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Exploring the water-energy nexus in urban and tourist areas of the western mediterranean. Empirical findings from Benidorm and Barcelona

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PhD Thesis

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Exploring the Water-Energy Nexus in Urban and Tourist Areas

of the Western Mediterranean:

Empirical Findings from Benidorm and Barcelona

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Abstract

Exploring the Water-Energy Nexus in Urban and Tourist Areas of the Western Mediterranean: Empirical Findings from Benidorm and Barcelona

The thesis analyzes the Water-Energy Nexus (WEN) by applying mixed methodology and focusing on the urban water metabolism in Benidorm and Barcelona. The case of Benidorm examines water supply at the municipal scale and the hotel and recreational sector, while the case of Barcelona explores the WEN at the household-level. The thesis quantifies *energy for water (energy intensity for water)* to evaluate different energy requirements for water supply and end-use. In addition, qualitative analyses are needed to apprehend the WEN as being dynamic and relying on evolving relationships; it interacts within and across scales. Following the urban political ecology approach, the empirical findings from the case studies manifest the complex and inequitable socio-natural relations involving the WEN in the urban area, which are influenced by socio-technical conditions as well as ecological, social and political processes manifested through various actors and institutions.

In Benidorm, an epitome of mass tourism, *energy for water* varies considerably according to different precipitation scenarios. Complex social arrangements and power relationships are unveiled in the urban water cycle, which is considered the backbone of tourism development. Desalinated water from the Muchamiel desalination plant increases *energy for water* significantly. While treated wastewater and emergency interbasin water transfer appear to be a more convenient solution energy-wise and in social terms, the strong governmental push for desalination in Spain forces the local water authority towards the use of a much more energy-intensive resource. It provides an example of political interests at the national level that interferes with probably more optimal solutions at the local level. In light of recent

technological and managerial developments, the Benidorm case demonstrates the challenges in the water-energy nexus, whereby scarcity is transferred from water to energy.

At the microscale, Benidorm's hotels and recreational facilities highlight that the use of both energy and water are essential for key activities, such as water heating and steam generation, swimming pool and laundry. The energy-mix of hotels that was surveyed relied on varied energy-carriers, which cause the diversification of *energy for water*. The use of reclaimed water and renewable energy, i.e. solar thermal panels, biomass and ground source heat pump systems, is observed as a new trend. Despite acknowledging low awareness on the WEN, I suggest that the use of *energy for water*, along with water- and energy-use intensity, could be a valuable indicator to identify the WEN trade-offs.

The Barcelona case study focuses on the WEN at the household-level by adding the social perspective. It examines households suffering from water and energy poverty – or vulnerability, namely those who experience insufficient water and energy flows required in their respective domestic metabolisms for sustenance, care and reproductive functions. At the metropolitan scale, a substantial number of households are paying disproportionately larger water and energy bills compared to their income. The WEN perspective calls attention to understanding water price increases in relation to energy as scarcity affects the energy requirement for water treatment and production. In addition, old housing stocks and the low infiltration rate of central heating provides hostile socio-technical conditions for vulnerable households.

Lastly, the thesis highlights the role of a social movement 'Aliança contra pobresa energètica' (English: 'Alliance against Energy Poverty', APE) in Barcelona in changing the discourse on water-energy vulnerability. I borrow the concept of the co-production of nature and knowledge to explain how APE transformed the discourse on politics, institutional and governance failure concerning commodified utilities. I argue that addressing energy and

water issues together more effectively demonstrates the reality faced by vulnerable households. Empirically, it also provides comparative lessons for enhancing the understanding of different institutional norms under market environmentalism.

Keywords**:** Energy for water; Urban water cycle; Water and energy vulnerability; Co-production of knowledge; Desalination; Energy poverty; Water poverty; Political ecology; Urban political ecology; WEN

Resumen (Spanish version)

Explorando el nexo agua-energía en áreas urbanas y turísticas del Mediterráneo occidental: resultados empíricos en Benidorm y Barcelona

La tesis analiza el Nexo Agua-Energía (WEN) a través de una metodología mixta y centrándose en el metabolismo urbano del agua en Benidorm y Barcelona. El caso de Benidorm examina el suministro de agua a escala municipal y en los sectores hotelero y recreativo, mientras que el caso de Barcelona el WEN se explora a nivel de hogar. La tesis cuantifica la energía para el agua (intensidad energética del agua, *energy for water*) para evaluar las diferentes proporciones de energía en el suministro de agua y el uso final. Además, el análisis cualitativo justifica el WEN como un concepto dinámico y en evolución, que interactúa dentro y entre las escalas. Siguiendo el enfoque de ecología política urbana, los hallazgos empíricos de los estudios de caso manifiestan la complejidad y las desigualdades en las relaciones socio-naturales alrededor del WEN, que están influenciadas por las condiciones socio-técnicas y los procesos ecológicos, sociales y políticos que ocurren entre varios actores e instituciones.

En Benidorm, un epítome del turismo de masas, la energía para el agua varía considerablemente según los escenarios climáticos. Complejos acuerdos sociales y relaciones de poder se manifiestan en el ciclo urbano del agua, considerado como el eje del desarrollo del turismo. El agua desalada de la planta de Muchamiel aumenta significativamente la energía para el agua del ciclo de agua. En cambio, las aguas residuales tratadas y los trasvases intercuencas de emergencia parecen ser una solución más conveniente desde el punto de vista energético. La fuerte presión gubernamental en favor de la desalinización en España está obligando a la autoridad local de agua a utilizar un recurso mucho más intensivo en energía. Benidorm proporciona un ejemplo de intereses políticos a nivel nacional que interfieren con

soluciones en principio más óptimas a nivel local. A la luz de los recientes desarrollos tecnológicos y de gestión, el caso de Benidorm demuestra los desafíos en el nexo agua-energía, especialmente cuando la escasez se transfiere del agua a la energía.

A escala micro, los hoteles y actividades recreativas destacan como el uso de energía y agua es esencial para actividades clave como el calentamiento de agua y el vapor, las piscinas y la lavandería. La combinación de distintas fuentes energéticas en los hoteles encuestados se basó en diversos vectores que causan las variaciones de la energía para el agua. El uso de energía renovable i.e. paneles solares térmicos, biomasa y sistemas de bomba de calor de origen terrestre, y el agua regenerada se observan como una nueva tendencia. A pesar de destacar una baja concienciación sobre WEN, sugiero que el uso de la energía para el agua, junto con la intensidad del uso de agua y energía, podría ser un indicador valioso para identificar pérdidas y ganancias asociadas al WEN.

El estudio de Barcelona aproxima el WEN a nivel de hogar, agregando una perspectiva social. Examina los hogares que sufren la pobreza energética e hídrica, o la vulnerabilidad, traducida en deficiencias en el flujo de agua y energía en el metabolismo doméstico para las funciones de sustento, cuidado y reproducción. A escala metropolitana, un número considerable de hogares está pagando facturas de agua y energía desproporcionadas en comparación con sus ingresos. La perspectiva de WEN llama la atención sobre aumentos del precio del agua en relación con la energía, ya que la escasez afecta a los requerimientos de energía para el tratamiento y la producción de agua. Además, las existencias de viviendas antiguas y la baja presencia de calefacción central proporcionan condiciones socio-técnicas poco adecuadas para los hogares vulnerables.

Por último, la tesis destaca el papel del movimiento social Alianza Contra la Pobreza Energética (APE) que, en Barcelona, cambió el discurso sobre la vulnerabilidad agua-energía. Utilizo el concepto de coproducción de la naturaleza y el conocimiento para explicar cómo

APE transformó el discurso en torno a los fallos políticos, institucionales y de gobernanza de las empresas comercializadoras. Sostengo que el tratamiento conjunto de la energía y el agua demuestra con mayor efectividad la realidad que con la que se encuentran los hogares vulnerables. Empíricamente, también proporciona lecciones comparativas para mejorar la comprensión de las diferentes normas institucionales que son propias del denominado ambientalismo de mercado.

Resumen (Catalan version)

Explorant el nexe aigua-energia a les zones urbanes i turístiques de la Mediterrània occidental: resultats empírics a Benidorm i Barcelona

La tesi analitza el Nexe Aigua-Energia (WEN) a través d'una metodologia mixta centrant-se en el metabolisme urbà de l'aigua a Benidorm i Barcelona. El cas de Benidorm examina el subministrament d'aigua a escala municipal i en els sectors hoteler i recreatiu, mentre que el cas de Barcelona el WEN s'explora a nivell de llar. La tesi quantifica l'energia per a l'aigua (intensitat energètica de l'energia de l'aigua, *energy for water*) per avaluar les diferents proporcions d'energia en el del subministrament i 'ús final de l'aigua. Per la seva part, l''anàlisi qualitativa justifica el WEN com un concepte dinàmic i en evolució, que interactua dins i entre les escales. Seguint l'enfocament d'ecologia política urbana, les troballes empíriques dels estudis de cas manifesten la complexitat i les desigualtats en les relacions socio-naturals al voltant del WEN urbà, que estan influenciades per les condicions socio-tècniques i els processos ecològics, socials i polítics que ocorren entre diversos actors i institucions.

A Benidorm, un epítom del turisme de masses, l'energia per a l'aigua varia considerablement depenent dels escenaris climàtics. Complexos acords socials i relacions de poder es donen a conèixer en el cicle urbà de l'aigua, considerat com l'eix del desenvolupament del turisme. L'aigua dessalada de la planta de Mutxamel augmenta significativament l'energia per a l'aigua del cicle d'aigua. En canvi, les aigües residuals tractades i els transvasaments interconques d'emergència semblen ser una solució més convenient des del punt de vista energètic. La forta pressió governamental en favor de la dessalinització a Espanya està obligant a l'autoritat local d'aigua de la Marina Baixa a utilitzar un recurs molt més intensiu en energia. Així, Benidorm ens un exemple d'interessos polítics a nivell nacional que interfereixen amb

solucions en principi més òptimes a nivell local. A la llum dels recents desenvolupaments tecnològics i de gestió, el cas de Benidorm demostra els desafiaments en el nexe aigua-energia, especialment quan l'escassetat es transfereix de l'aigua a l'energia.

A escala micro, els hotels i activitats recreatives destaquen com l'ús d'energia i aigua és essencial per a activitats clau com l'escalfament d'aigua, les piscines i la bugaderia. La combinació de diferents fonts energètiques dels hotels enquestats es va basar en diversos vectors energètics que causen les variacions de l'energia per a l'aigua. L'ús d'energia renovable i.e. panells solars tèrmics, biomassa i sistemes de bomba de calor d'origen terrestre, i l'aigua regenerada s'observen com una nova tendència. Tot i destacar una baixa conscienciació sobre WEN, suggereixo que l'ús de l'energia per a l'aigua, juntament amb la intensitat de l'ús d'aigua i energia, podria ser un indicador valuós per identificar pèrdues i guanys associades a guanys i pèrdues associades al WEN.

L'estudi de cas de Barcelona enfoca el WEN a nivell de llar, agregant una perspectiva social. Examina les llars que pateixen pobresa energètica i hídrica, o la vulnerabilitat, traduïda en les eficiències experimentades en el flux d'aigua i energia en el metabolisme domèstic per a les funcions de suport, cura i reproducció. A escala metropolitana, un nombre considerable de llars està pagant factures d'aigua i energia desproporcionades en comparació als seus ingressos. La perspectiva de WEN crida l'atenció sobre per comprendre els augments del preu de l'aigua en relació amb l'energia, ja que l'escassetat afecta els requeriments d'energia per al tractament i la producció d'aigua. A més, les existències d'habitatges antics i la baixa presència de la calefacció central proporcionen condicions socio-tècniques poc adequades per a les llars vulnerables.

Finalment, la tesi destaca el paper del moviment social, Aliança Contra la Pobresa Energètica (APE) que, a Barcelona, ha canviat el discurs sobre la vulnerabilitat aigua-energia. Utilitzo el concepte de coproducció de la natura i el coneixement per explicar com APE va transformar el discurs al voltant de la fallides de les polítiques institucionals i de governança de les empreses. Sostinc que el tractament conjunt de l'energia i l'aigua demostra amb major efectivitat la realitat que amb les s'enfronten les llars vulnerables. Empíricament, també proporciona lliçons comparatives per a millorar la comprensió de les diferents normes institucionals que són pròpies de l'anomenat ambientalisme de mercat.

초록 (Korean version)

서부 지중해 연안 도심 및 관광지에서의 물·에너지 넥서스에 관한 탐색적 연구:

베니돔과 바르셀로나의 사례조사를 중심으로

이 논문에서는 스페인의 지중해 연안도시인 베니돔(Benidorm)과 바르셀로나(Barcelona)의 사례에 혼합적 연구 방법을 적용하여 물·에너지 넥서스 (WEN)를 전체론적으로 접근하였다.

베니돔의 경우, 지중해 연안에서 대중적인 관광지의 대표적인 사례로서 선정되었다. 기후 별 시나리오에 따라 가뭄 시에 도시 물 순환의 에너지집약도가 어떻게 변화하는지, 현재의 수리·사회적 순환(hydro-social cycle)에 에너지가 어떤 역할을 하였는지 알아보았다. 또한 호텔과 레크리에이션 산업 분야의 WEN 을 연구하여 공급이 아닌 수요 측면에서 물 사용의 에너지집약도를 수치화하였다.

바르셀로나 사례의 경우, 도심이 관광대상인 도시의 예로서 선정하였다. 이곳 도시 내 약자인 물·에너지 취약 층에 대하여 연구하였다. 최종사용자의 입장에서 WEN 에 대하여 고찰하여 사회적인 관점을 더하고, 정의와 불평등의 문제를 제기하였다. 도시정치생태학에서 반복적으로 관찰되고 있는 빈부격차에 따른 자원의 접근성의 격차를 다루고, 시장메커니즘에 따라 물과 에너지를 상품화한 현재의 공익사업에서 거버넌스 실패와 제도적 한계를 설명하였다. 결론적으로 도심에서 WEN 은 복잡하고 불평등하게 사회와 자연의 관계 속에서 발현되고, 다양한 이해관계 속에서 사회기술적 조건과 생태적, 사회적 그리고 정치적 과정의 영향을 받아 형성된다.

Contents

Abstract iii

Resumen (Spanish version) vii

Resumen (Catalan version) xi

초록 (Korean version) xv

Contents xvii

Illustrations xix

Acknowledgements xxiii

Abbreviations xxv

1 Introduction 1

1.1 Outline of the thesis 3

1.2 Research objectives 5

1.3 Research questions 7

1.4 Research topic: Water-Energy Nexus 9

1.5 Overall context 40

1.5.1 WEN supply side: weaving in energy to the hydro-social cycle 40

1.5.2 WEN in the demand side: Looking into the micro scale 42

2 Research Methodology 45

3 The WEN in Mass Tourism – The Case of Benidorm 49

3.1 Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain 49

3.2 Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain....66

4 The WEN of Water and Energy Vulnerability – The Case of Barcelona Metropolitan Area 97

4.1 Politicization of Energy and Water from the Vulnerable – The Case of Energy Poverty and Water Poverty in Barcelona 97

4.3 '#No more thirst, cold, or darkness' - The co-production of knowledge of water and energy vulnerability 149

5 Conclusions........183

5.1 Summary and final conclusions........183

5.2 Key highlights........187

5.3 Future research........189

6 Bibliography 191

Annex I. Letters of coauthors 197

Annex II. Field notes........203

Annex III. Questionnaires and interview guides........219

Annex IV. Other reports........247

Illustrations

Figures

1. Introduction

1.4. A Review on Water-Energy Nexus and Directions for Future Studies: From Supply to Demand End

Figure 1. Water use cycle scheme 17

2. Research Methodology

Figure 1. A map indicating two case cities and a summary of methodologies (+: sequential mix, →:emergent mix) 45

3. The WEN in Mass Tourism

3.1 Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain. Sustainability

Figure 1. Map of water supply system in Benidorm and the Marina Baja Region 52

Figure 2. The urban water cycle of Benidorm in 2014: the system boundary of this study 56

Figure 3. Energy (electricity)-for-water for Benidorm in 2014 56

Figure 4. Water extraction activities in Marina Baja related to Benidorm's urban water supply 57

Figure 5. Results of energy (electricity)-for-water per scenario 60

Figure A1. Water use in Benidorm 62

3.2 Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain

Figure 1. Number of beds in hostelries in Benidorm (Source: HOSBEC) 70

Figure 2. Comparison with benchmarks adopted from Warren and Becken (2017) 76

Figure 3. Energy carriers for hot water system (Source: Own elaboration) 77

Figure 4. Total energy for water relationship between service washing and a. kitchen services and b. spa facility (Source: Own elaboration) 79

Figure 5. Reclaimed water use for tourism sector in Benidorm during 2012 -2017 (Source: El Consortio de Agua de la Marina Baja) 85

4. The WEN of Water and Energy Vulnerability

4.1 Politicization of Energy and Water from the Vulnerable – The Case of Energy Poverty and Water Poverty in Barcelona

Figura 1. 'El gobierno de la Generalitat marioneta de las empresas suministradoras' desde La campaña #oscurasmarionetas, 12 Marzo de 2015 (Fuente: Facebook APE) 100

4.2 The Water-Energy Vulnerability in Metropolitan Area of Barcelona

Figure 1. (A) % of reduction in utility consumption in the municipalities of AMB from 2009 to 2014 (the larger size of the bubble corresponds to the higher average of declared income before the economic crisis) (B) Summary of % reduction of consumption per inhabitant in box plot. Horizontal line in the box indicate the median, the boxes the interquartile range (Q2 and Q3). The upper whiskers extends to maximum (Q4), and the lower whiskers to minimum (Q1). × represents mean and dots represent outliers. Source: [71] 119

Figure 2. Box plot on the evolution of water price in the municipalities of AMB from 2009 to 2016. For explanation of box plot, refer to Figure 1 (based on consumption of 12m3/month, €/m3 VAT not included) Source: [91] 127

Figure 3. EPC certificate distribution in the municipalities of AMB. For explanation of box plot refer to Figure 1. Source: [98] 130

Figure B.1. Evolution of domestic electricity price in Spain (PPS/kWh, Source: eurostat) 139

Figure B.2. Evolution of domestic gas price in Spain (PPS/kWh, Source: eurostat) 139

4.3 #No more thirst, cold, or darkness' - The co-production of knowledge of Water and Energy Vulnerability

Figure 1. Socio-economic status of APE participants (a. Household income; b. Employment; c. Housing situation) 168

Figure 2. A schematic analysis conducted by T on the socio-technical structure of WEV in the City Council of Barcelona 172

Tables

1. Introduction

Table 1. The structure of the main sections of the thesis per sections with detailed information on the publication and language. 3

1.4. A Review on Water-Energy Nexus and Directions for Future Studies: From Supply to Demand End

Table 1. Existing energy sources and technologies 14

Table 2. Water consumption for raw materials 14

Table 3. Water intensity for thermoelectric power plants 15

Table 4. Energy intensity per water-use cycle in different regions 18

Table 5. Summary of different desalination technologies and their energy consumption 19

Table 6. Energy impact of new water treatment technologies 20

Table 7. Energy intensity for wastewater treatment plants in the United States and Australia 21

Table 8. Emerging water service infrastructure and energy sources 28

2. Research Methodology

Table 1. Summary of field work and research conducted 47

3. The WEN in Mass Tourism

3.1. Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain. Sustainability

Table 1. Coefficients on the supplied amount of water per source depending on scenario 54

Table 2. Estimation for pumping water in buildings applying Equation (4) 58

Table 3. Muchamiel desalination plnat performance data from July to December 2015 59

Table A1. Inhabitants and water consumption in 2014 per member municipalities to consortium 62

Table A2. Categories and sources of data collected 63

Table A3. Ranges of energy intensity data for the urban water cycle of Benidorm 63

3.2 Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain

Table 1. Respondent rates of the survey and face to face interviews for this research (% over survey requested hotels (No. & Beds)) (Source: Own elaboration) 72

Table 2. General characteristics of all hotels participated in the survey (* N=13, ** N=14, *** N=15) (Source: Own elaboration) 73

Table 3. Energy use intensity of hotels surveyed for fossil fuel energy carriers (Source: Own elaboration) 74

Table 4. Water consumption of hotels surveyed (water use from wells owned by hotels is excluded) (N=12) (Source: Own elaboration) 75

Table 5. Correlations based on Spearman's rho analysis between normalized water use intensity (L/gn·m2) and various energy use measures (N=12) (Source: Own elaboration) 75

Table 6. Energy for water on hot water use and comparison with total fossil fuel energy for water (green-yellow- red are used to indicate low-medium-high level of intensity) (Source: Own elaboration) 78

Table 7. Information on volume of pools and treatment for recirculation of water (source: information sheet from official inspection, 2009) 86

Table 8. Assumptions per groundwater recharge % and energy intensity of water (Source: Own elaboration) 87

Table A. Conversion to calorific value used for different types of fuels 92

4. The WEN of Water and Energy Vulnerability

4.1 Politicization of Energy and Water from the Vulnerable – The Case of Energy Poverty and Water Poverty in Barcelona

Tabla 1. Regulaciones sobre la pobreza energética a diferentes niveles 102

4.2 The Water-Energy Vulnerability in Metropolitan Area of Barcelona

Table 1. Water-energy nexus in the domestic environment 110

Table 2. Indicators on water and energy poverty 116

Table 3. Comparison of socio-technical regimes for energy gas and water vulnerability households 123

Table 4. Evolution of domestic energy prices (PPS/kWh) from 2007 to 2016 (all taxes and levies included (€)) 126

Table 5. Comparison of administrative scale and characteristics of energy and water 131

Table A. Summary of interviews conducted 138

4.3 #No more thirst, cold, or darkness' - The role of social movements in the co-production of knowledge of Water and Energy Vulnerability

Table 1. Research methods applied during the fieldwork period including evolution to action research 158

Table 2. Demographic information of APE participants (n= 61, significance = 0.10) 158

Table 3. The list of energy use categories considered essential in minimum income standard research in 2014 (adopted from Walker et al. 2016) 165

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Abbreviations

ACA	Catalan Water Agency Agència Catalana de l'Aigua
AMB	Metropolitan Area of Barcelona Área Metropolitana de Barcelona
APE	Alliance Against Energy Poverty Alianza Contra la Pobreza Energética Aliança contra la Pobresa Energètica
ATLL	Aigües Ter-Llobregat
COP	Coefficient of Performance
DHW	Domestic Hot Water
DOE	US Department of Energy
EIA	US Energy Information Administration
EPC	Energy Performance Certificates
ESCACC	Catalan Strategy for Adapting to Climate Change Estratègia Catalana d'Adaptció al Canvi Climàtic
FAVB	Federation of Neighbours' Associations of Barcelona Federació D'Associacions de Veïns i Veïnes de Barcelona
GSHP	Ground Source Heat Pump System
HOSBEC	Hotel Business Association of Benidorm, Costa Blanca and Valencian Community Asociación Empresarial Hostelera de Benidorm, Costa Blanca y Comunidad Valenciana
IDESCAT	Statistical Institute of Catalonia Institut d'Estadística de Catalunya
IDHC	Human Rights Institute of Catalonia Institut de Drets Humans de Catalunya
ILP	Iniciativa Legislativa Popular
INE	Spanish Statistical Office Instituto Nacional de Estadistica
Lpcd	Litres per Person (capita) per Day
MIS	Minimum Income Standards
PAH	Platform for People Affected by Mortgages Plataforma Afectados por la Hipoteca
PE	Political Ecology
PPS	Purchasing Power Standard
PSC	Socialist Party of Catalonia Partit dels Socialistes de Catalunya
STS	Science and Technology studies
UNWTO	World Tourism Organization
VAT	Value Added Tax
WE	Water and Energy
WEN	Water-Energy Nexus
WEV	Water And Energy Vulnerability

1 Introduction

The thesis deals with the intrinsic links between water and energy, which are two resources considered essential for human life. Comprehensive lists of research studies can be found on the water-energy nexus (WEN) that address the sustainable management of both resources (e.g. Hardy, Garrido, & Juana, 2012; Perrone, Murphy, & Hornberger, 2011; Sanjuan-Delmás et al., 2015; Siddiqi & de Weck, 2013; Wilkinson, 2000; World Economic Forum, 2009). However, the crisis over water and energy governance remains a global challenge in many urban areas around the world (Feitelson & Chenoweth, 2002; Frederiksen, 2003; Fischhendler, Dinar, & Katz, 2011; MDGI, 2015; Petersen-Perlman, Veilleux, & Wolf, 2017). The human population is becoming more concentrated in urban areas, where it can be observed that the increasing disparity in wealth and access to water and energy creates 'winners' and 'losers' (Bakker, 2010) in the process. Furthermore, climate change adds additional stress on managing water and energy due to unpredictable extreme weather events (e.g. heat and cold waves, droughts, torrential rains, floods, tsunamis). As numerous challenges affect water and energy, understanding their interconnectedness emerges as a significant topic.

