energy is consumed during the water treatment process which is relatively simple for greywater and extremely simple and frequently no-energy demanding for rainwater harvesting.

The rest of environmental impacts, either positive or negative, caused by the use of non-conventional sources are diverse and not easily quantifiable and therefore, this criterion has been expressed in qualitative terms. A life cycle analysis completed in Alexandria (Egypt) concluded that decentralised scenarios which included the separation and reuse of urine, faeces and greywater at source showed the lowest environmental impact as compared to more centralised approaches (El-Sayed et al., 2010). The separation of low polluted water at source and water reuse on-site generates a series of positive externalities such as reduced water demand and treatment requirements (Mah et al., 2009). In addition, rainwater harvesting technologies contribute to minimise the volume of stormwater run-off produced as well as other associated impacts such as floods and the pollution of the receiving water bodies (Herman and Schmida, 1999; Hatt et al., 2004).

Desalination technologies produce severe impacts on the environment due to the production of large amounts of brine that are detrimental for the aquatic life. Furthermore, desalination demands the use of various reagents with uncertain effects in the receiving water bodies (Meerganz von Medeazza, 2005). The later also applies to reclaimed water.

Notwithstanding the environmental impacts of the various technologies are certainly a concern in both scenarios, we argue that the protection and maintenance of the environment is critical for the degrowth one (for a growth scenario, the degradation of natural capital is usually argued to be offset by the increase of economic capital). In such degrowth scenario, rainwater harvesting and greywater reuse – the alternatives making use of the more local water sources – would be the most preferred alternatives.

5.1.4. Technological considerations

Lower dependence on state-of-the-art technology and the use of locally available technology and local knowledge/expertise are considered positive features within a degrowth scenario. In that sense, rainwater harvesting is the alternative making use of the simplest technology. The technological simplicity of greywater reuse systems varies depending on the type of system installed but in general terms, these systems use more advanced technology than rainwater harvesting. Centralised water supply systems and above all, desalination, employ state-of-the-art, sophisticated technology and as a result, their dependence on external resources is higher.

The ability of ensuring a continuous and reliable supply is also considered an important asset of water supply systems. This feature would be especially critical for capitalism and the incessant production of commodities that it requires. Centralised water supply systems offer a higher degree of reliability and flexibility as both desalinated and reclaimed water can be produced continuously. Furthermore, treatment processes are exhaustively controlled. In contrast, both greywater reuse systems and rainwater harvesting systems present a limited capacity to adjust yield and demand and an inferior level of technical control. Rainwater availability totally depends on the occurrence of precipitation episodes and therefore, rainwater production cannot be entirely assured throughout the year.

5.2. Technical analysis of the various non-conventional water sources in a growth and degrowth scenario

The possible rankings of alternatives with the higher coefficients obtained as a result of the mathematical aggregation of the criteria selected for both scenarios are presented in Tables 7 and 8. The technical analysis for the growth scenario shows that the solution with the highest support/likelihood is B–A–D–C. Thus, for the growth scenario the strongest alternative would be reclaimed water reuse followed by seawater desalination while the least desirable alternative would be greywater reuse. Water reclamation would be the most preferred alternative because it shows the lowest operation costs and a good level of reliability while it receives mid-range scores for the rest of evaluation criteria. The rankings with a higher coefficient for the growth scenario show a marked preference for centralised water systems while decentralised water systems seem to be less desirable.

For the degrowth scenario, results are significantly different proving that importance coefficients have a relevant effect on the results of the multi-criteria evaluation. The ranking with the highest coefficient is D–B–C–A implying that the most preferred alternative for a degrowth society is rainwater harvesting and the second preferred alternative is reclaimed water reuse. The least preferred alternative in the degrowth scenario is desalination, most probably due to the poor grades obtained for environmental criteria and technological simplicity which are all important criteria for degrowth. The preference for centralised or decentralised water systems is not clear in the degrowth scenario.

Notwithstanding this, rainwater harvesting and greywater reuse obtain better scores than in the growth scenario.