Still considered a fairly new concept, WEN has been widely advocated by international organizations, such as the World Bank and other development banks, United Nations, OECD, and World Economic Forum. The main thrusts of the WEN concept are the potential drawbacks generated by WEN trade-offs (e.g. power plant shutdowns due to lack of water), integrative imaginaries in water and energy governance and the advantages of WEN conservation (Allouche, Middleton, & Gyawali, 2015; Bartos & Chester, 2014; Bazilian et al., 2011; Cairns & Krzywoszynska, 2016; World Economic Forum, 2009). WEN was initially presented as a concept addressing scarcity and supporting integrated management of resources to improve climate change mitigation and adaptation policies. However, opponents have criticized how WEN has so far been largely used to support managerial responses to global challenges, which contradicts the views defended by political ecologists concerning global governance failure of managing resources in effective and equitable manners (Allouche, Middleton, & Gyawali, 2015).

In the same line of thought, the thesis adopts some of the research practices of the Political Ecology (PE) approach in WEN. Also known as the 'undisciplined discipline' or 'post-discipline', PE is considered as a way of doing research, whereby the relationship between nature, human and non-human actors are analyzed critically in terms of the environmental or ecological conditions that are the products of political processes (Robbins, 2004). Watts (2000, p.257) defines PE as a tool 'to understand the complex relations between nature and society through a careful analysis of what one might call the forms of access and control over resources and their implications for environmental health and sustainable livelihood'. Therefore, PE looks at environmental problems with a broader lens when analyzing the winners and losers, hidden costs, and power differences that produce unequal social and environmental outcomes (Robbins, 2004). Specifically, critical political ecology, which was inspired by the notion of the co-production of knowledge taken from Science and Technology studies (STS), emphasizes the analysis of knowledge, power, discourses, and politics at multiple scales (Peet, Robbins, & Watts, 2011).

In this thesis, I argue for why win-win WEN strategies are imperative for improving water and energy management and why it is important to overcome the inequality of the WEN tradeoffs, whereby solutions for water often results in shifting the problem to energy. In addition, I broaden the WEN tradeoffs in social terms, namely for winners that creates a problem for losers in either of the resources. At the same time, in following the vein of thought of PE, I enquire about the possibility of WEN addressing PE's central argument concerning water resources by studying WEN through multifactorial and multiscalar approaches.

1.1 Outline of the thesis

The thesis is structured in five sections based on five papers and one conference proceeding, thus fulfilling the requirements of the Department of Geography, Autonomous University of Barcelona for article-based theses. Table 1 summarizes the status of each article.

Table 1. The structure of the main sections of the thesis per sections with detailed information on the publication and language (Scopus 2017 database).

Sections	Publications	Journal & publication status (percentile, cite score)	Language
1. Introduction	1.4. A Review on Water-Energy Nexus and Directions for Future Studies: From Supply to Demand End	Published in *Documents d'Anàlisi Geogràfica* (37% , 0.47)	English
3. WEN in Mass Tourism (Benidorm)	3.1. Locating scarcity? The water-energy nexus in the mass tourist resort of Benidorm, Spain	Published in *Sustainability* (90%, 2.37)	English
	3.2. The Water-Energy Nexus in Hotels and Recreational Activities [1]	Submitted to the *International Journal of Hospitality Management* (97%, 4.1)	English
4. WEN of Water and Energy Vulnerability (Barcelona)	4.1. La Politización de la Energía y del Agua desde las Poblaciones Vulnerables – El Caso de la Pobreza Energética e Hídrica en Barcelona (Politicization of Energy and Water from the Vulnerable Population – The case of Energy Poverty and Water Poverty in Barcelona)	Published in conference proceedings[1]	Spanish
	4.2. The Water Energy Vulnerability in the Metropolitan Area of Barcelona	Major revision in Energy and Buildings (97%, 4.96)	English
	4.3. '#No more thirst, cold, or darkness' - The co-production of knowledge of water and energy vulnerability[2]	Submitted to Energy Research & Social Science (98%, 4.89)	English

The first section introduces and justifies the thesis, explaining the research objectives, the research questions in section 1.2 and 1.3. The section 1.4 introduces the main topic. It

[1] Previously entitled: The Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain
[2] Previously entitled: '#No more thirst, cold, or darkness' - The role of social movements in the co-production of water and energy vulnerability

consists of a literature review paper on the WEN concept by sharing the challenges and the research gaps. In section 1.5, I explain the elements that have contributed to frame the overall context of the thesis, which helps to address main findings from various research papers together.

The second section briefly introduces the research methodology, which is based on case studies focusing on two cities, i.e. Benidorm and Barcelona. It explains the selection of different research methods applied for meeting the research objectives in each case study. Details on the fieldwork in the two cities are also presented.

Sections three and four contain the main results of the thesis and are presented following the format, reference style and structure applicable to the corresponding journal. The scientific journals, in which these articles are published or submitted, were selected based on the suitability of the topic and academic performance (e.g. citation index, percentile, peer-reviewed).

Section three includes two research articles that investigate the WEN in the case study of Benidorm. The first one entitled 'Locating scarcity? The water-energy nexus in the mass tourist resort of Benidorm, Spain', focuses on the urban water cycle (section 3.1). The second one entitled 'The Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain', focuses on the WEN in one of the major actors of the tourism sector in Benidorm (section 3.2).

Section four, which is also composed of two research articles, approaches WEN from the domestic end-use perspective through the lessons learned from the experience of vulnerable households in the Metropolitan Area of Barcelona. The conference proceeding contribution entitled 'La Politización de la Energía y del Agua desde las Poblaciones Vulnerables – El Caso de la Pobreza Energética e Hídrica en Barcelona' (English: 'The Politicization of Energy and Water from vulnerable populations – The Case of Energy and Water Poverty in

Barcelona'), which was written and presented in Spanish [3], summarizes water and energy poverty as a domestic metabolism, which has been politicized (Section 4.1). Then 'The Water-Energy Vulnerability in Metropolitan Area of Barcelona (AMB)' represents the fourth paper of this thesis and it shares the affordability challenges experienced by the households related to the socio-technological structures in the AMB (Section 4.2). Lastly, the article entitled '#No more thirst, cold, or darkness' - The co-production of knowledge of water and energy vulnerability' highlights the active role of vulnerable households as indicators of the significance of WEN at the end-use (section 4.3).

In the last section of the thesis, I summarize and discuss the results derived from each article. The thesis ends with key highlights and the future research perspective to draw out the directions that will contribute to deepening the understanding of WEN.

1.2 Research objectives

The research has an exploratory approach of revealing the politicization of WEN that comes with the quantification of the nexus. Therefore, the main objective of this thesis is to analyze the urban water metabolism from the WEN perspective and is theoretically inspired by PE. This research also aims to provide empirical learnings gained from the process of linking water and energy, focusing on the processes it is affected by, and who are leading these processes.

Although each section of the thesis is aimed at understanding the different parts of the water cycle and the energy cycle, altogether the sections remain oriented towards the core research topic of WEN. It is the intention of the author of presenting the political aspects of WEN through the political ecology lenses, thereby showing how ecological, economic and political processes greatly affect the human-nature relationship.

[3] XXV Congreso de la Asociación de Geógrafos Españoles (25th Congress of the Association of Spanish

The first case study of Benidorm has the objective of quantifying *energy for water,* following each stage of the water cycle in the city. By investigating the water cycle by applying the PE approach, the following questions arise:

1) Socio-institutional: Who governs the respective cycle, public or private bodies?

2) Economic: What are the costs involved?

3) Environmental: What are the impacts generated?

The hotel and recreation sector are investigated with the aim of understanding WEN in the context of mass tourism at the end-users' scale, as well as exploring the nexus as a relation between the water and energy consumption level and management practices. The correlation between water and energy consumption within hotel facilities are analyzed. Moreover, the analysis is conducted on the potential of reducing WEN trade-offs.

The second part explores WEN in the context of water and energy poverty (or vulnerability, hereafter WEV) in the Metropolitan Area of Barcelona (AMB). This approach provides a social aspect to the WEN analysis concerning the demand side and the bottom-up approach of the WEN analysis. The socio-economic character is identified from the WEV affected households in the AMB. The intrinsic links between water and energy at the household level are summarized. In addition, by applying ethnographic research methods, the thesis expands to focus on a local social movement, 'Aliança contra Pobresa Energètica' (English: Alliance against Energy Poverty (APE)).

Geographers), Madrid, 25-27 Oct. 2017

1.3 Research questions

In exploring the multiple aspects of WEN, the following research questions are central:

- How is WEN empirically observed in the urban and tourist areas of Spain?
- What aspects of WEN signals the politicization of water and energy?
- How is WEN politicized, and specifically, in what ecological, sociotechnical and political landscapes does this politicization occur?

Each article tries to address directly and indirectly the different issues that revolve around the core research questions. The following questions were asked to understand WEN in the mass tourist resort for the case of Benidorm (Section 3.1):

- How does energy intensity involved in water provision vary depending on climate conditions?
- How much is energy intensity is involved in water provision?
- How does the hydro-social cycle of Benidorm work?
- Who are the main actors in connection to the end uses of water?

Concerning the research focus on WEN in the hotel and recreational sectors (Section 3.2), the following questions were asked:

- How is WEN evident in the hotel and recreation sector?
- How much is WEN considered in management practices?

The case study of Barcelona generates questions for understanding WEN in terms of end-uses by looking at extreme cases of scarcity (section 4.2). The questions asked include:

- How is WEN revealed in the end-use by the most vulnerable populations?
- What factors cause water-energy vulnerability?
- What are the socio-demographic characteristics of people suffering from this problem?

Moreover, focusing on the social movement, APE, which works to eradicate water and energy poverty, the research (section 4.3) addresses more open questions, such as the following:

- How is WEN politicized in the everyday practices of APE?
- What can be learned from APE regarding WEN?

1.4 Research topic: Water-Energy Nexus[4]

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A Review on Water-Energy Nexus and Directions for Future Studies: From Supply to Demand End

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Abstract

The intrinsic links between water and energy have produced a new concept known as water-energy nexus (WEN), which has been increasingly studied by scholars and global institutions since the 1990s. This paper provides a review of water-energy nexus studies in an interdisciplinary manner starting from two major approaches—*water for energy* and *energy for water*—which focus principally on quantitative studies, but also on policy and institutional dimensions. Many studies mention data collection, the lack of coordination between existing frameworks and the scale/boundary of the two resources as major challenges, whereas new technologies are seen as an opportunity for the nexus perspective. After identifying research gaps, the political ecology approach is proposed for a critical reflection on WEN. Additionally, water poverty and energy poverty (or fuel poverty) are also proposed as part of WEN studies in order to broaden their spectrum to include the demand-end perspective and introduce a social dimension in WEN.

Keywords: water-energy nexus; political ecology; water intensity; energy intensity; households

Resum. *L'estat de la qüestió sobre el nexe aigua-energia i les perspectives futures d'investigació: des de l'oferta fins a la demanda final*

Els vincles intrínsecs entre aigua i energia han originat una nova terminologia, l'anomenat nexe aigua-energia (NAE), que ha estat investigat cada vegada més per acadèmics i institucions globals des de la dècada de 1990. Aquest article presenta una revisió interdisciplinària dels estudis de les interrelacions entre l'aigua i l'energia a partir de dos enfocaments principals: l'aigua per produir l'energia i l'energia per subministrar i tractar l'aigua. La revisió se centra principalment en estudis quantitatius i en les dimensions polítiques i institucionals del NAE. Molts estudis esmenten la recollida de dades, la descoordinació dels marcs interpretatius existents i l'escala o límits de dos recursos com els desafiaments principals, mentre que les noves tecnologies es veuen com una oportunitat. Després d'identificar les àrees deficitàries en investigació, la l'autora proposa l'enfocament de l'ecologia política per endegar una reflexió crítica sobre el NAE. Es proposa també incorporar la pobresa hídrica i la pobresa energètica a les llars com a part dels estudis de NAE, ja que estan relacionades amb aquesta aproximació teòrica. Això permet ampliar l'espectre d'investigacions per incloure la perspectiva de la demanda i generar, així mateix, una reflexió social sobre el NAE.

Paraules clau: nexe aigua-energia; ecologia política; intensitat hídrica; intensitat energètica; llars

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[4] Yoon, H. (2018). A Review on Water-Energy Nexus and Directions for Future Studies: From Supply to Demand End. Documents d'Anàlisi Geogràfica, 64(2), 365. https://doi.org/10.5565/rev/dag.438

Resumen. *El estado de la cuestión sobre el nexo agua-energía y perspectivas futuras de investigación: desde el suministro hasta la demanda final*

Los vínculos intrínsecos entre agua y energía han originado una nueva terminología, el nexo agua-energía (NAE), que ha sido investigado cada vez más por académicos e instituciones globales desde la década de 1990. Este artículo presenta una revisión interdisciplinaria de los estudios de las interrelaciones entre agua y energía a partir de dos enfoques principales: el agua para producir energía y la energía para suministrar y tratar el agua. La revisión se centra principalmente en estudios cuantitativos y en las dimensiones políticas e institucionales del NAE. Muchos estudios mencionan la recolección de datos, la descoordinación del marco de relaciones existente y la escala y límites de dos recursos como los desafíos principales, mientras que la nueva tecnología se ve como una oportunidad. Después de identificar las áreas deficitarias en investigación, la autora propone estudiar el NAE a partir de un enfoque de ecología política. Se propone también incorporar la pobreza hídrica y la pobreza energética en los hogares como parte de los estudios de NAE, ya que están relacionadas con esta aproximación teórica. Ello permite ampliar su espectro de investigaciones para incluir la perspectiva de la demanda y generar, asimismo, una reflexión social sobre el NAE.

Palabras clave: nexo agua-energía; ecología política; intensidad hídrica; intensidad energética; hogares

Résumé. *État des lieux du nexus eau-énergie et perspectives futures de recherche : de l'offre à la demande finale*

Les liens intrinsèque entre l'eau et l'énergie ont conduit à une nouvelle terminologie désignée par les termesnexus eau-énergie (NAE), qui a été étudié par académiciens et les institutions depuis les années 1990. Cet article propose une revue interdisciplinaire des interrelations entre l'eau et l'énergie à partir de deux approches principales : l'eau pour produire de l'énergie et l'énergie pour fournir et traiter l'eau. L'examen porte principalement sur les dimensions quantitatives et aussi sur les dimensions politiques et institutionnelles de la NAE. De nombreuses études mentionnent la collecte de données, le manque de coordination entre des modes d'interprétation différents et les relations d'échelle et / ou les limites des ressources en tant que défis principaux, tandis que les nouvelles technologies sont considérées comme une opportunité. Après avoir identifié les zones déficitaires dans la recherche, l'auteur propose l'approche de l'écologie politique pour entreprendre une réflexion critique sur la NAE. En relation avec cette approche théorique, nous proposons également d'incorporer la pauvreté de l'eau et la pauvreté énergétique des foyers dans le cadre des études sur le NAE. Cela élargit le champ des enquêtes afin d'inclure la demande et aussi de générer une réflexion sur les aspects sociaux du NAE.

Mots-clés: nexus eau-énergie; écologie politique; intensité hydrique; intensité énergétique; foyers

Summary

1. Introduction
2. The Water-Energy Nexus
3. Challenges and Opportunities
4. Research Gaps
5. Conclusion
6. Future Research
Acknowledgements
Bibliographical references

1. Introduction

Water and energy are essential for human survival and intimately intertwined (Voinov and Cardwell, 2009). This connection between two resources is called the 'water-energy nexus' (WEN) (Scott et al., 2011). Even though the connection has been well understood and utilized by humans since ancient times in forms such as watermills, the myriad connections between the use of water and energy began to draw attention from academics only from the 1990s (Gleick, 1994; Wichelns, 2017). The main reason for the relevance of WEN is that the distribution of water requires enormous amounts of energy and the production of energy requires equally large amounts of water (King et al., 2008). The increasing demand for energy will put large pressures on limited water resources, creating direct competition between the two resources. Likewise, increasing demand for water to be satisfied with non-conventional resources such as desalination will require more energy.

The need for WEN studies has increased since both resources face scarcity conditions globally. It is reported that 2.8 billion people live in high water stress areas and 1.2 billion people live in areas of physical scarcity (World Water Assessment Program [WWAP], 2012). In terms of energy, 2.5 billion people have unreliable or no access to energy sources. At the same time, global energy demand is continuously increasing. It is expected that the global average energy demand will increase from 81.2 GJ per person in 2012 to 96 GJ per person in 2035, that is, a 40% increase. Especially in emerging economies such as China, India and Brazil, it is estimated that the energy demand will almost double current consumption over the next 40 years. This is challenging because the 35% increase in energy consumption from 2010 to 2035 would correspond to a parallel 85% increase in water consumption (International Energy Outlook, 2012).

Water and energy planning therefore must be based on an in-depth understanding of interdependencies taking into account existing and future water or energy constraints. Unfortunately, there is a lack of cooperation between planners and decision makers in the water and energy sectors and they often remain ill-informed about the drivers of WEN challenges, how to address them, and the merits of different technical, political, management, and governance options (Rodriguez et al. 2013). Several studies have highlighted that much effort is needed to improve the bureaucratic and administrative aspects of planning and management of these two resources and many international organizations and states have addressed WEN as a major topic in high-level conferences (OECD, 2010; World Economic Forum, 2009; WWAP, 2012). Moreover, more academic attention is required to advocate WEN studies (Muller, 2015).

This article aims to compile WEN literature and provide an interdisciplinary review covering quantitative to qualitative studies from various fields ranging from engineering to geography. Some of the challenges and opportunities are highlighted as WEN research often share difficulties derived from the experience where two different resources had to be treated in the same sphere including difficulties in data collection, separated policy and regulatory frameworks, and complexity. But new technologies are being experimented and proposed as possible solutions to these challenges. The article also aims to expand and variegate classic WEN studies by proposing future research directions to perhaps include a more visible notion of the nexus in the demand end ranging from demand management to the lack of resources due to unjust resource distribution, in what is commonly defined as energy poverty or water poverty.

The article also links into political ecology (Robbins, 2007; Peet and Watts, 1996); a broad academic field responding to the need for a critical perspective on WEN (Verhoeven, 2015; Williams et al., 2016). Fruitful insights from political ecology have brought together various fields such as ecology, social science, environmental science and political economy (Peet and Watts, 1996) to provide 'normative understanding that there are very likely better, less coercive, less exploitative, and more sustainable ways of doing things' (Robbins, 2004: 12). Thus, political ecology attempts to enhance our understanding of the relationships between water and energy and political, economic, and social factors.

This review is based on publications from academic journals, state and federal government agency reports, and international organization and nongovernmental organization reports on WEN. A few review papers also provided some insight and the state of development of the field (Gleick, 1994; Retamal et al., 2008; Kenway et al., 2011).

In the following section, WEN is explained according to two fundamental conceptual approaches, *water for energy* and *energy for water*. An overview of the research methodologies applied in policy and institutional dimensions and the demand-end of WEN is then provided. We challenge and stretch the boundary of the classic WEN studies by arguing that more focus should be placed on the demand-end, possibly including energy (fuel) poverty and water poverty from the WEN perspective. In section three, the challenges and opportunities drawn from the literature review are outlined. Section four recaps the research gaps diagnosed and conclusions are drawn in section five. Lastly, the review concludes with proposals for future directions for study.

2. The Water-Energy Nexus

The existing research on WEN has covered a wide range of dimensions ranging from technology, environment and economic to social and political/legal issues. Even so, it is widely argued that a systematic understanding of the interrelationship between water and energy is lacking and is needed in order to define an optimal policy or planning for the water and energy sector. The scale of research also varies from the local, state or regional to national levels (Kenway et al., 2011). More recent studies on the macro scale focus on analyzing interrelationships at the national level due to data availability. These studies are quantitative in nature and explore the status quo of the relationships.

In order to understand its complexity and to map the interrelationships, WEN is commonly studied from one side of the resource to another. As said before, these two approaches are respectively called *water for energy* and *energy for water*.

2.1. *Water for energy*

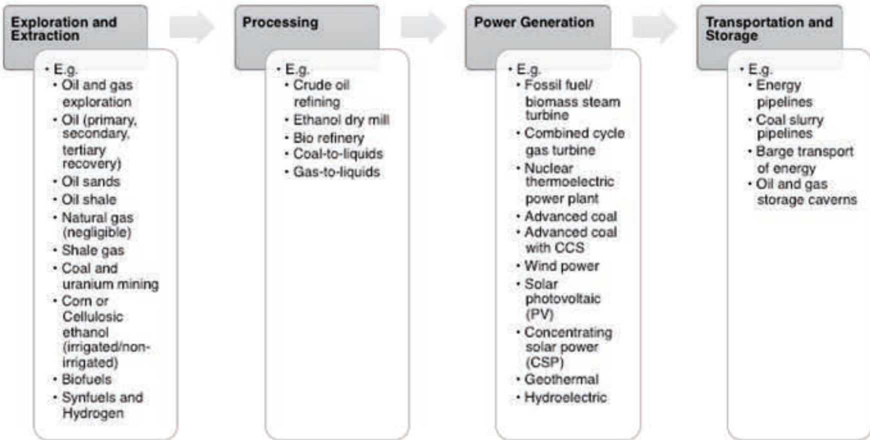
Water is required to produce all kinds of energy sources from extraction including the mining, refining and processing phases to the production of electricity (Table 1). This is a well-studied field given the relative priority and importance of the energy sector (Kenway et al., 2011). Water for energy is most commonly measured by calculating the water consumed per unit of electricity produced (m^3/GWh) either directly or indirectly. Water requirements are usually quantified based on three concepts: water withdrawal, water consumption, and water discharge. Withdrawal is defined as the amount of water taken from a water source (lake, reservoir, river, ocean, aquifer, etc.). Consumption is the water lost from the total water withdrawn through evapotranspiration or degraded due to contamination to such a point that the chemical or physical properties of the water have changed and it is no longer usable and has to be disposed of. Discharge is the amount of water that is returned to the water source although in a different state. It is important to understand that in some cases much of the water withdrawn can be returned back to the source. In summary, water consumption accounts for the amount of water withdrawn minus the water disposed according to the equation:

$$\text{Water withdrawal} - \text{Water disposal} = \text{Water consumption}$$

The importance of water in the energy sector has been recently highlighted once again as several power plants around the world were shut down due to water shortages. Globally, it is estimated that the energy sector accounts for 10% of the world's freshwater withdrawals mainly for power plant operations and the production of fossil fuels and biofuels (IEA, 2016). However, for countries like the United States, the share increases to 38% when accounting only for thermoelectric power plant water use over annual freshwater withdrawal (Maupin et al., 2014).

Water availability constraints influence the choice of technology, sites, and the type of energy facilities. Conversely, depending on the raw material or the technology selected to generate power, water consumption may vary significantly. Examining the current energy system and deciding on the future energy mix is of enormous importance, considering that water and energy stress is expected to exacerbate due to population and economic growth. Therefore, it is important to consider WEN to guarantee long-term energy provision (Rodriguez et al., 2013).

Table 1. Existing energy sources and technologies



Source: Mielke et al. (2010).

Water for fuel extraction, processing, and transportation

Primary energy sources like oil, gas, coal, and uranium all require a substantial amount of water in order to be extracted, processed, and transported (Table 2). As oil ages, it requires more water for extraction. Traditional oil extraction methods require 3–7 L/GJ (US Department of Energy, 2006). However, when oil is extracted by unconventional methods such as hydraulic fracturing or fracking, 70–1800 L/GJ of water are consumed (US Department of Energy, 2006). Some authors have argued that oil sand exploration only requires three times more water than the conventional crude oil (Olsson, 2012). Biomass, when it is irrigated and processed to produce bioethanol or biofuel, requires as much as 500 times more water than other types of fuel (Olsson, 2012).

Table 2. Water consumption for raw materials

	Raw material	Water for energy (L/MWh)	Transformation	Water for energy (L/MWh)
Oil	Traditional oil	11–25	Oil refining	89–232
	Enhanced oil Recovery	176–32,143		
	Oil sands	250–6,429		
Biofuels	Corn	32,413–357,143	Ethanol Biodiesel	168–179 50
	Soy	178,571–964,286		
	Sugar	N/A		
Coal	Coal	18–250	Coal-to-liquids	500–786
Gas	Traditional gas	Minimal	Natural gas processing	25
	Shale gas	129–193		

Source: US Department of Energy (2006).

Cooling water

Fossil and nuclear power systems account for 80% of electricity generation. These systems require cooling to condense the steam turbine exhaust and, additionally, for some secondary purposes such as equipment for washing and cooling, emissions treatments, and facilities for workers. Compared to the large volume of water withdrawn and consumed for steam condensing, water consumption for these other water uses is rather small (Table 3).

Cooling systems are key to the water intensity of the power plant and influence power plant efficiency, capital and operation costs, water quality, and total environmental impacts. Open loop cooling systems withdraw large amounts of water and therefore may not be appropriate for water scarce regions although most of these volumes are discharged back to the water source. As long as the quality of the discharged water is appropriately managed, water consumption remains small compared to closed loop systems. Closed loop cooling systems withdraw less water but most of this water is lost by evaporation in the cooling tower. Other alternative cooling technologies such as cooling reservoirs and dry cooling systems are also

Table 3. Water intensity for thermoelectric power plants

		Steam condensing	
Plant type Steam	Process	Withdrawal (L/MWh)	Consumption (L/MWh)
Fossil/biomass/waste	OL	75,708–189,271	~1,136
	CL tower	1,136–2,271	1,136–1,817
	CL pond	1,893–2,271	~1,817
Nuclear	OL	94,635–227,124	~1,514
	CL tower	1,893–4,164	1,514–2,726
	CL pond	3,028–4,164	~2,726
Geothermal steam	CL tower	~7,571	~5,300
Solar trough	CL tower	2,877–3,483	2,877–3,483
Solar tower	CL tower	~2,839	~2,839
Other			
Natural gas CC	OL	28,390–75,708	379
	CL tower	~871	~681
Coal IGCC*	CL tower	~946	~757

OL= Open loop cooling, CL= Closed loop cooling, CC= Combined cycle, IGCC= Integrated gasification combined cycle

Water for other cooling loads such as gas turbine, equipment washing, emission treatment, restroom, etc. which range from 26 to 530 depending on the plant type. Dry cooling systems require 0 withdrawal & consumption.

*Includes gasification process water

**Reference did not specify whether values are for withdrawal or consumption

Source: Adapted from US Department of Energy (2006). Data based on EPRI (2002), CEC (2002, 2006), Leitner (2002) and Cohen et al. (1999).

used in some power plants but their presence compared to the rest of the technologies remains low.

Water for renewable energy
The water requirements for renewable energy that does not require steam engines, such as photovoltaic and wind power, are very low. However, other renewable energy technologies such as concentrated solar power (CSP) and geothermal energy that produces power using heat may be water intensive depending on the cooling technology. Biofuel is one of the most water intensive renewable energy options available. For example, if the share of biofuels for transportation in the Spanish energy mix increase from 1% to 25% by 2030, this would imply the consumption of almost 6 times the total water consumed by the electricity sector in 2005 (Rio Carrillo and Frei, 2009).

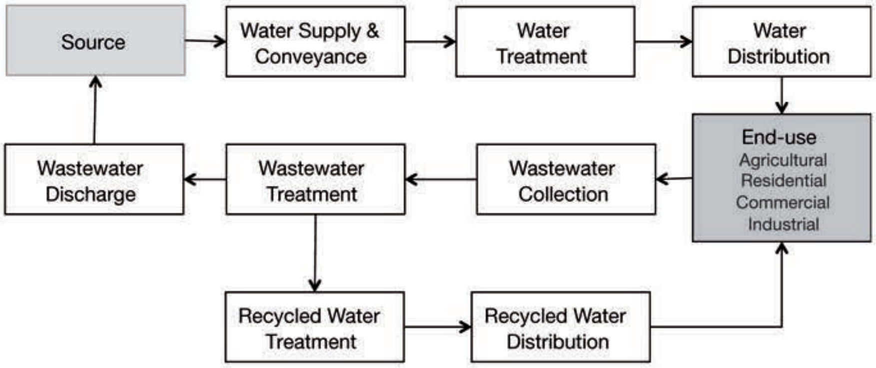
Hydropower
Although large dams are a very attractive source of energy, especially for developing countries (World Bank, 2013), they are considered unsustainable due to environmental and social impacts such as sedimentation, risks from dam failures, changing river patterns, altered ecosystems, and the displacement of people and economic activities. In WEN terms, water loss by evaporation from the reservoirs poses a problem in warm climates. However, this is often overlooked due to the fact that reservoirs will still provide water that would otherwise not be available (Olsson, 2012). The degree of evaporation varies depending on the size of the dam and its location, ranging from 0 to 540 m^3/kWh (IPCC cited by Olsson, 2012; US Department of Energy, 2006).

2.2. *Energy for water*

Energy for water studies is another side of WEN story where water supply is the central focus. For example, in the United States and China, it is estimated that energy use for water accounts for 4% of the country's electricity generation (Copeland, 2017; Li et al., 2016). Energy is used as water provides for urban, agricultural, and industrial needs through the water supply-use-disposal chain, which can be further divided into various stages (see Figure 1). Not all water uses have the same energy intensity. The energy requirement for supplying water depends on the geographical attribution, quality, and distribution of the water source, as well as the type of technology used for its treatment and mode of disposal. Energy for water, also called 'energy intensity' or 'energy embeddedness', is calculated by computing the energy required per unit of water volume measured (kWh/m^3) for each stage and may be aggregated according to the boundaries defined by each case study. A comparison of case studies demonstrates that the amount of energy consumed varies in specific stages of the water systems conditioned by their geological conditions, technologies, and infrastructures (Wakeel et al., 2016).

In comparison to energy, which is the major water user, energy use by the water sector only accounts for a small portion of total energy use. However,

Figure 1. Water use cycle scheme



Source: Adapted from CEC (2005).

because most countries attempt to reduce greenhouse gas emissions there are ample opportunities for creating a win-win solution for climate change, energy security, and water conservation (Hussey and Pittock, 2012).

Source and conveyance systems

For surface water extraction and transportation, the physical environment exerts a basic influence on energy requirements. Table 4 illustrates different energy intensities depending on the region and type of water extraction. Groundwater pumping has different energy intensities depending on the depth of the aquifer, the pressure and flow rate of the output water, and the efficiency of the pumping system. Commonly, it is assumed that the efficiency of pumping is around 50%. Based on a different approach, EPRI (2002) estimates the energy intensity of source and conveyance systems according to the sector in which the water is used. For example, the unit electricity consumption for groundwater is 0.185 kWh/m^3, whereas for surface water source it is 0.079 kWh/m^3 for domestic, commercial, irrigation, and livestock sectors. For the industrial and mining sectors, 0.198 kWh/m^3 were assumed for groundwater pumping with additional energy requirements such as frictional losses or higher pressures. In the power generation sector, values of 0.211 kWh/m^3 for groundwater pumping and of 0.040 kWh/m^3 for surface water supply were estimated (EPRI, 2002).

When conveyance is required over long distances with elevations, local treatment and distribution, and wastewater collection and treatment, water becomes more energy intensive (Wilkinson, 2000). Energy requirements at this stage of water provision depend on the number and performance of pumping systems required to transfer water from the source to the water purification plant. In the United States, around 4% of the nation's electricity is required for water conveyance, water treatment, and wastewater treatment. Of this use, 80% is for 'moving' water (EPRI, 2002).

Table 4. Energy intensity per water-use cycle in different regions

Stages	Region	Purpose	Energy for water (kWh/m^3)	References
Ground water extraction	USA	Groundwater pumping	0.14-0.79	(Wilkinson, 2000; EPRI, 2002; Plappally and Lienhard V, 2012)
	Australia	Groundwater pumping	0.48-0.53	(Rocheta and Peirson, 2011)
	China	Groundwater extraction (national average)	0.37	(Li et al., 2016)
	USA (Central Arizona)	Lifting groundwater	3.3	(Perrone et al., 2011)
	USA	Whole water supply system	1.02	(Griffiths-Sattenspiel and Wilson, 2009)
Surface water extraction	Australia (Sydney)	Surface water Pumping	0.92	(Kenway et al., 2008)
	China	Water storage & pumping	0.13 & 0.37	(Li et al., 2016)
Water distribution/ conveyance	USA (Northern California & Southern California)		0.04 & 2.4	(CEC, 2005)

Source: Adapted from Nair et al. (2014) and Li et al. (2016).

Desalination

Among the different water sources, desalination is a relatively new and non-traditional technology used to provide potable water from sea or brackish water. Because desalination is extremely energy intensive, it is criticized as being insufficient or maladapted as a new water source (March, 2015; Swyngedouw and Williams, 2016). Even so, in arid areas, such as in the Middle East and North Africa (MENA), desalination plants are the major sources of water supply and they are considered a feasible alternative to fresh water resources (Siddiqi and Anadon, 2011).

Table 5 shows the different types of desalination technologies and energy consumption per technology. There are several technological options available for desalination including thermal processes, such as multi-stage flash (MSF), multi-effect distillation, or mechanical processes, such as reverse osmosis, which is electrically driven. Studies have found that different types of desalination processes have distinct energy requirements. In terms of energy consumption, reverse osmosis (RO) is generally more efficient than thermal processes (Plappally and Lienhard V, 2012), which is also the reason why thermal processes have historically been implemented in countries with abundant energy resources but scarce water (Olsson, 2012). Current state-of-the-art seawater desalination with RO methods requires 3–5 kWh/m^3 and brackish water needs around 0.5–2.6 kWh/m^3. However, MSF typically requires 12–15 kWh/m^3 and up to 25 kWh/m^3 (Olsson, 2012; March, 2015). Attempts to increase the energy efficiency of desalination technology are closely related to direct impacts on operation costs and thus many plants

Table 5. Summary of different desalination technologies and their energy consumption

Type	Technology	Summary	Energy for water* (kWh/m³)
Thermal Process	Multistage flash distillation (MSF)	After heating water, pressure is diminished so that the water "flashes" into steam. It is the most widely used thermal process.	Pumping: 2.5–5.0 Thermal energy**: 6.8–20
	Multiple effect distillation (MED)	A number of evaporators are installed in series so that the water passes through and vapour from one series is used to evaporate water in the next series. It is the oldest modern desalination technique and is efficient in thermodynamic terms.	Pumping: 1.0– 2.9 Thermal energy**: 3–6.6
	Vapor compression (VC)	Water is evaporated to vapour to be compressed. The heated compressed vapour is used for the next feed of water.	8.0–17.0
Mechanical process	Reverse osmosis (RO)	Membrane screens molecular size to about 1 Angstrom (10-4 microns) and removes salinity from salty water (or brackish water) when it is introduced with high pressure. Recovery rate of the process is usually higher than 60% (ratio of desalinated water over initial water intake).	Seawater RO: 2.0–8.5 Brackish water: 0.5–2.6
	Electro-dialysis (ED)	Electrical field is applied across a set of cationic/ anionic membrane pairs which excite the ions to transfer through the membranes, leaving a stream of desalinated water.	0.8–1.7
	Forward osmosis (FO)	Relatively new process that uses injection of ammonia, carbon dioxide or other ingredients in the draw solution (salt) to increase the osmotic potential. Uses relatively little energy.	
	Pressure retarded osmosis (PRO)	Osmotic pressure is used to generate power where two solutes with different salt concentration are available. Newer technology.	

* Range of energy consumption is the minimum and maximum value of data from various studies over year

** Equivalent electrical energy

Source: Adapted from Olsson (2012), Plappally and Lienhard V (2012) and March (2015).

have deployed renewable energy on site in order to become self-producers of the energy.

Water treatment (water purification)

Energy use for water utilities varies significantly between treatment plants and cities depending on design flow rates, level of treatment, technology applied, source of energy, and scale of plant (Kenway et al., 2008; Rocheta and Peirson, 2011). Moreover, energy consumption for water and wastewater treatment in cities may be affected by local circumstances and regulations (Kenway et al., 2008). Table 6 lists the available treatment technologies applied in the mar-

Table 6. Energy impact of new water treatment technologies

Treatment technology	Energy for water (kWh/m³)
UV disinfection	0.19–0.26
Nanofiltration (Membranes)	0.476
Ultrafiltration (Membranes)	0.264
Low pressure micro filtration (Membranes)	0.026
Ozone	0.044

Source: Carlson and Walburger (2007).

ket together with their corresponding energy requirements. UV disinfection and membrane technologies are currently replacing chlorine despite its higher energy intensities.

More concretely, cases from the United States have shown that surface water treatment facilities that use processes including rapid mix, flocculation, sedimentation, and filters of 37,850 m^3/day have an estimated total electricity consumption of about 14,057 kWh per day, which is equivalent to a unit energy consumption of 0.371 kWh/m^3 (EPRI, 2002). This study found that variations are driven primarily by economies of scale, particularly in the case of small facilities, where unit electricity consumption decreases as the size of the treatment plant increases. Regardless of size, however, electricity is primarily used for pumping treated water into the distribution system, which normally accounts for between 80 and 85 percent of the total electricity consumption for surface water treatment (EPRI, 2002).

Distribution to end-users and waste collection

Energy is required in order to distribute water to the end-users. These distribution systems are usually equipped with chlorination points to meet the regulations on chlorine levels at the faucet for potable uses. When reservoirs are located in sufficiently higher places, gravity pressurization and distribution is also possible (Cohen et al., 2004). Depending on the location of the waste treatment plants, waste collection could also require energy for moving water through pipes.

Wastewater treatments

The average energy consumption per cubic meter of wastewater treated, regardless of the technology applied, does not differ much across countries as it ranges from 0.36–0.67 kWh/m^3 (Hernández-Sancho et al., 2011). However, when the volume of water treated in each country is considered, the difference in the net energy use could be significant. Economies of scale can generally be achieved at this stage. However, unit electricity consumption is higher as the degree of treatment and complexity of the process increases due to augmented salinity and organic material contents in the wastewater (Hancock et al., 2012). The highest energy consumption in wastewater plants is due to the aeration process (CEE, 2007). According to ICF Inter-

Table 7. Energy intensity for wastewater treatment plants in the United States and Australia

United States	Energy for water (kWh/m³)
Trickling filter	0.252
Activated sludge	0.348
Advanced wastewater treatment without nitrification	0.407
Advanced treatment with nitrification	0.505
Australia	**Energy for water (kWh/m³)**
Primary treatment	0.22
Secondary treatment (removal of C, including primary treatment)	0.46
Tertiary treatment (removal of C, N, and P, including secondary treatment)	0.90

Source: EPRI (2002) and Kenway et al. (2008).

national reports for the US EPA in 2008, it is possible to save 15% to 30% of electricity by installing high efficiency motors and pumps (cited in Water in the West, 2013).

At the national level, the energy intensity of wastewater treatment depending on the type of treatment facility has been calculated in the literature.[1] Unit energy consumption for water supply and wastewater treatment per plants are provided in Table 7 for the United States and Australia.

On average, energy intensity doubles between each treatment phase. Thus, it doubles between the primary and secondary treatment and doubles again between the secondary and tertiary treatment. Advanced wastewater treatment requires relatively more energy because of additional pumping (EPRI, 2002). After the tertiary treatment of wastewater, re-use opportunities may become more cost-effective as the additional energy required for re-use may be relatively small depending on energy requirements after treatment (Kenway et al., 2008).

Water end-uses

End-use energy intensity for domestic water is reported to be as high as 72% of the total water cycle (Plappally and Lienhard V, 2012). Among other household activities, water heating comprises 97% of total water-related energy use and is therefore of considerable importance (Arpke and Hutzler, 2006; Flower et al., 2007). According to Kempton (1988), energy use for water heating ranged from 1.8 to 4.7 kWh/day. In hot water use, behavioral and cultural

1. Primary treatment removes large solids (e.g., rags and debris) and smaller inorganic grit and is the first stage of each of the four representative processes (screening and settling). Secondary treatment removes organic contaminants using microorganisms to consume biodegradable organics (e.g., activated sludge or trickling filters). Advanced treatment systems go beyond secondary treatment to include nitrification (to convert ammonia to nitrates), denitrification (to convert nitrates to nitrogen), physical-chemical treatment (to remove dissolved metals and organics), and/or disinfection (to kill any remaining pathogens) (EPRI, 2002).

aspects of individuals and their demand for water have an important influence (Plappally and Lienhard V, 2012). The geographical situation and climate influence the energy input for heating water because colder inlet temperatures require more energy for heating (Gutierrez-Escolar et al., 2014). Other factors include habit, time of year, purpose of the building, temperature of cold water, temperature of domestic hot water (based on the European standard of 60 degrees Celsius), type of building, number of members in the household, and others (Gutierrez-Escolar et al., 2014). In Spanish residential buildings, energy consumption from domestic hot water accounts for about 20% of total energy use. Annual average domestic energy consumption for hot water is 1755.90 kWh per household and average water consumption is 142 L per capita per day.[2] In Australia, 0.2% of the total energy consumed is used by the water utilities but heating water is responsible for 25% of the residential energy demand and 27% of the greenhouse gas emissions in households, excluding transportation (Kenway et al., 2008).

Lost water (non-revenue water)
When water is lost, especially in urban areas, energy is lost as well. This lost water is called non-revenue water (NRW). Leakages are known to be main reason for losing water. Various studies estimate between 45 and 88 million m^3 of water are lost per day worldwide from the leakages in the water supply systems; that is, enough water to serve some 200–400 million people (Olsson, 2012). In addition to this amount, there is also water loss due to apparent (commercial) losses, among them meter inaccuracies, data mismanagement, or illegal connections. In order to reduce the level of NRW, poor utility performance needs to be improved, ageing infrastructure needs to be replaced and, when installing new piping, additional sensors have to be put in place to improve monitoring.

2.3. Research methods

Most of the research on WEN approaches the study of the relationship from an engineering perspective that uses quantitative analysis based on national data to provide a view according to one resource or from both. Some research focusing on the community or household level has developed methods for bottom-up data collection (Perrone et al., 2011). The methods used to analyze WEN include accounting (Gleick 1994; Kenway et al., 2008), life cycle assessment (LCA) (Muñoz, et al., 2010; Meldrum et al., 2013; Hancock et al., 2012), regional or community models (Rio Carrillo and Frei, 2009; Perrone et al., 2011), spreadsheet models (Wilkinson, 2000), case studies (Cohen et al., 2004; Kenway et al., 2008; Siddiqi and Anadon, 2011), and GIS (Wilkinson, 2000).

2. Banco Público de Indicadores Ambientales (BPIA). Available online: <http://www.mapama.gob.es/es/calidad-y-evaluacion-ambiental/temas/informacion-ambiental-indicadores-ambientales/banco-publico-de-indicadores-ambientales-bpia-/> (accessed on 11 September 2014).

It is increasingly noted that the nexus concept has to be understood at multiple scales such as facilities, cities, and regions (Retamal et al., 2008). Until very recently, the most commonly used methods have been accounting and case studies, but LCA is currently gaining popularity (Wang and Zimmerman, 2011).

Depending on the method used, the boundary of the selected consumption varies. For example, the whole system approach takes direct inputs into account but secondary and tertiary impacts (negative or positive) are not considered, despite the fact that these studies attempt to address environmental and economic implications and benefits. A broader analytical approach is useful for water managers and decision makers who are seeking to comply with regulatory requirements and policies to manage multiple objectives in cost-effective and economically efficient ways. On the other hand, life cycle assessments account for both direct and indirect inputs of resources (Retamal et al., 2008). For this reason, they are commonly used for analyzing WEN at micro scales (e.g., particular technologies, specific end uses, etc.) and they can effectively assess other environmental impacts. However, these assessments present difficulties in downscaling as they use national economic data as the main source.

Some studies incorporate regional or state scenarios or energy mixes to test sensitivity and make future projections for WEN (Rio Carrillo and Frei, 2009). Predictive modelling is applied to take into consideration climate variability, meteorology, and hydrology for improved energy and water resources planning (Hightower, 2006; Hoffman, 2010). Visual display tools, such as GIS, causal loop diagrams, and Sankey diagrams of WEN, facilitate a holistic understanding of water and energy consumption in terms of its distributional and relative consumption levels.

In addition to qualitative methods which tend to focus on supply and the point of use, a broader research question was proposed by other academics that took into account the governance, policy, and institutional dimensions of WEN. Their research revealed managerial challenges for decision makers, which make the full application of WEN difficult.

2.4. Policy and institutional dimensions

Even though the connectedness of water and energy is widely accepted, water and energy have been traditionally planned and managed separately. As tradeoffs between energy and water are becoming increasingly recognized, an important goal for academia remains to change the policy arena for effective implementation of water and energy policies. According to some, integrating sustainability science helped to improve WEN policy development in the United States (Stillwell, 2015). Research should be promoted to influence energy mixes for the future and also the selection of technology for water scenarios. Much of the difficulty in policy development and in fostering conversation between the two fields lies in the fact that the existing policy and institution framework is already fragmented. Moreover, tendencies towards inertia impede radical changes in institutional and personal behaviours (Hussey and Pittock, 2012).

For the water sector, the common understanding is that the water supply and distribution management is essentially a local issue as water is managed in many parts of the world at the municipal level, such as in water saving and efficiency programs. Thus, while analytical boundaries are set at a local level for water, energy boundaries unfortunately do not coincide much with the local sphere. Energy is managed at national level and in most countries depends on reserves that are concentrated in certain regions around the world. In other words, even though water and energy may be commodities with a close relationship, they share a fundamental difference: water is almost always local, whereas energy may be global and remains clearly linked to fungible commodities (Mielke et al., 2010).