5.3. Institutional analysis: conflict of interests?

The dendrogram of coalition formation presented in Fig. 2 is based on the equity matrix presented in Table 9. Fig. 2 shows the proximity of the interests and the possible coalitions formed among the various social actors involved in the management of non-conventional water resources in the MAB. Local decision-makers and scientists show the highest similarity index, i.e. the highest probability of coalition formation (0.8877). City council managers also join this coalition with a high similarity index (0.8634). Similar opinions between local decision-makers and city council managers were expected, as their interests and work are much related. The ranking of alternatives of this coalition shows that this coalition clearly supports the use of rainwater harvesting and greywater reuse. The willingness of decision-makers and local managers to advocate for decentralised water supply systems is significant, as they hold the greatest capacity to implement this kind of systems. Scientists, who are appreciated for their impartiality, also recognise the advantages of decentralised water supply systems.

The Catalan Water Agency joins this coalition with a medium–high similarity index (0.8080). This regional administration is the strongest supporter of desalination plants which fits the current policy of the Spanish and Catalan governments. However, overall rainwater harvesting is the preferred source for the regional water authority. This view contrasts with the scarce recognition this source receives in the strategic water management plans of the regional water authority.

The coalition formed by G1, G4, G5, and G8 is the most influential, since G1 (Catalan Water Agency), G4 (City council managers) and G5 (Local decision-makers) are the most important actors in policy and decision-making. Their preferences are captured in policies such as the Catalan River Basin Water Management Plan or the Local Regulations on Water Savings.

Neighbourhood and environmental groups form another coalition. Both groups share a low opinion of desalination. Rainwater harvesting is the preferred source for both groups and is particularly well appreciated by the environmental group. These results reveal a high level of environmental awareness which was expected for the environmental group but was less predictable for the neighbourhood associations.

The firms specialised in domestic water treatment technologies join the coalition formed by the aforementioned groups with a medium similarity index. This group is clearly in favour of rainwater harvesting but shows a much lower level of support for the rest of non-conventional sources considered. This social actor is probably the most heterogeneous, as it is formed by local suppliers with different business sizes, areas of specialisation and market interests. The interpretation of their preferences is therefore more difficult.

Water supply companies share the lowest level of coalition formation with the rest of actors. The main aim of water supply companies is to purchase bulk water and sell retailed water through centralised systems. Unsurprisingly, this is the actor that gives less support to rainwater harvesting since the installation of household rainwater harvesting systems could reduce their benefits and their control over the water cycle.

In sum, most actors agree on one point. Rainwater harvesting is one of the most appreciated alternatives by all social groups (except for the water supply companies). The level of preference for the rest of alternatives is more diverse. A pair-wise comparison between the use of reclaimed water and treated greywater – two alternatives that may be considered exclusive in certain contexts – reveals that most groups equally support both models. However, local managers, local decision-makers and scientists give more support to the use of greywater reuse technologies while the water supply companies give more support to the centralised model of reuse.

The main social actors of the water sector were also surveyed about their view on the desirability of handing over more responsibilities on water management to citizens which is required if a decentralised water management model is to be adopted. The Catalan Water Agency and the water supply companies are the actors more reluctant to give more "power" to the citizens. Neighbourhood associations give moderate support to this premise, which is a significant finding because it shows a low willingness of citizens to assume more responsibilities (Table 10). In these lines, the water supply companies and the Catalan Water Agency are also the actors that less agree with the statement "the administration should give incentives to install decentralised water supply systems". Unsurprisingly, the neighbourhood associations are the actor that agrees the most with this premise, as they would be the main beneficiaries of such policy (Table 10).

6. Discussion: degrowth initiatives in the urban water sector? Are rainwater harvesting and greywater reuse options to bring about a more democratic management of water resources?