Scale is an interesting perspective to consider in WEN as Scott et al. (2011) reported in a case study where local challenges lose importance when considered from broader perspectives. Conversely, regionally important challenges are not prioritized locally. Hence, there is a mismatch in translating challenges appearing at certain scales to institutions created for other scales. Moreover, energy suits the regionalization of adaptation to global change while water does not, as many of the impacts on water availability and quality remain local. Improved coordination between water and energy policy is needed and therefore WEN should be viewed in the light of institutions and decision-making approaches, and not just as a resource management issue (Scott et al., 2011).

In terms of planning, water utilities stress that regions should focus on increasing investment in water-efficient electricity generation, for example solar photovoltaic, wind power and coal gasification systems (Rio Carrillo and Frei, 2009). The linkages between efficiency improvements in water and energy use and the potential multiple benefits to be derived from them have been widely studied in California (Wilkinson, 2000). Water conservation measures are generally advocated as a means to reduce overall electricity consumption with varying impacts depending on the region (Bartos and Chester, 2014). Efficient water and energy use, and the facilitation of cost-effective measures to improve the efficiency of both, are important policy challenges and opportunities. Considering multiple benefits from integrated strategies provides potential opportunities for policy development (Wilkinson, 2000).

However, WEN research in the aforementioned arena does not fully consider impacts on the demand side. Rather it limits its role to the managerial problems of the water and energy supply. In order to have a holistic notion of WEN, the following section looks at the connectedness from the demand angle and its policy implications.

2.5. Demand side

WEN research has focused on the connectedness of both resources from the supply side. In contrast, demand has rarely been managed or controlled until recently even though it exerts a significant influence on the use of resources. Demand has been treated as a given when the the demand side of WEN could potentially bring additional insights into understanding the interconnectedness between the two vectors (Voinov and Cardwell, 2009). It is only very recently that one study proved that applying the ISO 50001 Energy Management System to water produced positive results on the demand side of water use management, like it would for energy use (Walsh et al., 2015).

The statistics of resource consumption demonstrates that domestic water and energy consumption varies largely between countries. For example, Australia uses 341m^3/cap/year in domestic water consumption and ranks as the world highest consumer followed by Canada with 279 m^3/cap/year and the United States with 217 m^3/cap/year. In comparison, the Chinese only consume 26 m^3/cap/year and the Germans 66 m^3/cap/year (Voinov and Cardwell, 2009). However, in addition to domestic water consumption, a significant amount of water used is not accounted for which corresponds to non-consumptive water use for thermal electric power for domestic use. For example, in 2010, the United States needed to extract 72 L of water for each kWh of electricity consumed.[3] It is also interesting to note that this indicator does not correlate with economic development as European countries would always tend to have lower levels of consumption than, for example, North America (Chapagain and Hoekstra, 2004). The same trends apply to the consumption of energy and other goods. Regardless, demand growth has a positive feedback that inflates itself as additional goods and services provided to meet new demands require additional infrastructure and maintenance (Voinov and Cardwell, 2009).

Today, much of the focus on demand management has been in the form of energy-saving regulations or voluntary and domestic efficiency programs. Increased efficiency is critical to attain the sustainable use of both resources as improved water efficiency reduces power demand and improved energy efficiency reduces water demand. Furthermore, in theory both will reduce the costs of water and power for consumers (Stillwell et al., 2011).

With time, it is foreseen that the focus will shift from the technical and engineering arena to the socio-psychological domain. Actually, the real limitation of the demand side of water and energy issue is that producing and selling energy and water is still viewed in many countries as means to generate profits, either benefiting the private sector or generating tax revenues (Voinov and Cardwell, 2009). This could imply the existence of a marginal population unable to access water and/or energy because it cannot be afforded (March and Sauri, 2017).

3. Challenges and Opportunities

3.1. Data collection

One of the main challenges in studying WEN is due to data availability, accessibility, and quality since much of the data are missing, unconsolidated, and

3. USGS, Thermoelectric Power Water Use <Water.usgs.gov/watuse/wupt.html> (Accessed on 5 October 2016)

imprecise. Some of the early studies on WEN were conducted in the United States by the Department of Energy (DOE), Electric Power Research Institute (EPRI), California Energy Commission (CEC) and the Pacific Institute. A great deal of the data that was produced from their reports has served as the basis for other research on WEN. Other data sources are national statistics offices or utility companies. When research is targeted at a lower scale, such as community, facility or infrastructure, bottom-up approaches have been developed for data collection (Perrone et al., 2011; Bartos and Chester, 2014).

Additionally, data collection in the water and energy sectors could be further strengthened to improve interactiveness, usability, and quality for stakeholders. Data sharing is an operating principle for any data access regime from which common goals and needs can be identified. Good data sharing would provide a firm basis for integrated planning. Priority must be given to data availability, usability, and quality in order to foster effective communication between administrators and policy makers in both sectors (Goldstein et al., 2008). When such data are not publicly available, research on WEN would be a good starting point to foster the discussion for the need of such data.

3.2. Existing policies and regulatory frameworks

The current policies and regulatory frameworks in the water and energy sectors are fragmented because there is a lack of integration between key agencies and sectors in the planning phase in the water and energy institutions. Thus, inconsistencies in the legislation on water and energy management abound, as they do in the legislation for each resource separately. In the United States, for example, water efficient technology and energy efficient technologies were promoted separately, and subsidies were actually driving the implementation of inefficient energy and water technologies (Cohen et al., 2004). Additionally, differing political agendas, visibility concerns, and power rivalries across ministries or agencies put too much effort into unproductive tasks and resulted in inefficient resource uses (King et al., 2008). Ongoing review and evaluation mechanisms should be implemented to identify these and other problems (Scott et al., 2011).

However, as cultural inertia and path-dependency makes water and energy ever more distant, it makes integrating water and energy management crucial to consider WEN. The two sectors have always operated independently and there is a (natural) resistance to their integration. A 'silo mentality' in the research community prevents greater integration of research, which then flows through to policymaking. The attitude that engineering and technical solutions are optimal remains dominant at the expense of more holistic solutions. (Hussey and Pittock, 2012).

Bazilian et al. (2011) proposed three approaches to support integrated policies and programs that would properly reflect on WEN. The first is to frame the issue around strong political 'motivators' such as lack of access, rather than purely in terms of environmental impacts. The second is to build institutional capacity to understand and act on the complex interactions; and third, to develop and apply modelling tools that can support integrated decision making.

Zhang and Vesselinov (2016) proposed a bi-level approach as a solution to achieve optimal WEN management whereby upper-level decision demands are satisfied first in a top-down decision making process. Their model quantifies the tradeoffs between the two-level decision makers in WEN management.

3.3. Complexity of nexus

WEN is often expanded to include themes such as food, land, and climate change, namely carbon emissions (Rico-Amoros et al., 2009; Bazilian et al., 2011; Yang and Goodrich, 2014; Biggs et al., 2015; Wong and Pecora, 2015; Cairns and Krzywoszynska, 2016; Gallagher et al., 2016; Wanjiru et al., 2016; Vanham, 2016; Wichelns, 2017). As the nexus incorporates more themes, it becomes more difficult to disentangle interconnections. This translates into more difficulties in managing nexus at the policy-making level as the greater involvement of different sectors would slow down the process, causing delays and adding inertia (Wichelns, 2017). Nevertheless, research on these complex relations is important as misunderstanding the interrelation between the two resources could add a greater stress to either one of them or to both.

3.4. New technologies

Underlying the motive for new energy technology, a strong drive comes from ensuring security by extracting resources that before were technologically or economically unviable. When these technologies are considered in the WEN context, it becomes highly questionable whether they are worthy at all. For example, the risk of fracking is very high in terms of the impact it may have on water resources, although little evidence of this has been collected until today (Vidic et al., 2013). Biofuels would also be a water intensive energy alternative, especially when they are produced with irrigated farming (Hardy et al., 2012).

Notwithstanding the above, new technologies also provide innovative applications for WEN. For example, applying solar heating systems would significantly save energy for supplying domestic hot water (King et al., 2008). Photovoltaic or wind power plants are built along with desalination plants in order to produce energy that could be either sold or consumed for part of the electricity needed for processing water (Siddiqi and Anadon, 2011). Some pilot studies have been conducted to combine wave energy with desalination plants (Viola et al., 2016). A number of Win-Win scenarios for attaining both energy and water security are proposed, taking advantage of technologies that are relatively new; for example, low-flow fixtures, energy-efficient appliances, rainwater collection for non-potable uses, solar hot water heating, geothermal heat pumps, electricity peak shaving as a demand response method, solar PV power, wind power, combined heat and power (CHP), hydropower, and con-

Table 8. Emerging water service infrastructure and energy sources

Objective	Technology
Water efficiency	Low flow showerheads, dual flush toilets, tap flow regulators, and efficient washing machines and dishwashers
Source substitution*	Rainwater harvesting, stormwater harvesting, greywater recycling, wastewater recycling and groundwater/aquifer (integrated use of all possible options in this table)
Emerging sanitation systems	Alternative sewerage systems – Reduced inflow gravity sewers (RIGS), Septic tank effluent disposal systems (STED), Innoflow interceptor tank – Orenco sewer – AdvanTex treatment pod system, Pressurized sewer systems, Vacuum sewers, waterless technologies
Pumps	Rain tank pumps, submersible septic tank effluent pumps, macerator pumps with pressure sewers and house pumps
Alternative energy sources	Wind farm and solar farm in catchment land reservations with low visual impacts, using access reservations for solar generation, biogas production from sewage treatment and placing small-scale hydroelectric turbines

* Source substation is the application of the "fit for purpose" or "water quality cascade" principle, which seeks to match the quality of the water supplied to where it will be used.

Source: Adapted from Retamal et al. (2008).

verting municipal waste to energy (King et al., 2008). Rainwater harvesting in hilly areas would not only provide water to residents but also offers solutions for energy conservation (Chiu et al., 2009). A list of emerging water service infrastructures and energy sources is provided in the table 8.

4. Research Gaps

4.1. Urban landscape and cities

The importance of studying the interdependence between water and energy is widely recognized in the context of ensuring security for the two resources in both developed and developing countries (Nair et al., 2014; Retamal et al., 2008; Cohen et al., 2004). It is estimated that some 75% of the world population could face water scarcity in the future as demand for good quality water in urban areas will increase substantially (UNESCO, 2012). However, our understanding on the 'complex and pervasive' connection between water and energy in cities remains very limited and rudimentary (Kenway et al., 2011).

According to Kenway et al. (2011), urban metabolism provides the conceptual framework to understand urban systems considering the mass balances of all materials, water, and energy. However, more research on urban systems is necessary to enable a valid comparison of populations and their metabolic performance. Some research areas that need further studies concern building a systematic description of the multiple points of connection within cities or within urban landscapes more generally. There is an insufficient understanding of WEN in cities and broadly in urban landscapes, thus few studies have studied the nexus at this scale (Fang and Chen, 2017; Lam et al., 2017). Furthermore, research on the optimization of water and energy systems is almost non-existent even though there are fervent calls for optimization and collaboration in the water and energy sectors.

4.2. Scale of the research

Kenway (2011) observed that in terms of spatial scale, a range of studies have been conducted for appliances, households, buildings, facilities, catchments, cities, states, and nations geographically concentrated in the United States (Stillwell et al., 2011), Australia, New Zealand, and Canada, while some studies can be also found for countries of Europe (Murgui Mezquita et al., 2009) and Asia (McDonnell, 2013; Gu et al., 2014; Keskinen et al., 2016) with a strong drive from China (Gu et al., 2014; Smith et al., 2016; Zou and Liu, 2016; Smith et al., 2017).

No specific study at the global level was found on the interconnectedness of water and energy. In terms of temporal scales, no studies have been performed probably because of the difficulties involved in collecting data over time. Only a few studies have addressed the urban energy implications of the combination of on-site decentralized and centralized water systems operating simultaneously (Retamal et al., 2008). Urban metabolism has been widely studied in the past forty years using models that address the flows between economy and environment, but the relationships between the elements at vertical and horizontal scales require further exploration (Holmes and Pincetl, 2012).

Although studying WEN at the municipal or community level is important for sustainable resource management, studies in this regard are rarely conducted compared to analyses of WEN at national or state levels, again probably due to data availability issues (Perrone et al., 2011). WEN research at lower scales is more apt to draw attention to the possible local collaboration in two sectors and for the better implementation of policies with a reflection on local geographical conditions, notwithstanding the fact that some local jurisdictions are impeded by national policies due to scale mismatches. According to this perspective, especially the collaboration between the two sectors at the municipal level can provide lessons which could give rise a bottom-up approach to influence national policies.

4.3. Demand-end WEN

As WEN relies on national statistical data, its approach is mainly from the supply side, which focuses on withdrawal or exploitation, treatment, supply and delivery, and water recollection and disposal. Thus, the approach remains partial as it neglects or fails to analyze WEN at the demand end. Much of this information and data are difficult to incorporate in the analysis when the supply side approach is taken. Moreover, considering that both water and energy are resources with significant efficiency and management dimensions, the study of WEN from the demand end deserves more attention from academics in the field.

WEN studies focusing on the demand end use data collected from the household (Wanjiru et al., 2016; Vieira and Ghisi, 2016), commercial or industrial sectors (Thiede et al., 2016), including tourism (Becken and McLennan, 2017) and municipal sectors, and are highly likely to be conducted using a bottom-up data collection process. This may allow effectively addressing social issues; for example, the relations between energy (fuel) poverty and water poverty, and might be able to find technological means for reducing poverty in water and energy (Vieira and Ghisi, 2016). But to achieve this goal, we need further research on interactive demand management and the water-energy nexus relationship.

4.4. Critical analysis on WEN

Most WEN studies have concentrated on unravelling the interrelatedness by quantifying water for energy and energy for water. These studies conceptualize nexus bounded to quantified numbers, where emphasis is placed on trade-offs and improved efficiency at its best summarized as 'saving water saves energy' (Copeland, 2017: 2). This type of research often conceives nexus as a managerial tool (Cairns and Krzywoszynska, 2016). Under its dominant theoretical framework, WEN transmits a rather limited and reduced picture of the WEN reality. Whereas WEN is often explained in a static and two-dimensional fashion, the political ecology framework allows for an in-depth analysis of the dynamic and multiple social and political aspects at interplay in the nexus. As Williams et al. (2016) stated, politicizing the nexus would enrich our understanding of the nexus. These authors focus particularly on the capacity of political ecology to capture the essence of human-nature relationships. Such an approach, which mobilizes an emergent, critical and theoretically informed understanding of the water-energy nexus, is developed through a historical process of *coproduction as* 'fundamentally processual and socio-technically heterogeneous' (Williams et al., 2016: 4).

5. Conclusion

This review has attempted to cover areas that are already well researched in the WEN literature and other areas for which knowledge gaps still need to be filled. WEN research is capturing the increasing attention of a number of government and international organizations. Scholars in the field are hopeful that with the right data and with multi-stakeholder engagement, it will be possible to achieve the goal of making water and energy systems more resilient by applying conservation measures and innovations in policy, market, and technology (King, 2013).

It must be remembered that 'no panacea exists' for solving WEN issues. But answers to WEN issues for energy in terms of the water perspective would depend on the local context (World Economic Forum, 2009). Moreover, in order to address increasing interdependence, greater attention is being paid to integrated resource planning, location of water and energy facilities, and systems thinking at multiple scales (e.g., facility, city, and region) (McMahon and Price, 2011: 184)

The study of WEN has to deal with imperfect data availability. Thus, much effort by researchers is still needed to evaluate the actual water and energy consumption of countries, urban areas, decentralized facilities or systems, and non-traditional technologies that are starting to gain popularity. Research across time scales, such as comparisons of current and past WEN, remains an understudied area. Moreover, research is needed to analyze WEN in closely unravelling the tradeoffs between the two resources given various types of policies, institutions, capital, technology, and cultural and religious conditions.

A broader framework provided by political ecology is proposed to help position WEN in the social context and the relationships between two resources that are constantly evolving in a dialectical process. Such a framework would be able to provide a normative understanding that is not limited to the physical relations of nexus, unlike most studies which grant more importance to quantified versions of the nexus, especially in relation to the efficiency of resource use. In other words, it will allow expanding the scope of WEN to reveal a variegated reality of the nexus, which is physical but also social, economic, and political and which therefore requires a holistic understanding with an equal imperative as when water and energy are treated separately.

6. Future Research

Other than exploring WEN for specific sectors (tourism, for instance) and localities, a major topic for future research is to focus on the demand end of WEN, not only to complete both the supply and demand sides of the story, but also to insist on the importance of rebuilding the connection of humans, society, and basic rights to the resource as Linton (2014) would emphasize. This means that a rather ambitious research approach is necessary; one which would cover institutional, social, technological, cultural, economic, and political dimensions that form the context of our understanding of resources from the analysis of the water cycle from the supply (from extraction to end-use) to the demand end (from the perspective of users and households). Unfortunately, 'modern' concepts have often perverted social values and made us believe that we are able to appropriate and manipulate resources without a holistic understanding of the social consequences. Rather naïve and optimistic expectations have brought ecological modernization theorists like Mole, Sonnenfeld and Spaargaren to claim that environmental challenges can be solved through continued industrial development, since the increase in efficiency from the development would eventually exceed the increase in overall production (cited in York and Rosa, 2003). Hence, we dispute their claim by studying the unequal power of the population that, from the demand end, worries about not being able to consume enough water and energy. A case study may reveal WEN experienced by them regarding the problem of limited accessibility, affordability and efficiency and its relation to power struggles. It may also enlighten us with some findings on how these resources are managed in the urban socio-environmental context and how benefits and costs are socially and spatially distributed.

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1.5 Overall context

This section describes the context of the research addressing the two case studies under the framework of WEN. The political ecology approach is applied to address the WEN, which includes analyses of the ecological, social, and political processes that influence the human-nature relationship, in this case regarding water and energy.

Urban areas are at the center of the social metabolism with flows of energy and materials based on social and political relations, which are often contested through tensions, contradictions and conflicts (Swyngedouw, 2006). Political ecologists consider cities an important intellectual terrain to explore how socionatural relations are formulated (Heynen, 2014). The thesis follows the line of thought of urban political ecology by taking an integrated and relational approach to decipher the interlinked economic, political, social, and ecological processes which results in creating highly uneven urban landscapes (Heynen, 2014). Moreover, the analytical framework seeks synergies from borrowing concepts such as the co-production of science (Jasanoff, 2005) to understand how science and political ecology interface, and adding critical thought towards understanding the reconstruction of science and the power of knowledge (Forsyth, 2003).

1.5.1 WEN supply side: weaving in energy to the hydro-social cycle

Exploring the WEN in view of the urban hydro-social cycle provides a unique opportunity to consider the role of energy for water supply systems and the socionatural relationships involved in the water provision. The urban water cycle has undergone various transitions in terms of governance in the history of modernization where both government and market failures have been addressed by numerous scholars. The crisis around water scarcity was often addressed through large scale infrastructures, which are innately planned and designed at national scale, by applying managerial and engineering approaches (McEvoy, 2014; Swyngedouw, 2015). During this process of conceiving large projects, major limitations were unveiled around the issue of reproduction of existing power relationships. Instead of widening the access to water for all, a stark contrast was created between winners and losers, as some populations were left without access to water (Mehta, 2007). More recently, urban water systems demonstrate a shift from creating new water sources (e.g. desalinated water, a reservoir, a new groundwater captures) to managing water by means of various tools, alternative sources, tariff structures and education (Bakker, 2010). Yet, in many parts of the world new infrastructures requiring high capital investments are being introduced, for which the proponents and investors use the logic of economic growth and the subsequent water consumption increase to justify their actions.

Starting in 2004, Spain began to plan and build numerous desalination plants with a total capacity of 1,063 hm^3 along the western Mediterranean coast, as part of the *programa AGUA* (AGUA program) approved under the mandate of Zapatero’s socialist government. The country officially tapped seawater, which was considered an infinite water source. These plants are considered as part of the techno-managerial fixes and are criticized as another form of capital accumulation (Swyngedouw & Williams, 2016). Moreover, as many of these plants remained idle and failed to meet the promised water price, water planning based on desalination plants has been criticized, among other aspects, for not sufficiently exploring an integration of more sustainable water alternatives such as gray water, reclaimed water, and rainwater harvesting (March, Saurí, & Rico-Amorós, 2014).

Along these lines, Benidorm, usually regarded as the epitome of a mass tourism resort, was selected as a case study in order to explore an example of a city for ‘sun and sand’ tourism but highly exposed to water stresses. Previous studies on Benidorm’s water management have highlighted its efficiency, which to a greater extent, is a result of its model of urban expansion based on vertical growth. In addition, previous experiences of water shortages have transformed Benidorm into a water efficient city, as the importance of water for tourism has been instilled in the local population. The thesis explores the WEN concept for the city, by which I intend to reveal a complex and intrinsic link behind the water supply and use and the energy needed to fuel it.

Moreover, Benidorm is used as a case study because it provides an insightful example of new WEN examples, manifested in the Muchamiel desalination plant. The plant, conceived as part of the AGUA program, had finally started operating in June 2015 after the severe drought faced by this area. Desalinated water has been a useful tool for introducing and reinforcing market mechanisms in water management (Williams, 2018). The Muchamiel desalination plant is run under the service contract for operation and maintenance by a private company selected by a tender managed by ACUAMED. Furthermore, the plant also creates new flows of materials. For example, it requires changing 24 filter cartridge for each hm^3 of water produced. Furthermore, energy consumption of the plant is estimated annually around 27,900,000 kWh. This amount is much higher compared to the estimation of energy consumption foreseen for the interbasin water transfer from the Tagus river of 1,904,482 kWh. In this case, the desalination plant as a state-imposed infrastructure interferes with the municipal and supra-municipal water system, thereby adding fragmentation and inefficiency to the existing water jurisdiction.

1.5.2 WEN in the demand side: Looking into the micro scale

Following the WEN analysis and looking into the challenges of supply in the hydro-social cycle, the focus of the research is on the demand-side. This thesis aims to add a microscale perspective for addressing the WEN in tourism or domestic use. Compared to the supply side, the WEN studies have shown little interest in the demand-end. However, there is an acute need for strengthening investigation in this area due to the inequalities and disparities found at the demand side, and the potential of alternative management methods (e.g. education, campaigns, rainwater harvesting, pumps) that need to be put into practice at this scale (Voinov & Cardwell, 2009).

The modern standards of hygiene, comfort and cleanliness have substantially increased resource consumption, especially that of water. Amongst those uses, the WEN is evident, particularly in activities dealing with water heating, steam generation for space heating, dishwashing, laundering, and cooking. The necessity for water and energy in these activities is affected by cultural, economic and developmental aspects where the consideration for comfort and hygiene plays a central role along with dominant socio-technical regime (Plappally & Lienhard V, 2012; Shove, 2003). Along with the understanding of water and energy consumption, a significant role in co-shaping the WEN in demand is shaped by essential aspects like technology choices, the given structure of the urban environment and user habits (Gabarda-Mallorquí, Fraguell, & Ribas, 2018; Han & Hyun, 2018; Kneebone, Fielding, & Smith, 2018; Sánchez-Guevara Sánchez, Mavrogianni, & Neila González, 2017).

Demand-end analyses in this thesis include the cases of Benidorm and Barcelona, addressing the hotel and recreation sector as well as the domestic sector, respectively.

First, the hotel and recreation sectors of Benidorm represent a major energy and water consumers in the municipality. Hotels and recreational sites are the mainstay of the mass tourism industry. They provide comfort and entertainment to meet the needs of tourists. They also represent the ‘winner’ actor, who has priority in the water access, since the Water Consortium Marina Baja and local irrigation communities came to an agreement to prioritize urban water use to support Benidorm.

Secondly, the case of Barcelona focuses on the WEN at the household level. The Barcelona case addresses the local population suffering water and energy poverty (or vulnerability) as a representative example of the ‘weaker actors’. The research follows the advocacy of APE, a local social movement that has groundbreakingly initiated the discourse on water and energy poverty together in an open platform by mobilizing biweekly counseling sessions. Analyzing the perspective of the 'weaker actors' reveals the complexities of water and energy governance, due to the different scales of governance and administrative power involved. It also addresses core aspects considered crucial in understanding energy poverty, such as the affordability perspective (Fankhauser & Tepic, 2007), the WEN impact on the vulnerability (Browne, Petrova, & Brockett, 2018) and the importance of securing both resources in the perspective of comfort, hygiene, and well-being (Chenoweth, López-Avilés, Morse, & Druckman, 2016; Shove, 2003).

APE develops a number of interesting practices through which the affected households organize themselves to address the political economy and political ecology of water and energy. Households become empowered as they discuss, build and execute strategies, whereby their lived experiences with both resources are also revealed. Furthermore, the rules applied in water and energy commercialization and other practical knowledge are transferred between the affected households and other actors. This leads to the co-production of knowledge (Jasanoff, 2005). Weaker actors therefore become stronger, able to imagine and to demand a different form of governance for themselves.

2 Research Methodology

As previously explained in the introduction, the research design is based on two case studies: Benidorm and Barcelona. Figure 1 shows the location of both cities and summarizes the research methodology applied. Each section in sections 3 and 4 follows the format of a journal article, providing further details of the methodology applied. However, in this section more general information about the methods is given in order to address some of the issues that could not have been dealt with in the individual papers.

Figure 1. A map indicating two case cities and a summary of methodologies (+: sequential mix, →:emergent mix)

The thesis consists of multiple case studies, chosen to investigate a contemporary phenomenon in a real world context, and that aim for an in-depth understanding on the field by asking 'how' and 'why' questions, which are considered essential for political ecology approach (Yin, 2014). I have attempted to benefit from the complementary advantages of a theory-building structure that involves a series of exploratory researches examining various facets of the WEN (Yin, 2014). Each case study was selected to apply mixed research methods, considered better for understanding the context of the issue in the given scale and boundary. The complexity of the problem also contributed in selectin mixed methods as these tend to be more efficient and expeditious compared to single methods (Morse & Niehaus, 2009). In most cases, sequential mixed methods were applied to supplement core methods except for one case where an emergent mixes method was included to address the unexpectedly low response rate. For various mixed methods, the point of interface was in the narrative of the results. However, the insights gained during the field visits and interviews must have influenced the thesis unconsciously.

For Benidorm, I applied multiple research methods in order to address two distinct scales. Each scale was analyzed with a mixed methodology. The first part of the research focused on supply side to quantify *energy for water* in the water cycle of Benidorm based on data collected from various water related institutions(Annex III-1-a). Amongst those, most information was collected from the Consorcio de Aguas de la Marina Baja (English: Water Consortium of Marina Baja) who is in charge of securing water for nine municipalities including Benidorm. Then quantitative information was supported with qualitative data collected in the meetings with the stakeholders, especially water managers. The second part of the research focused on WEN at the microscale of hotels and recreational activities. Based on a survey (Annex III-1-b), quantitative data were collected from the hotels and analysed with non-parametric statistics due to the low number of hotels that responded. Results obtained were compared with consumption data from previous studies (Warren & Becken, 2017). Moreover the interviews were included in the research analysis as part of an emergent mixed methodology component.

Four fieldtrips were conducted to discover the local environment and context of Benidorm (Table 2, Annex II-1). The crucial component of the case study was in the introduction to the local environment by Prof. Antonio Rico of the University of Alicante, who guided me through understanding the waterscape of Benidorm. Based on years of experience in investigating water issues in the region, he provided me useful information, contacts, and relevant specific publications. Particularly, the local contacts enriched contextual information with many anecdotes nonetheless relevant for my work.

Table 1. Summary of field work and research conducted

No.	Period	Entities contacted
1	1 – 6 June 2015	- Desalination plant - Interbasin water transfer (Acuamed) - Local water company (Hidraqua) - Tertiary waste treatment plant - Wastewater treatment plant - Former worker of Water Consortium of Marina Baja - Water Consortium of Marina Baja - Visit reservoir, pump stations, aquifer (fountain)
2	2 – 7 Nov 2015	- HOSBEC - Water Consortium of Marina Baja (follow-up meeting) - Four hotels and one waterpark visited
3	27 Jun – 2 Jul 2016	- Three hotels
4	9 – 13 April 2018	- Four hotels

The case of Barcelona belongs to a different scale and context. I was introduced to APE in February 2015 and for about the period of two years I was able to follow their work and be part of the movement working to eradicate water and energy poverty. The intrinsic sensitiveness of the topic was perceived as a big challenge for a foreigner with limited knowledge of the local language. This added to the challenges in data collection. The energy data, especially, were difficult to obtain as private companies do not facilitate this data to the public.

The selected methodology, which started with a mixed approach with an objective of having quantitative data analysis as the core component, had to be changed. The research took qualitative data analysis at the main strategy together with participant observation stemming from ethnographic research approaches (Annex II-2), which in fact, are also considered a mixed method (Morse & Niehaus, 2009). The survey conducted with participants in APE meetings supplemented quantitative data (Annex III-2). Lastly, linking Water and Energy Vulnerability took into account quantitative analysis based on affordability measures. Over the household income, 10% income threshold for energy bills and 3% income threshold for water bills were applied for AMB based on the Spanish survey on Living Conditions[5]. This was supported by 33 interviews. Sequentially the whole methodological process developed into an action research approach, which allowed me to learn from everyday experiences through APE (Cahill, 2007; Kindon, Pain, & Kesby, 2007).

In addition, I admit I have felt in some moments more involved and included in APE but also outsided and marginalized from time to time due to cultural barriers. That explains why I have spent a long time doing fieldwork with APE, as I felt that I was not understanding the issue enough and felt a need to be more implicated. Participating in various actions also had to be controlled, to certain extent, as I preferred not to be identified by the police to avoid any drawbacks as a foreign researcher relying on a residence visa. However, the first-hand experience in the struggle against the hardship of energy and water poverty households made it clearer to me that a limit needed to be found to the perverse logic of neo-liberal or private market system that impedes flexible and inclusive social policies towards utility use.

[5] The analysis was conducted with the help of IERMB (Barcelona Institute of Regional and Metropolitan Studies)

3 The WEN in Mass Tourism – The Case of Benidorm

3.1 Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain[6]

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Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain

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Abstract: The energy intensity of water—'energy (electricity)-for-water'—is calculated for Benidorm, a mass tourism resort in the Spanish Mediterranean coast, where the urban water cycle has evolved in response to a series of episodes of water stress. The analysis is based on primary data compiled from various actors involved in the urban water cycle encompassing water extraction, end uses, and wastewater treatment, including tertiary treatment. The results provide one of the first analyses of the relations between energy and water in a mass tourist center, which may be of potential interest for other tourist areas. It is estimated that a total of 109 GWh/year of electricity is required to operate the water cycle of Benidorm. About 4% of total energy use in Benidorm is dedicated to extracting, transporting, and treating water. The most energy-intensive stage is represented by end uses, which accounts for 20% of the total energy use in Benidorm when the energy required for water pumping and hot water use is considered. Additionally, energy intensity for water extraction was estimated for normal, wet, and two dry year scenarios. In comparison with the normal scenario, energy intensity is six times larger when desalinated water is incorporated during a dry year, whereas the emergency interbasin water transfer resulted in a more moderate increase in energy intensity. While treated wastewater and emergency water transfers appear to be a more convenient solution in energy terms, the strong impulse given to desalination in Spain is forcing local water authorities towards the use of a resource that is much more energy intensive, although, on the other hand, much less dependent on the vagaries of climate. In light of recent technological and managerial developments, the Benidorm case illuminates the challenges appearing in the analysis of the water-energy nexus, especially the fact that scarcity may be transferred from water to energy.

Keywords: water-energy nexus; energy intensity for water; energy (electricity)-for-water; desalination; Benidorm

1. Introduction

Water and energy are fundamental to human survival, well-being, and economic and non-economic activities. In water-energy nexus studies, the intrinsic links between the two resources are unraveled and summarized as energy-for-water or electricity-for-water (hereafter energy (electricity)-for-water)—energy requirements for water—and water-for-energy—water requirements for energy [1]. Even though these two resources have been treated separately for a long time, the significance of the nexus between the two is gaining attention due to its impact on resource management. Nexus studies have been largely motivated by deprivation affecting the development of one or the other resource, for example, water scarcity restricting electricity production because

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of the lack of cooling water for thermal power plants [2]. On the other hand, the conservation nexus [3] has focused on synergies for reducing energy use for water provision, or vice versa, as an opportunity to achieve sustainable resource use with the aim of reducing operation costs and carbon dioxide emissions [4]. Previous studies have also targeted the trade-offs between water and energy, whereby solving problems from one resource may cause problems for the other. This article offers primary data on the urban water cycle at the municipal level, which are highly inaccessible in Spain since water and energy supply tend to be managed by private companies in Spain. The energy-for-water is calculated for the mass tourism resort of Benidorm, where water stress is a recurrent problem due to high tourism activity and the semi-arid climate of the region. The study includes the new water supply source contributed by the Muchamiel desalination plant and demonstrates changes in energy intensity for water extraction. In the light of recent technological and managerial developments, the Benidorm case illuminates the challenges of transferring scarcity from water to energy.

Urbanization is a significant factor in the water-energy nexus, as water and energy consumption are highly concentrated in urbanized spaces. Globally, urban areas occupy around 2% of the land but account for 70% of energy consumption [5]. Urban water demand increases as cities grow in population. This fact challenges decision-makers and institutions to secure a sufficient quantity and quality of energy and water, as many cities are located in water-stressed areas [6]. However, urban areas may benefit from dense geographical patterns, as these patterns maintain efficiency by lowering the intensity of resource use (i.e., consumption per capita) [7]. For this reason, urban water management focuses not only on improving the existing water supply but also on ensuring adaptive measures to climate change through integrated planning that considers energy intensities of their water systems [6].

It is estimated that energy-for-water accounts for 8% of global energy demand [8]. Energy is needed throughout the water cycle for pumping, transport, purification, urban supply, and wastewater treatment. It is also needed for the mobilization of alternative water resources, such as rainwater or greywater [9]. Thus, energy-for-water calculations vary significantly depending on how the system boundary is defined [10,11]. Previous studies have analyzed the urban water-energy nexus from various scales and directions [11–14] or as single case studies [2,15,16]. Some studies have aimed at understanding the whole water cycle [16,17], whereas others have focused on specific stages of this cycle [11]. Previous studies have found the estimation of end use energy (electricity)-for-water difficult, as it depends mainly on the behavior of end users. However, this estimation is gaining importance as significant uses of energy are detected in this stage [10,12,17].

In tourism studies, water and energy are increasingly being recognized as crucial resources that require efficient management [18–23]. Water management often faces challenges in popular destinations because availability does not always match demand. For this reason, the importance of water management at the regional and local scales is emphasized along with the importance for water to become a top priority in political agendas [19]. Furthermore, the hotel sector has been proven a relevant target to encourage water conservation through demand management [23]. Along with water, better energy management is increasingly being sought after to reduce carbon dioxide emissions in the tourism industry as well [20,24–26]. Thus, exploring the case of energy (electricity)-for-water in the area with strong tourism activities would also serve to re-evaluate urban water cycles with high energy intensities as a potential target area to lower carbon dioxide emissions.

Benidorm, one of the largest tourist resorts of the Mediterranean coast, provides an interesting example of water management in an area specialized in mass tourism. The importance of water has been recognized as a key factor for the expansion of tourism in Benidorm, as water shortages due to periodic droughts have jeopardized tourism activities in the past [27]. However, its urban water cycle has rarely been examined in relation to energy intensity. Given their importance in economic, social, and environmental terms, an accurate assessment of water and energy interrelationships appears critical to ensure a more efficient use of both resources in mass tourist centers [28].

For many water challenged areas where conventional water resources are scarce or unreliable, desalination is increasingly being adopted as a water supply option. In this regard, Spain is following countries, such as China and the U.S., in expanding desalination to meet water needs. This expansion has called for caution due to the high energy costs required to make seawater drinkable. However, the implicit vision of 'abundance' from a non-depletable water source (the ocean) is accelerating the expansion of desalination [29]. In Spain, the conflicts among regions created by interbasin water transfers, such as that of the Ebro River to the eastern and southeastern areas, has enabled desalination to appear as the main water alternative for the coastal Mediterranean regions. As a result, desalination effectively evaded conflicts over water supply and emerged as a technological fix that allegedly solved water constraints for economic growth, urban expansion, and climatic and hydrologic challenges [30]. Large investments were made, but desalination plants in many cases remained idle as they were built with a strong subordination to failed growth-based planning and little consideration towards other alternative options [31].

This study assesses energy (electricity)-for-water (also called energy intensity and energy embeddedness) in the urban water cycle of Benidorm based on collected primary data. The data reveal the costs involved in order to improve the water cycle towards a more sustainable path. The analysis includes domestic hot water [32–34] and water boosters for high-rise buildings [35,36] in the end-use phase. In order to reflect the complex water supply system that alters water sources depending on their availability, four extraction scenarios are designed based on precipitation. The results emphasize the importance in water-energy nexus thinking of how water scarcity and uncertainty are dealt with by transferring the problem from water to energy, mainly through the introduction of desalination plants.

The paper is organized as follows. In the next section, Benidorm as a city of successful mass tourism is introduced. Then, the methodology is explained. Section 4 presents the urban water cycle, the various stakeholders involved, and the influence of energy in the water cycle. Then, the results of energy (electricity)-for-water are presented for each stage of the urban water cycle. The paper ends with a section summarizing different energy intensities for different climate scenarios followed by a conclusion.

2. Benidorm: The Epitome of Mass Tourism

Benidorm is a mass tourist enclave in the province of Alicante, based on the model of "sun and sand", and a successful example of an international vacation site surviving economic crisis and forecasted inevitable declines [37,38]. Today, Benidorm is the third most visited tourist destination in Spain after Barcelona and Madrid, attracting annually around 2 million visitors with 11 million overnight stays [39,40]. During the peak season, the city population is about four times the permanent population, which increases pressures on resources enormously.

Tourism activities make Benidorm a large consumer of water and energy. Every year, about 10 million cubic meters, or approximately half of the total water supplied in the Marina Baja area, is consumed in Benidorm. 64% of water use in Benidorm is dedicated to tourist, recreational, and commercial activities, while around 30% is for permanent residents (around 30% of the permanent residents in Benidorm are foreigners) (Figure A1, Table A1). Energy consumption also demonstrates similar use patterns per sector. 29% of this figure derives from the residential sector (134 GWh); 2% from the industrial sector (7.6 GWh), and 69% from the service sector, including hotels (311 GWh). The total energy consumption in 2015 for Benidorm was 453.6 GWh [41].

However, the success of Benidorm as a tourist destination faces important challenges as periodic droughts that last 2 or 3 years in extreme cases challenge the local water supply systems. Ensuring sufficient water and promoting efficiency has been the primary goal of water management in the city. For example, water losses in supply have been reduced to a minimum of 5% through a highly optimized distribution network [22]. Moreover, Benidorm has succeeded in cutting its water consumption per capita by 25% during a period in which the population doubled [42]. Today, the complex water supply system developed from accumulated managerial practices during the past forty years in principle allows Benidorm to have sufficient water for its needs (Figure 1).

Water saving campaigns are being promoted with a particular emphasis on the hotel sector through the implementation of water saving equipment in bathrooms. Some studies have found out that hotel vacationers typically use three times more water than an average household [20]. In Benidorm, the water consumption of hotels varies between 147 and 361 liters per bed occupied with a tendency towards higher consumptions in higher hotel categories [7,39]. Energy savings and green energy use are also promoted extensively mainly to reduce costs. During the last few years, electricity from energy companies specializing in renewable energy supply has been offered at better prices to hotels with a membership in the HOSBEC (Hoteliers Association in Benidorm, Costa Blanca, and Valencian Community, in Spanish Asociación Empresarial Hostelera de Benidorm, Costa Blanca y Comunidad Valenciana) association. However, CO_2 emission management has still not been implemented in most of the hotels.

Benidorm is unequivocally singular in its compact vertical expansion and density, with less than 5% of the housing stock built between 1996 and 2005 pertaining to single houses or condominiums. There are 77 buildings higher than 25 floors, of which 27 reach more than 100 m in height. This character has allowed the city to be efficient in its resource and space use [22,43]. On the other hand, however, vertical urban growth increases energy (electricity)-for-water. This needs to be supplied vertically, creating larger end-use energy intensities [44]. Studies on the energy requirements for pumping in an urban water supply demonstrate that the average energy consumption of residential buildings equals 45% of the pumping energy needed to deliver water from treatment plants to apartments in a building [39].

Figure 1. Map of water supply system in Benidorm and the Marina Baja Region (Source: Adopted from Marina Baja Water Consortium).

3. Materials and Methods

The water-energy nexus is approached from the energy intensity or energy embeddedness of water flows in the urban water cycle of Benidorm following the methodology developed by the California Energy Commission [2]. Quantitative data were collected through email requests followed up by three field trips in June 2015, November 2015, and June 2016. A total of nine meetings with key stakeholders—a water company, wastewater treatment plant managers, the Marina Baja Water Consortium (Consorcio de Aguas de la Marina Baja in Spanish, hereafter called the Consortium), tourist boards, and hotel groups—added important insights on water management in Benidorm. Based on the data collected, the energy intensity of water provision was calculated for water extraction, transportation, end-uses, treatment, and reuse. Since the urban water supply of Benidorm relies on electricity as the main energy source, most of the data collected are electricity data. The only exception affects end use where various types of energy are commonly used for hot water. Last, in order to consider climate variations and their influence in the water-energy nexus, different energy requirements for water supply were computed based on different water supply options. These calculations were provided by the Consortium based on data from the past 25 years of experience in water management by this organization. Data collection posed several challenges due to the lack of detailed information on water and energy at the municipal level, and therefore it was supplemented with a set of plausible hypotheses in order to reconstruct a model able to fit the system boundary. These hypotheses are explained in the results section along with other details of the calculations. The lack of data also challenges the robustness of the analysis performed in this study. Water data may imply errors of 6 to 11% depending on the water source. At any rate, we believe that our calculations may serve as a benchmark for other cases as this is one of the first studies conducted on energy (electricity)-for-water in a large mass tourist center. The year 2014 was selected as the base year except for end uses and energy intensities associated with emergency water transfers (Table A2).

Energy (electricity)-for-water is calculated by dividing the quantity of water by the energy required for each phase of the cycle (1). The unit used is kWh/m^3, where at stage i and at year t, $Ew_{i,t}$ stands for energy (electricity)-for-water, $E_{i,t}$ for energy required, and W_i for water produced or treated.

$$Ew_{i,t} = \frac{E_{i,t}}{W_{i,t}} \tag{1}$$

When there are several plants or processes involved within a stage (for example, water extraction, water treatment plant, and wastewater treatment plant), in order to take into account the total energy (electricity)-for-water, the following equation is applied, where SE_i refers to the sum of energy required within stage i and SW_i to the total amount of water produced or treated within a stage.

$$Ew = SE_i / SW_i \tag{2}$$

Among numerous factors, precipitation is one of the main parameters that affect the physical availability of surface water and groundwater. Thus, the energy intensity of water supplied to Benidorm is not fixed but dynamic depending on precipitation. To take this into account in this study, changing energy intensities in different climatic conditions are compared by hypothesizing four scenarios, namely dry (A), dry (B), normal, and wet years. To each water source, a coefficient (c) varying between 0 and 100% is applied with the purpose of comparing energy intensity for withdrawal by applying the equation below.

$$Ew_{extraction} = \sum_{j=0}^{n} c_j \cdot Ew_j \tag{3}$$

Table 1 illustrates the coefficient value for different options for extraction (*j*) according to four different scenarios.

Table 1. Coefficients on the supplied amount of water per source depending on scenario.

j = / Scenarios	Dry (A)	Dry (B)	Wet	Normal
1. Wells Algar/pumping Algar	9.6%	9.6%	28.0%	21.2%
2. Wells Beniardà	28.5%	28.5%	1.7%	15.1%
3. Interbasin transfer	48.4%	-	-	-
4. Amadorio reservoir	13.5%	13.5%	70.3%	63.7%
5. Desalination plant	-	48.4%	-	-

Considering that water withdrawn in the Marina Baja area is sent to seven municipalities, including Benidorm, the total energy use for water supply in Benidorm is estimated by applying the proportion of water supplied to Benidorm over the total water supplied in the Marina Baja in 2014 (Table A1). The proportion ranges from 51 to 59% with an average of 54% over the past 25 years. This option was considered more reasonable than simply applying proportions from population data as the number of residents does not include tourists.

The energy needed for the end use of water is best captured in Benidorm through the case of the domestic and hotel sectors as their hot water use and water pumping are the two main nexus points. Since hot water is not metered separately, Spanish national statistics for domestic hot water use were used as proxies. On the other hand, hot water use at hotels was calculated based on data collected from a four-star hotel. The data provided daily hot water and diesel consumption over a period of 5 years that supplemented solar water heating system. Energy intensity for water pumping is calculated by the following equation:

$$\mathrm{P} = \frac{\mathrm{q\rho gh}}{\eta_c}\left[kW\left(\text{or } \frac{kN\cdot m}{s}\right) = \frac{m^3}{s}\cdot\frac{kN}{m^3}\cdot m\right] \quad (4)$$

where P is the power for lifting water, h is water lift height, g is gravity, q is flow through the pipe, and ρ is the specific density of the water. Due to different pumps installed and varying loads, design parameters are defined to simplify the calculations to predict the energy requirement. For simplicity, the overall efficiency (ηc) 0.5625 [35] is selected based on the fact that the pump efficiency ranges between 50 and 80%, the mechanical transmission efficiency is about 90–100% accounting for the power transmission between the motor and pump, and the electricity motor efficiency is 70–90% [45]. The energy intensity for water pumping ($E_{w,pump}$) is calculated, where n is the pumping capacity (m^3/h) and the friction loss (α) within the pipe is assumed to be 30%, as follows [44]:

$$\mathrm{E}_{w,pump} = \frac{\mathrm{P}(1+\alpha)}{\mathrm{n}}\left[\frac{kWh}{m^3} = \frac{kW}{m^3/h}\right]. \quad (5)$$

Some authors warn about the limitations of this approach, as habits regarding energy and water use vary and, therefore, the nexus (energy intensity and water intensity) is difficult to generalize especially for end uses [17]. Despite criticisms, the generalized approach is useful as it helps to estimate the nexus when microdata generation and collection is difficult and costly. Finally, and due to limited data availability, the carbon emissions for energy (electricity)-for-water were not included in this study.

4. Results

4.1. Energy in the Urban Water Cycle of Benidorm

The urban water cycle of Benidorm has been developed in response to a series of droughts of different intensity and impact. The episode of 1978 is recorded as the worst water crisis in the history of the city. After sources of water supply dried out, Benidorm had to resort to shipped water from the port of Alicante by tanker in what locals named Operación Barco. Other drought episodes followed in subsequent years from 1981 to 1984, 1992 to 1996, 1999 to 2001, and most recently in 2015. However, none had the gravity and impact of that of 1978. Although it was created a few months before of the water crisis of 1978, the Water Consortium of the Marina Baja, formed by seven municipalities, the Provincial Council of Alicante, and the Júcar River Basin Authority, had the basic aim of avoiding the occurrence of water scarcity episodes in the Benidorm area. First, the water supply network connected surface water and groundwater (Algar-Guadalest-Amadorio) sources through the Torres, Mandem, and Algar pump stations. Later, during the prolonged drought of 1992–1995, the Rabasa-Fenollar-Amadorio pipeline, with a total length of 47,860 m and a maximum flow rate of 910 L/s, was connected to water from the Tajo-Segura interbasin aqueduct.