Water governance in Catalonia appears to be trapped into a techno-institutional lock-in between the development of traditional centralised (transfers) and "new" water infrastructures (desalination plants) under the flag of ecological modernisation. Both are rooted in the idea to increase unendlessly water supply in order to cope with continuous growth. However, we argue that centralised utilities are not *per se* incongruent with degrowth principles. Rather, as they are currently conceived, centralised utilities continue prisoners of growth-serving objectives which remain intact and exogenous to the planning process (Kallis and Cocossis, 2003). In order to allow sustainable transitions (see for instance Truffer et al., 2010) in urban water infrastructure, and at the same time, progressing towards a more democratic, fair and inclusive water paradigm, it is basic to envisage new forms of governance closer to the user and less-dependent on the international circuits of capital. Rainwater harvesting and greywater reuse (see for instance, Domènech and Saurí, 2010, 2011; Domènech, 2011) could be options to improve the strength of the water

Table 10
Results to the questions 5 and 6 of the survey (1: very much agree … 5: Very much disagree).

Social actor	Citizens have to assume more responsibilities in water management		Public administration has to incentive the use of decentralised systems	
	Avg.	SD	Avg.	SD
Catalan water agency	2.75	0.96	2.75	0.96
Neighbourhood associations	2.50	1.73	1.00	0.00
Environmental groups	1.00	0.00	1.25	0.50
City council managers	1.79	0.92	1.26	0.45
City council decision-makers	1.54	0.52	1.31	0.48
Water technology related firms	1.25	0.50	1.00	0.00
Water supply companies	2.63	1.51	2.13	1.25
Scientists	2.57	1.81	1.57	0.79

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system, while at the same time provide an interesting case of the emergence of new management and provision models within the dominant socio-technical water regime. To what extent rainwater harvesting could be considered as community cooperation in Barcelona, remains an interesting question.

Decentralised water supply systems may change power arrangements over the flows of urban water, and as a result they generate different reactions among the main social actors involved in water management. One of the key implications of decentralised water supply systems is the promotion of a more horizontal governance model in which the collaboration and cooperation of the various social actors involved in service delivery (citizens, local government bodies, water technology related firms) becomes critical, thus fulfilling a priori one of the principles of the degrowth movement, i.e. decentralising and deepening democratic institutions (Schneider et al., 2010).

On the other hand, the implementation of decentralised systems is not leading *per se* to a degrowth conceptualisation of the water cycle. Decentralised systems are currently seen in the Barcelona area as new niches for the blossoming industry of non-conventional water systems. They are still oriented for new urban developments, against the label of eco-neighbourhoods, or for the suburban and rich municipalities, with a high potential for rainwater harvesting for garden watering purposes. In the Barcelona area, some municipalities are promoting these systems as part of water conservation and efficiency programs integrated in urban planning. They use a combination of enforcement measures and subsidies to attain the general objective of reducing water consumption from conventional sources. These systems are rarely seen in the already built environment, especially in low-income neighbourhoods. This poses an important problem of credibility as they are still seen as residuals or complimentary systems. Despite its apparent simplicity, those systems, especially greywater resuse, are designed to be fitted in new buildings, or if installed in the built environment they may require important works.

Some may argue that returning water management responsibilities to users could be constitutive of the neoliberalisation of the environment. Actually, we recognise that the implementation of such systems could be the result of ecological modernisation striving to capture additional and more local flows of water. In turn, this could create a new niche for capital accumulation and circulation similar to that of desalination. In addition, we could argue that making the citizen responsible for managing its own "water supply" could be seen as an example of the State losing a key role in water provision in favour of the private initiative. Decentralisation in that sense could be seen as a step forward to the weakening of the role of the State in ensuring basic services such as water supply.