Beyond more conventional hydraulic solutions, one of the most distinctive features of the urban water cycle in Benidorm is the use of non-conventional flows based on the agreements between several agricultural communities and the water authorities of the region. In accordance with the agreement, the agricultural communities provide clean water to the city in exchange for treated wastewater of a quality high enough to be used in irrigation. This scheme has been valued positively, but it was considered a case difficult to interpret in traditional water market terms because the transactions were established without formal pricing [22]. Rather, according to the agreements, the right of Benidorm and other cities to exploit aquifers for clean water is granted in exchange for payments for pumping costs (electricity) of irrigation communities that range between €420,000 and €600,000 per year. Even though water is handed at no value, the water-energy nexus reveals that energy costs are also at the center of this water exchange scheme. The energy costs of these agreements also appear in the need to lower conductivity values in the wastewater for their use in irrigation. In 2006, a desalination unit was added to the wastewater treatment plant of Benidorm to lower conductivity values below 1300 μS/cm. Hence, energy was also at the center of non-conventional solutions for the urban water cycle of the city.

In 2015, the Muchamiel desalination plant (52 m above sea level (a.s.l.)) was added to the urban water cycle of Benidorm as part of the A.G.U.A. Program ("Actuaciones para la Gestión y Utilización del Agua") of the Spanish Ministry of Agriculture, Fisheries, Food, and Environment. The plant uses reverse osmosis technology to produce potable water from seawater. Muchamiel is located 35 km from Benidorm. Therefore, additional energy inputs are required for water transportation via pipeline to reach the city. To date, the water produced cannot be supplied to Benidorm because the pipeline connection remains incomplete. Instead, the plant supplies water to Alicante, which suffered a severe drought in 2015. The pipeline between Muchamiel and Benidorm remains disconnected because litigation on an unjust bidding process for the pipeline's construction has put the project on hold [46]. However, since it was built with the objective of providing water to Benidorm, the study takes this facility into account as an important prospective water source to be incorporated into the water cycle of the city.

The urban water cycle of Benidorm is depicted in Figure 2 based on the water moved at each stage along with the institutions in charge of each part of the cycle. The Marina Baja Water Consortium, a public, supra municipal company, is responsible for water supply to Benidorm and nearby municipalities. Water purification and urban water distribution in Benidorm are performed and managed by Hidraqua, a private company, who has formed a partnership with the municipality. Finally, a wastewater treatment plant is managed by the public entity EPSAR.

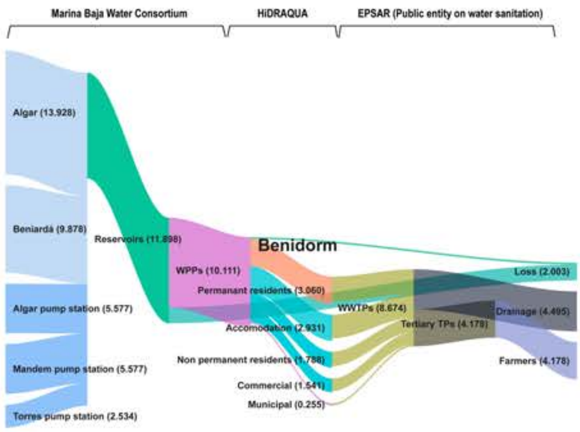

Figure 2. The urban water cycle of Benidorm in 2014: the system boundary of this study (unit: million m^3). WPPs: water purification plants; WWTPs: wastewater treatment plants; TPs: treatment plants.

In sum, a varied number of entities of different character and scale govern the water cycle in Benidorm. Furthermore, as desalination and the reuse of wastewater have been spotlighted as one of the key alternative technologies for water management in arid areas [21], both of them are present in the urban water cycle of Benidorm with important implications for energy use. In the following part, the energy (electricity)-for-water in each stage of the cycle is presented.

4.2. *Energy (Electricity)-for-Water: Quantitative Analysis*

Figure 3 illustrates the average energy intensity of the urban water cycle of Benidorm in 2014. The range of energy intensity is summarized in Appendix A Table A3. The total energy use for the urban water cycle of Benidorm is estimated to be on average 109 GWh/year. The figure represents a normal condition and does not include the energy intensity of emergency water systems that are activated only in cases of severe drought. Further analysis on the use of the emergency water system is presented in Section 4.3.

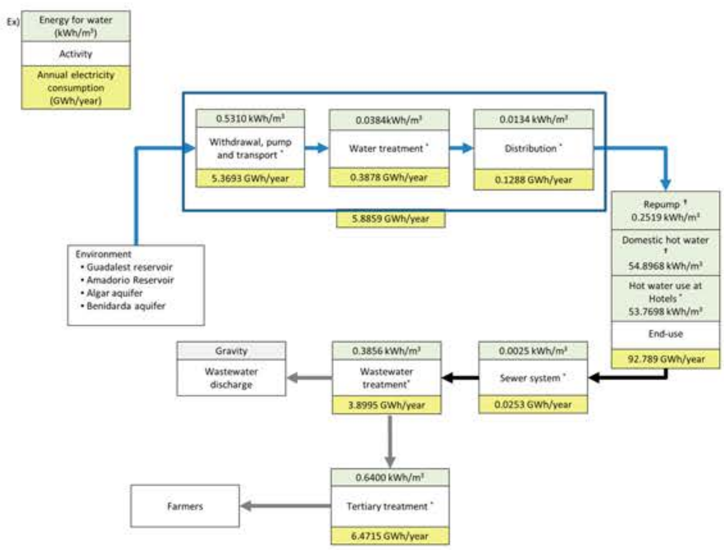

Figure 3. Energy(electricity)-for-water for Benidorm in 2014 (* mark values calculated based on primary data and † mark those calculated based on primary and secondary data).

4.2.1. Withdrawal, Transport, Treatment, and Distribution

Water withdrawal for Benidorm relies on surface water from the Amadorio (95 m a.s.l.) and Guadalest (350 m a.s.l.) reservoirs and groundwater from the Beniardà and Algar aquifers. Three large pump stations capture these water flows. The Algar pump station sends water to the Guadalest reservoir. The Mandem pump station, located at the conjunction of the Algar and Guadalest rivers, sends water to the Canal Bajo del Algar pipeline. The Torres pump station, pumping excess water from the Algar-Guadalest basin and the Torres River, is connected to the Amadorio reservoir and operates when it rains. For urban supply, water is transported through gravity without additional energy input. The topography of the reservoir and the conveyance system allow water to be efficiently delivered to the city. For surface water, the energy intensity of the pumping stations oscillates between 0.17 and 0.96 kWh/m^3. Groundwater extraction requires a higher energy intensity of 0.35–0.78 kWh/m^3. The total energy intensity for withdrawal, pumping, and transportation accounts for 0.5310 kWh/m^3 (Figure 4).

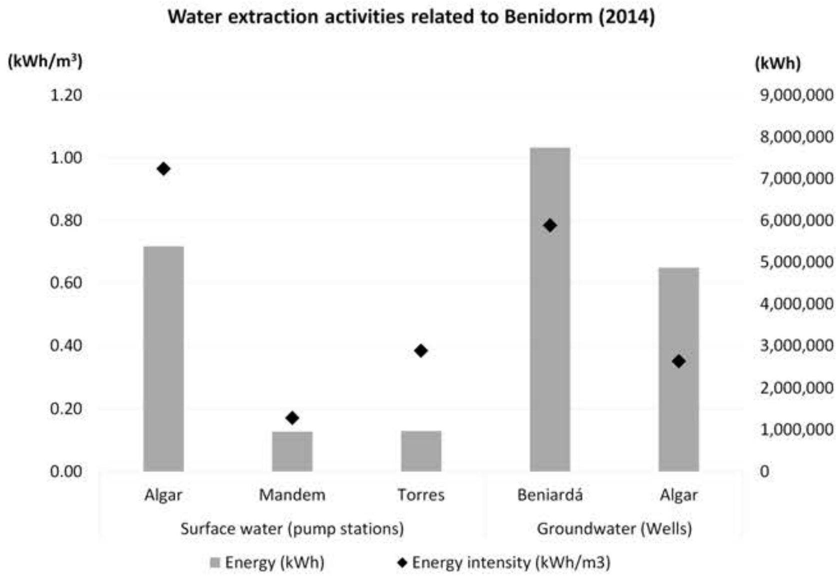

Figure 4. Water extraction activities in Marina Baja related to Benidorm's urban water supply.

Before arriving in the city, water goes through treatment for purification in the Benidorm (0.0311 kWh/m^3) and Galandú (0.0726 kWh/m^3) plants. Purified water is then distributed to the city, with 0.0134 kWh/m^3 required to meet the minimum water pressure.

In total, fresh water withdrawal, pumping, and transportation required 3.8 GWh in 2014. From withdrawal to the distribution of water to the city, about 5 GWh is consumed every year in Benidorm.

4.2.2. End Uses: Hot Water Use and Water Pumping for Buildings

Water, as hot water, carries heat and provides people with convenient, comforting, and vital services, such as hot showers and baths (including spa-type devices), washing, cleaning, and cooking. According to a study conducted by Kempton [47], energy use for domestic water heating oscillates between 1.8 and 4.7 kWh/day. Domestic hot water use in Benidorm is estimated based on the average water heating data provided by Spanish Environmental indicators (*Banco Público de Indicadores Ambientales (BPIA)*). In Spain, the annual average domestic energy consumption for hot water is 1755.90 kWh per household. Thus, 1.902 kWh/person·day are required for domestic hot water considering an average household size of 2.53 persons (INE 2013). The domestic water consumption for inhabitants of Benidorm is 0.192 m^3/person·day. Assuming that, on average, 18% of domestic water is used as hot water [48], an energy intensity of 54 kWh/m^3 is estimated for domestic hot water use in Benidorm. Based on data provided by a four-star hotel during 2010 to 2015, on average, 25.5% of the water used in hotels is for hot water. The calorific value of 10.61 kWh/L (83.19 MJ/L) was applied for unit conversion. Therefore, an average energy intensity of 53.8 kWh/m^3 (standard deviation 4.63) is estimated for hot water use in hotels in Benidorm, with energy intensity ranging from 49.8 to 64.0 kWh/m^3. Hotels in Benidorm tend to spend much more energy for water heating than residents, as most hotels still use central oil boilers fuelled with diesel and use larger quantities of water compared with the residential sector.

The second consideration is the energy required for water pumping within the buildings as Benidorm stands out for its skyscraper landscape [49]. Water pumping in high buildings is gaining attention, for example in China, as the number of high skyscrapers is expanding and buildings are becoming increasingly tall [35,36]. In our case, the maximum heights of all types of buildings (hotel or residential) were calculated from cadastral data of the Spanish Ministry of Finance and Public Administration) [50]. Pump height was calculated as an average height, excluding the buildings lower than or equal to four floors ($\leq$12 m), with the story height assumed to be 3 m. By applying Equations (4) and (5) (refer to Section 3), the energy needed for pumping water in tall buildings is estimated to be about 0.2519 kWh/m^3 (Table 2).

Table 2. Estimation for pumping water in buildings applying Equation (4).

Variables	Amount	Units
Specific weight of water	9.81	kN/m^3
Pump height	40	m
Flow (of water registered)	0.3036	m^3/s
Overall efficiency	0.5625	
Energy intensity for repumping water	0.2519	kWh/m^3

4.2.3. Wastewater Treatment Plants

Wastewater from Benidorm is directed to the Benidorm and Villajoyosa wastewater treatment plants (WWTP). The WWTP of Benidorm (143 m a.s.l.), with a capacity of 60,000 m^3/day and an average flow rate of 36,490 m^3/day (2015), shows an energy intensity of 0.35 kWh/m^3, which is smaller than U.S. (0.407 kWh/m^3) and Australian (0.46 kWh/m^3) plants [14,51] and the WWTP of the Spanish coastal resort of Calafell, which has an energy intensity of 0.457 kWh/m^3 [52]. The biogas cogeneration in the Benidorm WWTP helps in saving 25% of the total electricity required. In monetary terms (applying an electricity price of 0.10 €/kWh), the energy savings from the cogeneration system would amount to €140,000 per year on average. This has helped the plant to reduce energy costs when it cannot meet the optimal treatment level due to fluctuations of water use during the low tourist season. The Benidorm Tertiary water treatment plant, equipped with ultrafiltration and reverse osmosis systems, needs an energy equivalent of 0.64 kWh/m^3. The treatment is adjusted to meet the demand from irrigators. Therefore, in periods with sufficient rain the plant diminishes its activity. The water treated per year oscillates between 2,000,000 m^3 and 4,000,000 m^3 and operates on average 16 h a day treating 24,000 m^3.

The WWTP of Villajoyosa has a smaller treatment capacity compared to that of Benidorm and only treats the wastewater generated from the *Poniente* section of Benidorm. This plant has an average energy intensity of 0.54 kWh/m^3. In total, 6.3 GWh of electricity is consumed annually to treat wastewater from Benidorm and other towns in the Marina Baja, of which 3.8 GWh per year is estimated to be spent in Benidorm.

4.2.4. Emergency Water Provision

Benidorm may resort to an emergency water provision scheme, which becomes the vital water source for the city in severe drought periods. The existing scheme activates interbasin transfers when prolonged droughts reduce the water level in the Guadalest and Amadorio reservoirs. In these cases, the interbasin water transfer from the Rabasa-Fenollar-Amadorio system supplies water from the Canales de la Mancomunidad del Taibilla, 60% of which is desalinated water [53]. Pumping water from the vicinity increases energy intensity moderately compared to surface water and groundwater use in the Marina Baja. Based on data from 2001 to 2015, the average energy intensity of this system is 0.79 kWh/m^3. (Note that this does not include the energy intensity required to withdraw water in the Mancomunidad water system, which also includes desalination plants).

In addition, and as mentioned above, the Muchamiel desalination plant will be added to the urban water cycle of Benidorm. According to operational data from July to December 2015, the plant has an average energy intensity of 3.27 kWh/m^3 with a monthly water production between 539,753 m^3 and 1,061,242 m^3 (average 683,380 m^3) working approximately at 45% of its capacity (Table 3). However, this energy intensity will increase as additional pumping would be required to transport water through the existing Rabasa-Fenollar-Amadorio pipeline to Benidorm. Assuming that this does not take into account water transportation from the plant to the city through the existing emergency pipeline, it can be estimated that the energy requirement would increase to 4.064 kWh/m^3.

Table 3. Muchamiel desalination plant performance data from July to December 2015.

Category (unit)	Values
Amount of water produced (m^3)	4,100,280
Energy consumed (kWh)	13,413,380
Total energy cost (€)	1,087,637
Energy cost per water produced (€/m^3)	0.2653
Energy cost per energy consumed (€/kWh)	0.0811

4.2.5. Others

Other activities related to the water cycle—sewage system, discharge, and grey water distribution—require energy. Sewage systems transporting sewage and surface runoff require a minimum amount of water, which in 2014 accounted for 0.0025 kWh/m^3. Discharge of water requires no energy as gravity is used. Farmers pump up the treated water needed for their farms from the tertiary treatment plant, but since electricity use is measured individually in the farms, data is very hard to obtain. Thus, this stage of the water cycle was not included in the energy (electricity)-for-water calculation.

4.3. Desalination: A Blessing or a Burden?—ScenarioAnalyses

Among various factors, precipitation conditions play a pivotal role in deciding which water source is withdrawn for use. In this section, the results of energy (electricity)-for-water are assessed according to three precipitation scenarios: wet, normal, and dry years, with the dry years further divided into two scenarios.

During years with abundant rain, the Torres pump station directs water to the Amadorio reservoir. Surface water provides sufficient water for supply, and consequently the need to pump groundwater decreases. Furthermore, pumping from the Algar aquifer requires less energy as the water head rises. In a normal season, the water is provided from the Amadorio reservoir but groundwater pumping from aquifers is required. During a dry season, surface water often runs out, and groundwater pumping increases to provide water for urban uses following the agreements between the farmers and the Consortium. When surface water runs out, the emergency Rabasa-Fenollar-Amadorio interbasin transfer starts operating in collaboration with the *Mancomunidad de los Canales del Taibilla*. This interbasin water transfer provides close to 50% of the water required in Benidorm.

Our results show that energy intensity increases as dry climate conditions lower the water stored in reservoirs (Figure 5). In a dry year, the Rabasa-Fenollar-Amadorio interbasin transfer is activated and this results in increasing energy intensity up to 0.75–1.2 kWh/m^3, more than twice the energy intensity of normal years. If the Muchamiel desalination plant is incorporated by substituting it for the emergency interbasin transfer, the total amount of desalted water in the urban water cycle would increase. Compared with the options used in normal years, desalination increases the energy intensity by a factor of 6. The introduction of the Muchamiel desalination plant in Benidorm demonstrates a paradoxical reality whereby high construction and energy costs were not considered a serious impediment. This results in the production of desalted water that is high in energy intensity and therefore more expensive. Consequently, it requires subsidies or an exemption on amortization to lower the water price and make it affordable for users.

During wet years, the energy (electricity)-for-water for withdrawal remains around 0.33 kWh/m^3. Most of this energy is used to pump water so that as much excess water as possible could be stored in the reservoir. During the period when there is plenty of water, the Algar aquifer overflows and reduces the level of energy required. During a normal year, 0.38 kWh/m^3 is required for maintaining the balance of pumping water from reservoirs and aquifers.

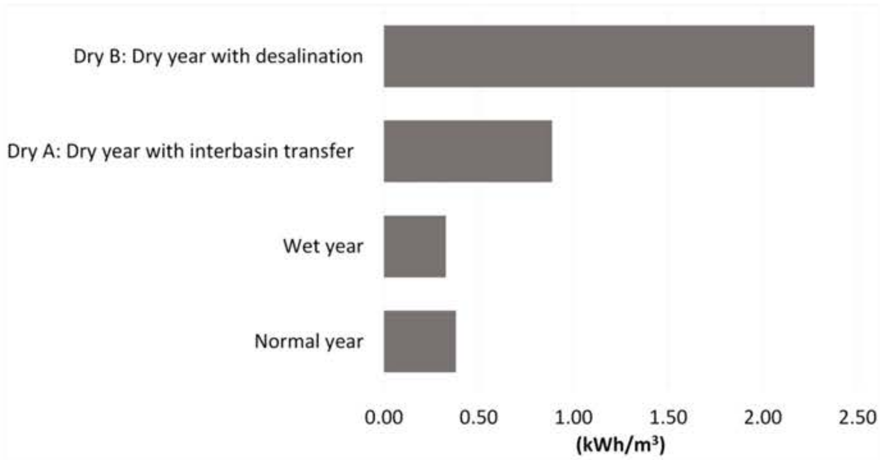

Figure 5. Results of energy (electricity)-for-water per scenario.

5. Discussion

The results obtained show that 4% of the total energy consumption in Benidorm is dedicated to water supply and treatment (water withdrawal, transport, purification, and waste treatment). Water purification is low in energy intensity as the quality of groundwater and surface water requires minimum treatments. The energy intensity for wastewater treatment is known to increase as the treatment technology advances in sophistication. In this case, the energy intensity of the tertiary treatment plant increases and consequently doubles the energy required for secondary treatment. In Benidorm, additional energy intensity from adding tertiary treatment is inevitable not only to guarantee the water quality of the effluent but also to respect the agreements with irrigation communities for water reuse.

The most energy-intensive stage was end uses, which accounted for 20% of the total energy use when the energy required for water pumping and hot water use was considered. This highlights the relevance of considering the water-energy nexus from both the supply and the demand sides [1]. Considering that other energy uses for water (swimming pool maintenance, laundry, etc.) were not included in this study due to data availability, it is likely that the energy intensity in end uses might be slightly larger. Conversely, as the weather in Benidorm tends to be milder compared to other parts of Spain, it is also possible that domestic hot water use may be lower than average. Vertically developed Benidorm requires further attention compared with other horizontally developed coastal towns in Spain because the compact model bears a special type of energy use that may not be necessary for low-rise buildings.

The energy (electricity)-for-water per precipitation scenario demonstrates that energy intensity varies as much as 600% depending on the water option selected in dry years, which raises sustainability questions. Energy intensity is highest when desalinated water is used. This is reflected in high water prices, which make water from desalination less attractive compared to other water sources. The desalination plant of Muchamiel, the water of which is imposed over other options, may bring tensions to the existing urban water cycle arrangements.

On the other hand, the current water agreements between farmers and the Water Consortium of the Marina Baja imply using the same technology (reverse osmosis) as the desalination plant. The same technology applied to different contexts (i.e., site, scale, and water quality requirements) results in increasing energy intensity for wastewater treatment but below that of desalination plants.

While the water agreements with irrigators provide a safe environment to secure water, Benidorm is not free of tensions and conflicts over the resource. For example, the farmers of Callosa d'en Sarria rely on their aquifer water and do not comply with the water agreements as they oppose the Consortium [54,55]. Moreover, hotels and amusement parks in Benidorm are accused by the farmers of worsening water quality by inappropriately discharging salty water to the drains from their premises [56]. In this respect, it must be remembered that many hotels maintain private wells with water of high salt content used for cleaning tasks [56].

Last, contractual terms with the electricity company pose operational difficulties in managing water due to the rigid requirements enforced when defining the contracted power. An annual contract with a fixed contracted power lacks flexibility to account for the fluctuating power requirement, which depends on the water situation of the region. This is a problem not only for the consortium but also for other entities as it is difficult to foresee the water situation. This results in adding fixed costs to water, as water managers are forced to maintain a high-voltage electricity supply throughout the year even when precipitation levels do not require further energy inputs. Thus, there is a discrepancy in the socio-technological arrangements of energy and water, whereby a lack of contractual flexibility of the energy sector may become an obstacle for the water sector.

6. Conclusions

In this paper, energy (electricity)-for-water was explored in Benidorm, a mass tourist center where water acts as a major player in the development of the tourism industry. Benidorm exemplifies a case of increased energy intensity to ensure water, especially in conditions of water stress. In this sense, the Muchamiel desalination plant, which will be introduced in the water cycle of Benidorm, may change the notion of water scarcity and availability by providing a resource not bound by climatic constraints. However, the result of the study warns that it may transfer water constraints to energy as its energy intensity is three times higher than the existing emergency interbasin transfer and six times higher than the normal water provision scheme. This new technological fix imposed by national water authorities may act as an external pressure to change the existing urban water cycle at the local level in several ways, either prompting more conservation and efficiency measures because of high prices or discouraging these if the perception of an ample and limitless supply gains adherents in the tourist sector. Desalted water has a cost beyond the purchasing power of farmers. However, national authorities are already planning to restructure these high water costs by allowing exemptions for the amortization of the construction costs, as the project has an 'environmental character' [57]. Given the unreliability of current supplies in face of climate change and the potential socio-territorial conflicts associated with interbasin transfers, desalination may become the only feasible alternative. To avoid transferring the problem from water to energy, Benidorm should work forward the nexus findings through a greater integration of research and policy across both sectors.

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Author Contributions: Hyerim Yoon and David Sauri conceived and designed the experiments; Hyerim Yoon and Antonio M. Rico Amorós collected the data; Hyerim Yoon analyzed the data; and Hyerim Yoon wrote the paper with David Sauri and Antonio M. Rico Amorós.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix A

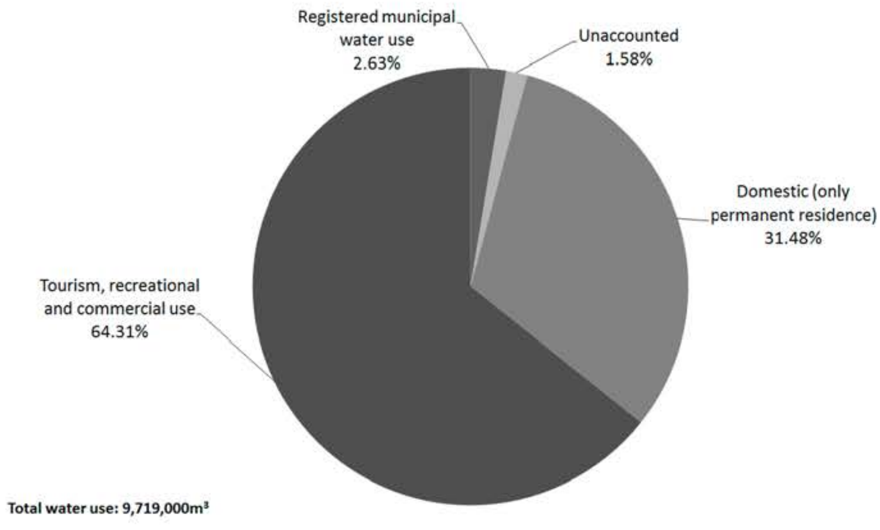

Figure A1. Water use in Benidorm (Source: Hidraqua).

Table A1. Inhabitants and water consumption in 2014 per member municipalities to consortium (Source: Spanish Statistical Office, Cosortium).

Municipality	Inhabitant	Water Billed (m^3)	Water Provision per Capita per Day l/Capita/day
L'Alfàs del Pi	21,357	2,392,755	306.95
Altea	22,518	1,819,165	221.33
Benidorm	69,010	10,111,705	401.44
Finestrat	6265	668,070	292.15
La Nucia	20,029	1,538,041	210.39
Polop	4313	524,610	333.25
Villajoyosa	33,951	2,285,000	184.39
Callosa d'en Sarrià	7370	0	0.00
Total	177,443	19,339,346	

Table A2. Categories and sources of data collected.

Category	Data Collected	Sources
Extraction	Energy consumed 2014/Water extracted 2014	Water Consortium of the Marina Baja
Water treatment	Benidorm: Energy consumed 2014/Water treated 2014 Gandalú: Energy consumed 2015/Water treated 2015 (January–June)	HiDRAQUA
Distribution	Energy consumed 2014/Water registered 2014	HiDRAQUA
Sewer system	Energy consumed 2014	HiDRAQUA
WWTP(Wastewater treatment plant)	Energy consumed 2014/Water received 2014	Wastewater treatment plant of Benidorm
Tertiary treatment	Water received and energy consumed for a normal year	Tertiary treatment plant of Benidorm
Rabasa-Fenollar-Amadorio (Emergency water transfer)	Energy consumed 2001&2015/Water transferred 2001&2015	Acuamed
Desalination	Energy consumed 2015/Water produced 2015	Acuamed

Table A3. Ranges of energy intensity data for the urban water cycle of Benidorm.

Categories		Energy Intensity (kWh/m^3)
Water withdrawal	Surface water extraction Groundwater extraction	0.171–0.964 0.349–0.784
Emergency water supply	Interbasin transfer Desalination (water production only)	0.753–0.832 3.211–3.334
Water treatment		0.031–0.073
Distribution		0.012–0.148
Wastewater treatment		0.346–0.542
Tertiary treatment		0.5–0.7
End use	Domestic hot water Hotel hot water	47.054–65.876 49.800–63.992

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3.2 Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain.[7]

Abstract

Benidorm is an epitome of the mass tourism offering 'sun and sand' tourism through 128 hotels attracting more than 2 million domestic and international visitors annually. This success exerts an enormous pressure on water resources, manifested in the impacts of recurrent droughts. This paper analyzes the water-energy nexus (WEN) in Benidorm, focusing on hotels and recreational sector to estimate the energy used for water in tourism. Based on an exhaustive survey of 12 hotel samples in Benidorm, we estimate an extensive water and energy use with a value of *energy for water* of 160 - 1060 MJ/m^3 for hotels and of 28 - 71 MJ/m^3 for a waterpark. Interviews with the managers unveil that the notion of conservation nexus is still unexplored. We highlight hidden trade-offs between energy and water in the groundwater extraction for the waterpark water provision and hotels.

Keywords: WEN; waterpark; energy for water; energy intensity; water intensity; Spa; hot water

1) Introduction

Tourism is emerging as one of the main economic assets for many countries around the world. The sector accounts for 10 % of world GDP, 7 % of global trade, and provides one out of ten jobs (World Tourism Organization (UNWTO), 2018). Tourism is also known to have a high dependency on resources such as water and energy, which have been at the focus of investigations by practitioners and academics alike (e.g. Becken et al., 2003; Dief and Font, 2012; Gössling et al., 2012; Warren and Becken, 2017). Resource scarcity and climate change highlight the importance of sustainable management in hotels and recreational facilities where innovative measures are gaining attention for

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activities and facilities such as golf, swimming pools, spas, ski, etc. (Becken and McLennan, 2017; Cazcarro et al., 2014; Gabarda-Mallorquí et al., 2017; Kampel et al., 2013). However, whereas there are abundant studies addressing water and energy consumption of hotel and recreational activities, it is only recently that relationships between these two essential resources have started to be explored. In this article, the water-energy nexus (WEN) for hotel and recreational activities is analyzed looking at the mass tourism resort of Benidorm, in the Spanish Mediterranean coast. We focus on describing the current resource management practices of the hotel and recreational sector that expose the importance of WEN for improving sustainable management principles in mass tourism.

The objective of the article is to analyze WEN in the hotel and recreational sector around the following questions; which energy sources are used? Is there a relationship between water and energy consumption? How is WEN considered in the management practices of the hotel and recreational sectors? Are there WEN-related synergies and trade-offs? Moreover, energy intensity for water is quantified to evaluate the effectiveness in addressing sustainable management of hotels and recreational facilities.

Former studies have emphasized various saving measures and practices implemented in the sector where the physical scale, water facilities, and business practices of hotels were identified as the main factors correlating with the water consumption (EPA, 2012; Trianti-Stourna et al., 1998; Warren and Becken, 2017). Among various elements, consumer behavior is singled out as one of the most influential factors in resource management as, in the end, resource use depends to an important extent of user's habits and actions (Barberán et al., 2013; Dief and Font, 2012; Gabarda-Mallorquí et al., 2018). Thus environmental awareness and environmental friendly behavior by consumers can provide new insights and strategies for hotel managers in their efforts in achieving sustainable tourism (Gabarda-Mallorquí et al., 2018). However, there are still many management practices and behaviors that depend on the technical characteristics of existing installations.

We argue that the intrinsic link between water and energy has not been sufficiently explored in the tourism sector, although there is evidence that it may be becoming more and more relevant. For example, Becken and McLennan (2017) have emphasized the importance of WEN to achieve absolute resource reduction as a long-term solution to challenges associated with various trade-offs in managing water and energy supply. A number of studies also have addressed energy and water consumption together as core resources for hotel industry with the aim to establish benchmarks, and thus assess management practices (Trung and Kumar, 2005; Warren and Becken, 2017). However, these studies in our opinion may lack an in-depth understanding of the interconnectedness of water and energy. Therefore, we propose a first step approach in developing WEN thinking for better water and energy management in the hotel and recreational sectors. In doing so, we provide a bottom-up approach of WEN, enriched with data collection and opposed to the top down approach, more commonly observed in WEN studies. Whereas the concerns of policy makers and international advocacy group such as international banks, advocate for top-down approaches, addressing WEN at the supply scale, the importance of the nexus at the demand end from a consumers perspective in various sectors and smaller scales, requires further studies (Voinov and Cardwell, 2009; Yoon, 2018). Therefore, the study turns to the nexus at the scale of end-uses in order to understand possible synergies and tradeoffs in the everyday practice of water and energy use (Becken and McLennan, 2017).

The objective of the article is to provide a snapshot of WEN in the hotel and leisure sectors of Benidorm, collecting evidence on possible synergies and tradeoffs in the current practices of water and energy provision and consumption. Moreover, some pioneering actors in the sector are identified along with WEN tradeoffs often overlooked in their environmental management routines. As water is one of the significant resources in the local context, we explore the *energy for water* dimension. However, the energy system, (electricity and natural gas) operates in a system boundary different to that of the local water cycle as it is managed at the national level. Regarding energy services, we focus on the innovative energy technologies that are being implemented in the hotels of Benidorm, in order to improve the environmental performance with a particular focus on socio-institutional aspects.

The following section introduces Benidorm and WEN in Tourism. Data collection and methods are explained in section 3 and the results presented in section 4. The article ends with discussion and conclusions.

1.1) #BenidormAlwaysSummer

Tourism is an important contributor to the Spanish economy representing around 11 percent of the national GDP. In Valencia, the tourism industry accounted for 13.2 % of the total GDP generated in the region, and 14.4 % of total employment (Generalitat Valenciana, 2016). Benidorm, the epitome of mass tourism in the Spanish Mediterranean coast is located in the Marina Baixa (Alicante province) where half of the GDP in tourism for the Valencia community is generated. Benidorm attracts on average about 50 % of tourists coming to the Alicante province. The semi-arid climate with mild winters provides optimal conditions for promoting “Sun and Sand” tourism for visitors from the UK, Russia, Northern European countries and Spain. Spanish tourists mostly consist of senior pensioners who have been paramount in reducing seasonality imbalances in Benidorm.

Benidorm developed one of the first urban projects planned and executed in Spain with a specific objective of promoting mass tourism. Water supply has always been an issue of concern for Benidorm and for the last 50 years the city has created a complex hydrosocial cycle that involves surface water (local and long-distance transfers), groundwater and even desalinated water as well as complex exchanges of waters of different quality with nearby irrigators. The current system allows for stable water supply but at a high energy intensity, showing the deep connections between the two resources (Yoon et al., 2018).

Hotels represent the most common accommodation type in Benidorm (53 % of total lodging, Figure 1). Most of them are 3 and 4 star hotels (51 and 37 % respectively) built in the 1960s and 1970s (only 20 hotels were built after 1980). 90 % of these older hotels were renovated in the 1990s and 2000s to maintain the quality of service and improve their market competitiveness. Environmental and sustainable development projects played an important role in this attempt to consolidate and expand attraction (Vera-Rebollo et al., 2010). The city offers various leisure facilities, such as a waterpark that opened in 1985, a large amusement park and two golf courses.

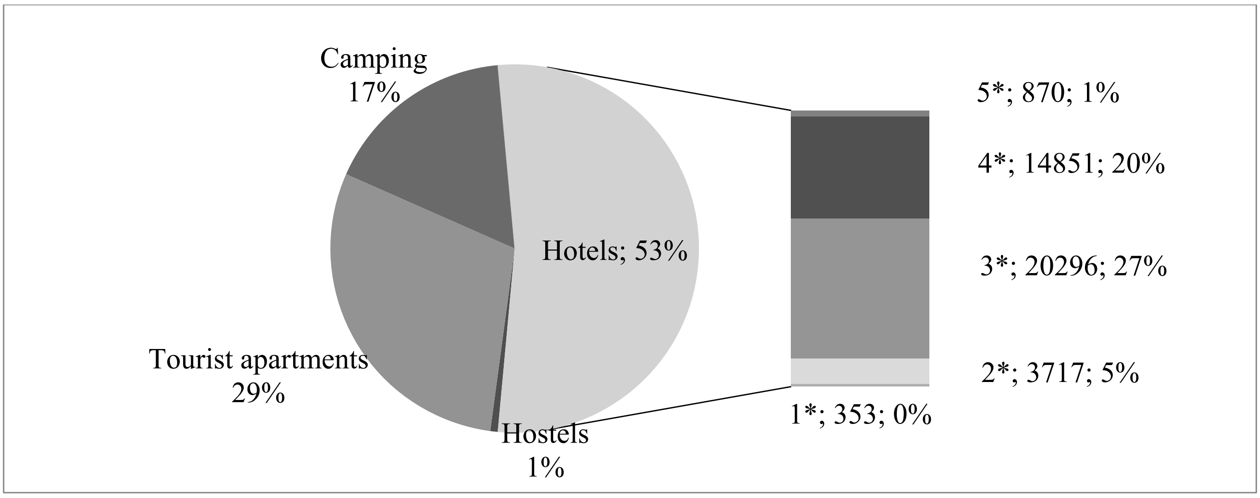


Figure 1. Number of beds in hostelries in Benidorm (Source: HOSBEC)

Institutional efforts to mitigate environmental impacts and promote sustainable tourism are driven by supports from the Valencian Tourism Council (Agència Valenciana del Turisme). In 2007 and 2008, the hotel sector received subsidies of 294 113.15 € and 838 166.48€ which account respectively for 70 and 82 % of the total subsidies provided to hotel sector (Vera-Rebollo et al., 2010). Most of these funds were allocated to the improvement of resource management practices.

1.2) Water energy nexus in Tourism

According to Cairns and Krzywoszynska (2016), the water energy nexus is many ways plural, fragmented and ambiguous. These authors analyzed several applications of WEN studies as a global science-policy issue; emphasizing an increasing integration across water and energy sectors; a tendency to focus on technical solutions; an inclination for win-win solutions; an optimization of processes or 'outcome-improvement'; and an avoidance of negative trade-offs (win-lose). As to the small sale level of individual installations and users, the conservation nexus is approached with the vision that water savings contribute to energy savings and vice-versa (Bartos and Chester, 2014; Jiang et al., 2016).

Previous studies have highlighted the importance of indoor hot water use management to reduce energy consumption and carbon dioxide emission in the hotel sector (Chhipi-Shrestha et al., 2017; Rankin and Rousseau, 2006). However, beyond hot water supply, various activities increasingly relying on machines such as dishwashing and laundry are also examples of the ubiquity of the WEN. Cultural and behavioral differences make difficult to evaluate energy and water use for these activities at home and in hotels. Moreover, the improvement of the efficiency of heat exchangers is contributing to the use of them for space acclimatization, which expands the range of activities at the nexus level (Al-Alili et al., 2014). Furthermore, humidity control also adds another dimension to the WEN concept (Chu et al., 2005; He et al., 2017).

2) Materials and Methods

The research is based on a mixed methodology of questionnaire and interviews. Two field work periods in Benidorm were conducted. In the first, 32 hotels in the two, three, four and five star categories were selected according to the previous knowhow on the level of collaboration on such events and samples size based on the confidence level 95 % and confidence interval 15 with the support from the local expertise, especially of the Hotel Business Association of Benidorm, Costa Blanca and Valencian Community (HOSBEC). Follow up phone calls and emails were made a week or two weeks after the first contact in order to increase the response rate. Although carefully chosen, to have hotels participate in the research proved very difficult. Hotels in the two star categories did not respond to the research request. Therefore, it was decided that focus would be placed on the hotels in the upper categories of, three, four and five stars. In total, 16 hotels responded to the survey via email as summarized in table 1. Of the 16 hotels that participated, 12 hotels accounting for 16 % of total number of beds in three-star and four-star completed the survey providing all data (response rate 37.5 %). The research also includes 8 in-depth interviews with hotel managers or technical managers while visiting hotel facilities related to water and energy use.

Table 1. Respondent rates of the survey and face to face interviews for this research (% over survey requested hotels (No. & Beds)) (Source: Own elaboration)

*s	Total Number of Hotels		Survey Requested		Survey responded				Survey with full data				Interview participants			
	No.	Beds	No.	Beds	No.	(%)	Beds	(%)	No.	(%)	Beds	(%)	No.	(%)	Beds	(%)
5*	3	870	1	695	0	(0)	0	(0)	0	(0)	0	(0)	1	(100)	695	(100)
4*	36	14851	14	6439	10	(71)	4154	(65)	6	(43)	2698	(42)	6	(43)	1900	(30)
3*	60	20296	13	5351	6	(46)	2798	(52)	6	(46)	2798	(52)	4	(31)	1534	(29)
2*	23	3717	4	735	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
1*	6	353	0	0	0	-	0	-	0	(0)	0	(0)	0	-	0	-
Total	128	40087	32	13220	16	(50)	7097	(54)	12	(38)	5498	(42)	11	(34)	4129	(31)

The questionnaire included four sections: general information on the hotel, water consumption, energy consumption and, lastly, a request to provide their energy and water logs often managed in the format of excel tables by the hotel management team.

Interviews are reflected in the field notes taken by us. During the second field trip and in agreement with persons interviewed, interviews were recorded and selectively transcribed, open-coded and analyzed.

The relatively small size of the data set meant that it was not possible to conduct comprehensive statistical analyses. Despite this, we believe that data provides us meaningful results that reiterate the complexity of socio-technical structures in hotels whereby providing comfort and entertainment is institutionalized in mass facilities (Shove, 2003). In addition, considering that this is to our knowledge one of the first study dealing with this topic in tourism studies, insight gained may contribute to conducting further research in one of the key areas for achieving sustainable practices in the sector. We believe that the limited participation in the survey was due to two major reasons: First, the complexity of the survey addressing both energy and water probably reduced the participation rate as many engineering details were not controlled in day to day practices; Second, the perceived environmental impacts might have alarmed hotel managers as to possible repercussions on their business. Despite challenges in data collection, we would argue that the Benidorm hotel industry should disclose current water and energy practices in order to make visible good and innovative actions and, at the same time improving less sustainable practices.

3) Hotel Sector

3.1) General characteristic of hotels

Most of the hotels were built before the 1980s when the boom of hotel constructions was at its peak in Benidorm. All hotels have been through various degrees of reform for aesthetic or technical performance improvements. The more significant reforms in terms of water and energy include façade improvement, kitchen reforms, installation of natural gas piping, solar thermal systems and upgrades in acclimatization systems. One third of the hotels have received subsidies from the Regional Government of Valencia to conduct these reforms.

Many of the buildings correspond to medium- or high-rise structures (average of 10.4 floors) making Benidorm a vertically developed tourism town. Hotels are relatively large in terms of size with an average of 68 employees and 440 beds. Guests stay an average of 5.5 nights which is typical of Sun and Sand tourism destinations and longer compared to city vacationers. (Table 2)

Table 2. General characteristics of all hotels participated in the survey (N=13, ** N=14, *** N=15) (Source: Own elaboration)*

	Mean	Median	Standard Deviation
Building area*	13387.6154	11217	9450.49459
Height of the building**	36.21	28.5	20.87
Number of floors***	10.4	9	6.936
Number of beds	438.25	338.5	281.764
Number of employees***	96.13	55	115.737
Average nights per client	5.5	5	1.31656
Guest night 2015	141945.69	117387.5	90821.305

3.1.1) Energy consumption

Hotels mix various energy carriers to provide lighting, water heating and distribution, HVAC (heating, ventilation and air conditioning) or acclimatization, and cooking (Table 3). Electricity is the most common energy carrier, with an average intensity of 500 $MJ/m^2 \cdot a$ (MJ per building surface per year). Propane is the next more common energy carrier, but with a low use intensity as it is usually employed for outdoor cooking. Diesel is commonly used for water heating although some hotels have decided to switch to natural gas (or city gas), newly introduced to Benidorm. The use of natural gas use in hotels demonstrates varying intensity levels due to an outlier. Hotels in the Poniente area of the Benidorm still lack city gas as it is in the phase of feasibility studies. According to the non-parametric analysis provided by the Mann-Whitney U test, 3 and 4 star hotels presented a similar distribution in terms of total normalized energy use intensity.

Table 3. Energy use intensity of hotels surveyed for fossil fuel energy carriers (Source: Own elaboration)

Energy carriers	N	Minimum	Maximum	Average	Standard error	Standard deviation
Electricity ($MJ/m^2 \cdot a$)	12	331.26	763.72	499.8010	37.26507	129.08998
Propane ($MJ/m^2 \cdot a$)	10	22.10	125.55	66.1924	10.75292	34.00371
Diesel ($MJ/m^2 \cdot a$)	6	145.88	333.32	213.8795	26.24651	64.29055
Natural gas ($MJ/m^2 \cdot a$)	4	21.58	4289.02	1149.2035	1048.01406	2096.02811
Butane ($MJ/m^2 \cdot a$)	1	7.37	7.37	7.3684	.	.
Total fossil fuel use ($MJ/m^2 \cdot a$)	12	399.74	5185.66	1045.5829	378.07308	1309.68356
Total fossil fuel use normalized ($J/m^2 \cdot a$)	12	1980.32	54519.32	10430.2878	4285.25612	14844.56264

3.1.2) Water consumption

With a history of water shortages, water saving is regarded as a central issue in Benidorm. HOSBEC has provided hotels in Benidorm with basic management tools and rules to control the use of water. In practice, however, hotel managers were not familiar with the terminology of water saving measures or showed generally less interest control over the water flow as long as comfortable services were secured for their customers. The hotels had an average water consumption per guest night of 215 $L/gn \cdot a$ (Table 4).

Table 4. Water consumption of hotels surveyed (water use from wells owned by hotels is excluded) (N=12) (Source: Own elaboration)

Type	Minimum	Maximum	Average	Standard error	Standard deviation
Potable water (m^3)	4958	61593	34796.83	6127.475	21226.195
Water use intensity ($m^3/gn\cdot a$)	0.11	0.41	0.2153	0.02223	0.07701
Total fossil *energy for water* (MJ/m^3)	159.96	1063.18	350.3189	70.49237	244.19273

Dry and sunny weather provides fertile conditions for mass tourism to flourish. Recapitulating the logic in words of Technical Manager in the field, " [in Benidorm], it rains very little. This is a paradise." (Interview # 1, Technical Manager of Hotel, 04/09/2018). Previous studies have addressed the changing energy intensity of water in Benidorm as it taps on various sources depending on the availability, policies, and institutions established (Yoon et al., 2018). However, hotels appear to grow less sensitive to water issues as a steady water supply seems guaranteed, and some even argue that "there is no water problem" in Benidorm.

3.2) End-uses in Water-energy nexus

The nexus between water and energy was observed from non-parametric correlation analyses. The analysis revealed that there are relatively strong bilateral positive correlations between energy and water consumptions in hotels (Table 5) with various significance level depending on the measure of energy use chosen. Both normalized water use intensity and normalized energy intensity (only fossil fuels) showed relatively strong negative correlations with the built-up surface area of the hotels (ρ =-.867 and -0.825, significance level=0.05).

Table 5. Correlations based on Spearman's rho analysis between normalized water use intensity (L/gn·m2) and various energy use measures (N=12) (Source: Own elaboration)

	Energy use intensity including biomass ($MJ/m^2\cdot a$)	Fossil fuel normalized energy use intensity($J/m^2\cdot gn$)	Fossil fuel energy use intensity ($MJ/m^2\cdot a$)
Coefficient	0.755^{**}	0.867^{**}	0.734^{**}
Significance level (bilateral)	0.005	0.000	0.007

Comparing with other studies conducted on water and energy consumption, the hotels were consuming 0.1 – 0.3 m^3/gn for water and of 10 – 25 kWh/gn for energy. On average these figures are lower than those in New Zealand, Tunisia, Vietnam and Australia (Figure 2).