However, this argument could be revisited and the implementation of such decentralised systems could be seen also from a "commons" perspective. Both neoliberal reformers and 'commons' defenders raise the issue of dissatisfaction with centralised bureaucratic state provision (Bakker, 2007). Thus, we could contend that bringing the user (and by extent the community) closer to the resource could inform a strategy opposed to water commodification narratives. In other words, by intervening actively in a fundamental part of the urban water cycle, users would be less alienated from the "production" of water and, at the same time, they would integrate into their practices the environmental limits of water supply. Domènech and Saurí (2011) argue that rainwater harvesting systems could "shrink" the size of the urban water cycle, therefore making more visible the components of the hydrosocial cycle to citizens (Kaika, 2005; Head, 2008). This experience would then become crucial to counter-attack the underlying notion of an "endless supply" (as long as it can be afforded, of course) and the emancipation from the climate and hydrology brought about by desalination; at the same time, it could raise a barrier to the unfettered circulation of capital through the hydrosocial cycle in favour of a more democratic control of the resource. In a context such as Barcelona, where private international capital controls most of the water cycle, these alternatives could challenge the hegemony of the market in the control of urban water flows.

In that sense, as Domènech and Saurí (2010) argue, social learning (see for instance Pahl-Wostl and Hare, 2004 or Pahl-Wostl, 2007, 2008) processes have to be launched to build trust among citizens in the new governance network if decentralised alternative systems are to thrive in the urban and suburban fabric.

7. Conclusions

As a result of increasing drought periods, in part exacerbated by climate change, and changing patterns in water consumption, non-conventional water technologies are gaining support. These alternatives may be implemented at different scales and therefore, may be centralised or decentralised. From a degrowth perspective, and according to the weights given to the criteria, rainwater harvesting emerges as the most preferred alternative. This is because its major simplicity, its reduced environmental impacts and the promotion of self-sufficiency, considered as very important principles for degrowth (this does not mean that they are not desirable in a growth scenario, however other criteria are more important). The use of local sources such as rainwater and greywater could help to reduce the dependence on large infrastructures such as dams, water transfers and desalination plants, thus improving the quality of freshwater ecosystems and reducing the conflicts around water resources. Not only the aquatic ecosystems would benefit from these savings but also energy consumptions and the use of materials would drop.

The technical evaluation undertaken from a growth perspective reveals that reclaimed water reuse and desalination are the preferred alternatives against the criteria considered. These two sources are indeed the alternatives gaining more prominence in the MAB, which suggests a prevalence of growth principles in water management. Since July 2009 the desalination plant in the Llobregat River has been active despite operating at a low capacity. In the near future it is expected that the Foix desalination plant (south of Barcelona) will add 20 hm^3 of desalinated water per year to the system. Reclaimed water is also promoted in the MAB but at a lower scale. In 2009, 18.7 hm^3 of reclaimed water from four different wastewater treatment plants was reused in the MAB mainly for agricultural and environmental purposes (EMA, 2010).

Even if the institutional analysis reveals that the most appreciated alternative is rainwater harvesting while most social groups argue that desalination is the least desired option, these results do not match with reality. Today, rainwater harvesting still receives little consideration – it is only promoted by few municipalities in the MAB – while the use of desalination it is escalating at a dramatic pace. These results evidence the difficulties to challenge deeply rooted supply-side management approaches, the influence of powerful companies and vested interests and the consideration of water and fossil fuels as endless resources.

In the light of our results, we state that the use of a social multi-criteria evaluation (SMCE) helps to shed more light on the social desirability, acceptability and feasibility to implement a series of non-conventional water supply systems. We strongly stress one of the main contributions of SMCE: the transparency of the evaluation process. Bringing more transparent mechanisms in the process of policy and decision-making could help to better involve the citizens in the management of the urban water cycle. We recognise

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however, as Kallis et al. (2006) argue, that SMCE relies heavily on experts and involves less participation during the goal-setting process in comparison with other methods, such as workshops.

We cannot leave aside that degrowth in water consumption does not only mean decreasing the consumption and/or withdrawal of water in the benefit of the environment. It must bring about a fairer and more equal access to water resources as well. Democratic control over the hydrologic cycle and defending water resources as commons and not as commodities are crucial to enable subsequent changes towards these goals. We contend that the use of decentralised and alternative water resources, such as rainwater could be an important step towards a more democratic society were environmental resources are controlled by the citizenry and used in a rational and renewable fashion. In this sense, and as Harvey (1996) so forcefully asserted, socio-ecological projects are political projects and vice-versa.

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