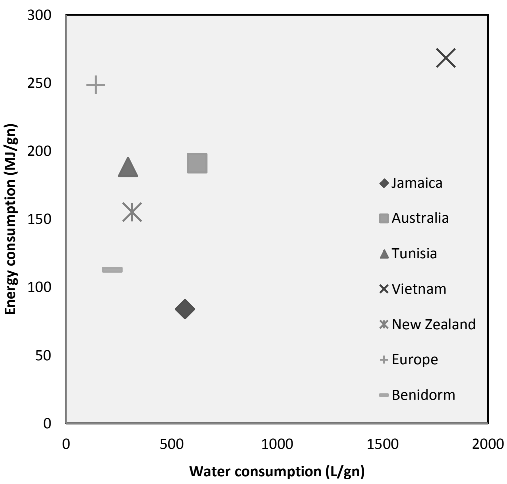


Figure 2. Comparison with benchmarks adopted from Warren and Becken (2017)

However, their water consumption was 1.5 times higher on average in comparison to the benchmark proposed by Styles et al., (2015) for European hotels (140 L/gn·a). Only one hotel had an average consumption lower than the suggested level. On the other hand, Benidorm hotels used on average less energy compared to other hotels regardless of the type of energy source (Warren and Becken, 2017).

Besides the WEN observed in the yearly consumption, there are specific activities that hotels take in order to provide services for the achievement of cleanliness, convenience and comfort (Shove, 2003). Although these activities are essential for hotels, data at hotels is not managed in a sectoral manner. Tele-monitoring is becoming more popular as an effective tool to manage water and energy flows, but in practice the extent of detail controlled in the logs is limited. In most cases, cost efficiency management was more important for data management than environmental sustainability or WEN.

3.3.1) Water heating and steam generation

By providing hot water to rooms and pools, and steam for heating, water heating and steam generation remains at the core of the WEN activity in hotels. Water heating represents approximately 30 % of the total energy consumption in some hotels (Deng and Burnett, 2000). Seven hotels that provide hot water consumption spent on average 25 % of their potable water for sanitary hot water. Most commonly, hot water was generated by a diesel boiler alone or accompanied by solar thermal heating. Other hotels used natural gas, propane gas and biomass furnaces. The mix of two energy types was most commonly found in the hotels participating in the survey because solar thermal installations required diesel or natural gas to meet the total demand (Figure 3).

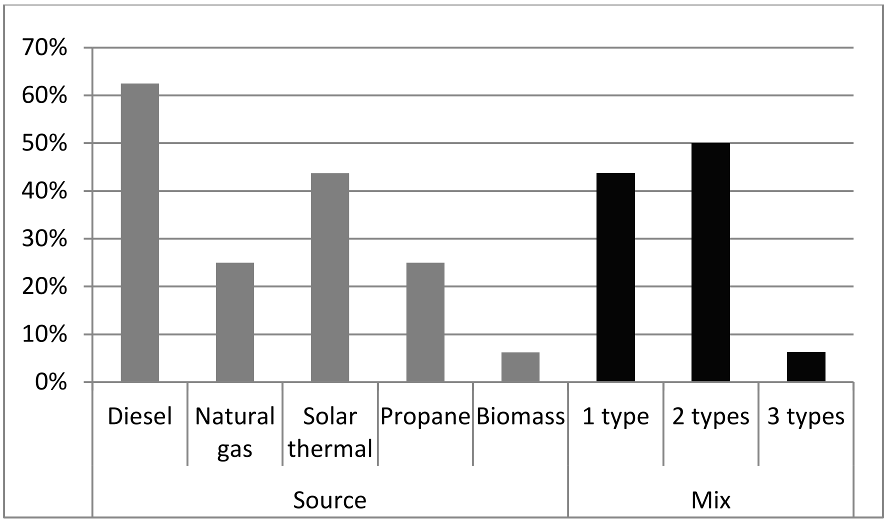


Figure 3. Energy carriers for hot water system (Source: Own elaboration)

Table 6 shows the *energy for water* chart according to the energy carrier options in comparison with the average fuel consumption data. Solar thermal systems save 25 to 40 % of energy for water heating and steam Solar thermal systems reduced the energy intensity for water heating and steam generation but did not contribute to reducing the total fossil *energy for water*. Moreover, *energy for water*, when calculated according to the amount of water heated, recorded highly different energy intensities from 36kWh/m^3 to 191 kWh/m^3. This demonstrates how energy intensity for water is easily influenced by total water and energy consumption, thus again asserting the difficulties of measuring WEN at the micro scale.

Table 6. Energy for water on hot water use and comparison with total fossil fuel energy for water (green- yellow- red are used to indicate low-medium-high level of intensity) (Source: Own elaboration)

	Energy for water heating and steam[8] (kWh/m^3)	Energy for water heating and steam[9] (kWh/m^3)	Total fossil fuel *energy for water* (MJ/m^3)
Diesel	21 - 40	128 - 147	340
Natural gas	17	36	265
Biomass + solar thermal	NA	NA	160
Diesel + solar thermal	17-23	59 - 191	333
Natural gas + solar thermal	11	44	614
Diesel + propane	NA	NA	265

From interviews we could observe that there is confusion about which energy source should be used for water heating.

> *Today it seems that I do not have all the contestable data but thousand gallons of hot water is much cheaper with electricity. They already talk about much cheaper with electricity than with gas, with pellet than with diesel. In the end the technology collapses efficiency. Now natural gas is arriving. Well, everyone is making the most efficient boiler proposal and such. I resist to believe what they are saying to me. (Interview # 4, CEO 04/12/2018)*

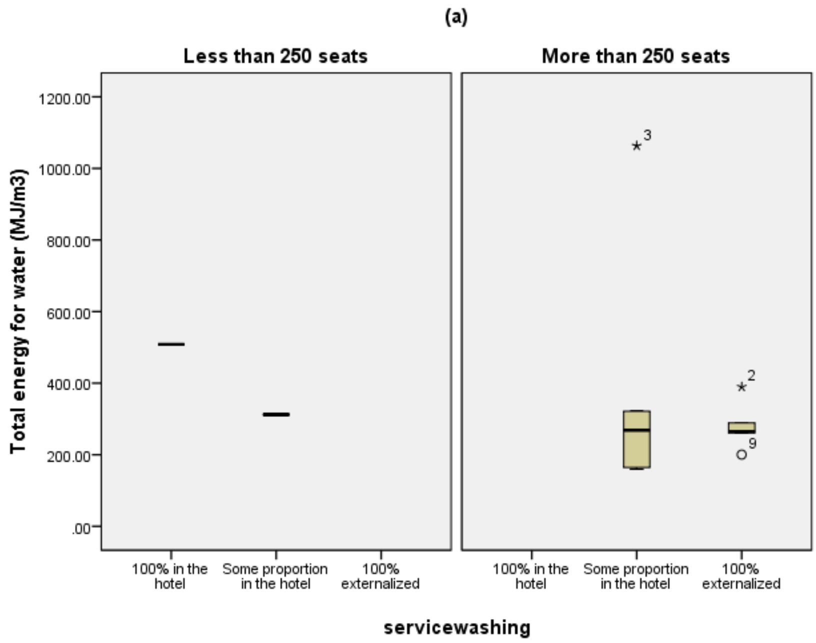
More recently, heat pumps have become a tool for energy and water savings in for hotels (Chan et al., 2018). However, the choice of heat pumps is related to the more complex question of what types of water heating devices to use, where directors would often prioritize cost efficiency over environmental sustainability.

3.3.2) Water-energy appliances

Additionally, many services involving WEN are performed by appliances which make the holistic understanding of nexus at the end use more complicated. These electro domestic appliances are sometimes known to be more efficient than conventional or traditional utensils (Plappally and Lienhard V, 2012; Siddiqi and de Weck, 2013). However, they also require energy and water in large flows especially in the hotel sector. Kitchen, laundry and spa

[8] Calculated by energy required for heating water divided by total potable water consumed
[9] Calculated by energy required for heating water divided by water heated

facilities rely on these activities with a trend of bigger facilities having more appliances to meet the scale of the demand. Box plot graphs in Figure 4.a demonstrate that high *energy for water* is observed in the hotel with laundry services regardless the kitchen size. On the other hand, Figure 4.b shows that some hotels with most of the laundry service externalized could present high *energy for water* when they have spa facilities.



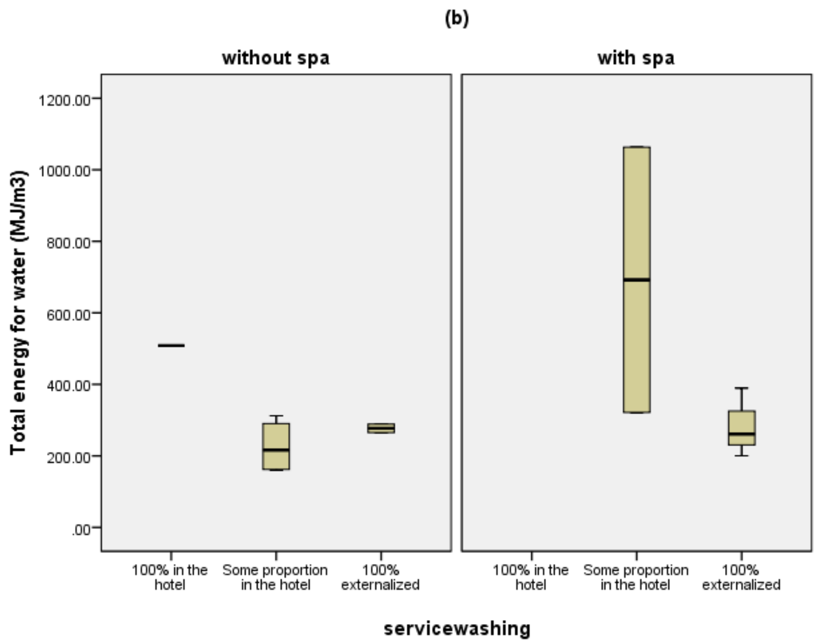


Figure 4. Total energy for water relationship between service washing and a. kitchen services and b. spa facility (Source: Own elaboration)

Laundry, which is known to account for 12 to 47 % of water use, is largely externalized in order to reduce costs and environmental impacts within the hotels. On the other hand, however, it increases water consumption in other parts of the Marina Baixa area, requiring a water supply of 20 L/s to run the facility. 44 % of the hotels have confirmed that they had externalized all laundry activities. Most commonly, electricity was used for laundry services with some exceptional cases using natural gas, or a propane gas drier. The operation of these machines was strictly controlled by internal norms defining the intensity and run-times. Optimal consumption for laundry was suggested around 684 MJ/m^3 in energy intensity for water for the activity (Styles et al., 2015).

In mass tourism, restaurants and bar services have an important function as some of the hotels offer all-inclusive or semi-inclusive deals that allow vacationers to dine in the premises. 70 % of the hotels confirmed that they had dining areas with more than 250 seats. Whereas a basic dishwasher and glass washer were commonly observed in hotels, the larger facilities were equipped with bigger industrial warewashers. The operation of these facilities was directly related to the WEN. Assuming that 10 racks per day for industrial warewasher and 50 racks per day of load for rest of the machines, based on the water and energy consumption data from efficient commercial dishwashers (EPA, 2018), an average *energy for water* for this stage is estimated as 149 kWh/m^3 (Min.=61 kwh/m^3 , Max.= 237 kWh/m^3).

Lastly, pumps are one of the essential appliances at the nexus to distribute water in buildings where there is a potential for energy saving, especially, in the high-rise buildings (Cheung et al., 2013). Most hotels were equipped with various pumps to manage the distribution of potable water and hot water. Assuming 25 % of pump efficiency with 360 days 12 hours functioning for equal flow of water, *energy for water* was estimated in 0.162 kWh/m^3.

Information on pumps was difficult to collect while the efficiency of pumps or flow rates were not controlled on a daily basis.

> *Nowadays pumps and motors spend less energy than the old ones, so they provide considerable savings. It must be renewed. I found a very important saving, the controlled speed in the electric pumps. That is very important because it can save you up to more than 50 % of the energy. That changes speed depending on the demand. Because it is not the same as starting a motor, a water pump 100 % or at 10, 20, 30 %. (Interview # 1, Technical Manager of Hotel, 04/09/2018)*

3.3.3) Recreational facilities

Swimming pools have been at the center of concern in the building sector as one of the highest activities in the sports facilities together with ice ranks (Kampel et al., 2014, 2013; Trianti-Stourna et al., 1998). One of the best performing swimming pools consume 116 - 130 kWh/m^3 with some reaching 324 kWh/m^3 (Kampel et al., 2014). From the water pumps in the swimming pool, we estimated 10hrs of function with 80 % efficiency, or on average 74 kWh/m^3 (Min=7 kW/m^3, Max=178 kWh/m^3).

Spas in a bigger hotel may require higher *energy for water* due to the hedonic behavior of vacationers who tend to be extravagant when using this facility. It is difficult to expect environmentally friendly behaviors from those who enjoy this type of tourism as comfort and service are put before any environmental concern or regulations.

Three hotels confirmed to have their own groundwater well which was used for swimming pool, garden irrigation, toilet flush as well as a water tank. However, they were not able to state how much water they were extracting. Whether this was because they did not have a meter or because they did not want to disclose the information was not clear. The groundwater discharged directly to sewer puts pressure in the water cycle as it increases salinity of effluent which is treated to be used for irrigation.

3.4) Renewable energy use and challenges

Renewable energy use in tourism is generally considered a recommended strategy especially in cases when the installation yields benefits for a relatively short period of payback time (Dalton et al., 2009a, 2009b). The most common source of renewable energy in Benidorm was solar thermal systems. 42 % of the hotels participating in the survey reported the use of such facilities with collector surface areas ranging from 187 to 501m^2. However, only three hotels had the information on the savings generated from solar thermal plants (saving around 17 000 €). The boom in the installation of solar panels began in the 2000s and technical managers expressed general satisfaction as these systems required little maintenance. However, the efficiency of the technology, in some cases was so low that it did not bring much savings for the hotels. One hotel recently installed higher efficiency panels confirming that the operation of the hotel improved substantially. One hotel with a lowest fossil fuel energy use intensity of 272.95 MJ/m^2·a had a biomass furnace installed as environmentally friendlier solution than a diesel boiler. At the time of the visit, the hotel had produced total 4 728 790 kWh with biomass, reducing the consumption of gasoil worth 156 050 €.

The second common renewable energy system used was the open loop geothermal system also called the ground source heat pump system (GSHP), that draws groundwater from a well, and passes it through a heat exchanger to take advantage of the relatively constant earth temperature – warmer than the air in winter, and cooler than the air in summer. Then the water is discharged back to the aquifer through an injection well. The technology is considered highly efficient for space heating and cooling with a coefficient of performance (COP) of 3.0 – 4.0 for heating and 11.0 – 17.0 for cooling. Their potential to reduce primary energy consumption contributing to mitigation of greenhouse gas emissions has been recognized as it also benefits users with low running costs compared to other conventional heating and air conditioning systems (Mustafa Omer, 2008). According to our investigation, there are three hotels with GSHP for acclimatization. These projects were part of subsidized endeavors for energy savings and efficiency in buildings by the regional government of Valencia, with the support of Institute for Small and Medium Industry of the Generalitat Valenciana (Instituto Valenciano de Competitividad Empresarial *in Spanish*).

One of the main challenges for Benidorm, like many other cities, is that solar thermal or photovoltaic energy for these hotels must face the constraint of a limited surface area. In one case, solar thermal cooling system did not work as there was not enough space to dissipate the heat. However, alternatives for hotels to benefit from solar energy such as PV installation on the façade of buildings, are not explored for mainly for two reasons: additional costs from taxes, and aesthetic considerations. As one of the hotels' technical managers notes;

> *Nowadays, it is sad to say but [PV] is not profitable because of taxes. But all the problem is due to the taxes. As for operation, option was to store power in batteries with half of the wall [with panels]. (Interview # 5, Technical Engineer/Quality Manager, 04/12/2018)*

Low-rise hotels point at aesthetical reasons;

> *If there are panels here, they are seen from all the buildings. When you go up to the third floor to the balcony, you can see all the land - from low to high … If it had height as [mentions a high-rise hotel], then you can install [panels] (interview # 4, CEO 04/12/2018)*

Apart from the absence of interest or motivation from hotel managements, the lack of institutional stimuli in energy-related regional policy was addressed. Solar energy is not sufficiently leveraged in Spain even though it is a type of renewable energy that requires relatively small water withdrawals and consumptions to produce electricity (IEA, 2016). Spanish regulations on renewable energy have been criticized for discouraging small and medium size ventures. (Gabaldón-Estevan et al., 2018). Most evidently, after the economic crisis in 2008-9 the renewable energy program implemented a 'tax on the sun', that burdened prosumers directly as they were to be charged per kWh generated in order to connect to the grid. Hotels find this an important obstacle to plan investments in this area (Royal Decree 900/2015, of October 9 (Ministerio de Industria, Energía y Turismo, 2015).

One experienced technical manager pointed out how Benidorm lacks innovative and decentralized water management. Rainwater harvesting or gray water recovery system are still not enforced or practiced.

> *I was in Canary Islands for 17 years, and I thought it was the third world. In 1986, it surprised me, they were advanced to rainwater harvesting. The water from the toilet and bidet were being treated for gardening. Here we do not. And we are in 2018! Of course, this had to be done when the hotel was built. Now it is impossible. [...] (Interview # 1, Technical Manager of Hotel, 04/09/2018)*

Recently GSHP has been introduced in several hotels to reduce conventional energy use for space cooling and heating based on the performance of improved heat pumps. However, these hotels were challenged as public institutions took long time to approve the project

> *Above all it is the knowledge. And then the knowledge of the City Hall as well. We went to the City Hall to explain but everything we were talking [about geothermal] sounded like Chinese to them [...] having the office authorization delayed many years, really. It took them a lot of efforts to understand it. Now it seems that they have taken the momentum and the second application was [easier] (Interview # 3, Technical Engineer/Quality Manager 04/12/2018)*

Additionally, the deficient installation of GSHP, not controlled in the past, has been criticized by farmers, which left a negative perception on this type of energy.

4) Recreation sector

4.1) Golf courts and gardens for bigger hotels

In Benidorm, reclaimed water managed by the irrigators' community of Canal Bajo de Algar is finding a new application in the tourism sector. Reclaimed water use in Benidorm has played a fundamental role in reducing water stress for tourism as farmers agreed to relinquish potable water to urban use in exchange of reclaimed water for irrigation during drought periods (Rico Amorós et al , 2016). Traditionally, hotels with larger garden areas are infamous for very high water consumptions. Strong positive correlations between water consumption and garden size have been observed (Gössling, 2001). Along with drip irrigation, the use of reclaimed water it is seen as an effective way to reduce stress on potable water sources for luxurious hotels where garden areas are much bigger than those of the average hotels in Benidorm. Other recreational uses include irrigation in camp sites, conventional hotels, second homes and municipal areas. Additionally, golf courses are also maintaining their facilities with reclaimed water. It can be seen from the figure 5 that the reclaimed water use is in increasing trend with peak in 2014 and 2015 when it rained less than in other years.

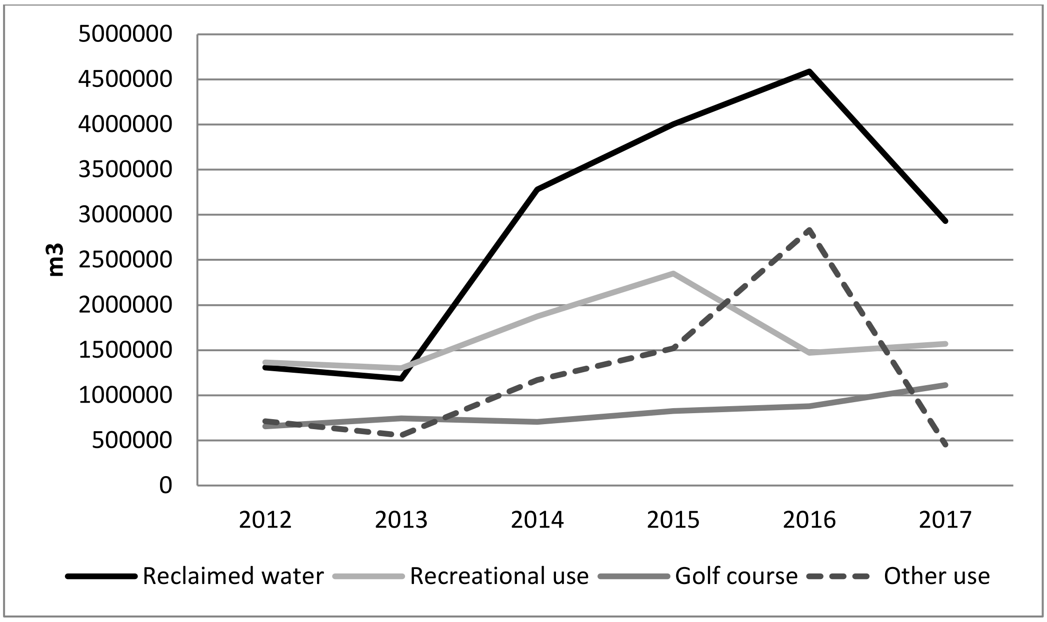


Figure 5. Reclaimed water use for tourism sector in Benidorm during 2012 -2017 (Source: El Consortio de Agua de la Marina Baja)

For agricultural irrigation, reducing water use has been partly compensated by the new purchases by the tourism sector. New urban forms and tourist amenities in the periphery of Benidorm are emerging. Amongst others, golf courses, known as a high water consuming activity of the recreational sector are starting to become one of the most important consumers for the Association of Canal Bajo Algar. They foresee that the reclaimed water use will increase especially with plans for more golf facilities.

4.2) Water theme park

The thirty-year-old aquatic park located in Benidorm is open during the summer season (April to October). During the season, it runs on saline water supplied from three wells with pumps of 50hp (37.285 kW) (flow rate 14m^3/h), and two smaller 25 hp (18.642 kW) - with a total flow of 500m^3/hour withdrawing from head of 140 m, 120 m and 170 m, respectively. Saline water is improved with sand filters. Moreover, the park is equipped with two water tanks of 1 000 m^3 each with the difference in level of 33 m and 300 m of impulsion for the swimming pools.

Table 7. Information on volume of pools and treatment for recirculation of water (source: information sheet from official inspection, 2009)

Pool size	N	total of pumps (average)	Water flow filtration (m^3/h) (range)	Average treatment cycle (h)
Less than 500m^3	5	6 (1.2)	272 (188-400)	0.72
500 to 1000m^3	0	-	-	-
1000 to 1500m^3	1	2	900	1.17
Greater than 1500m^3	3	7 (2.3)	856 (800-900)	2.77

Primary data collected from the waterpark confirms that, initially, the pools with a total volume of 8956.39 m^3, filtered hourly about 50 % of total volume of water (Table 7). As part of the energy and cost management, managers took advantage of the electricity P6 tariff (approximately 8 hours in the evening, whole August and weekends and national holidays), which is the lowest of six different tolls offered for high voltage contracts. For example, P1 which is the highest price charge about 12.5 times more per €/kWh for energy consumption and about 6 times more per power access (IDAE, 2015). For example, in July 2015, 652MWh of electricity was consumed of which about 40 % was spent in the P6 tariff period.

Based on the primary data collected, a range of energy (electricity) intensity of water use was calculated, with a minimum based on the off season and a maximum on the peak season. We hypothesized that around 2, 5, 7, 10, 15 and 20 % of daily water flows required refilling. During the peak season the facility was run 12 hours and daily. The facility run during 5 months (150days) and was left inactive during the rest of the year. Table 8 summarizes the result of simulated calculation of the energy intensity of the aquatic park which varies on the level of ground water recharge required. It is important to note that the diminishing energy intensity does not refer to a better performance as it implies more extraction of groundwater already suffering salt intrusion. During the months when the waterparks are closed, the energy intensity for water is reduced to 7.83 kwh/m^3 while during the high season energy intensity for water increases, ranging from 17 to 23 kWh/m^3 depending on the daily groundwater recharge rate. It is also estimated that the year-round energy intensity for water would range from 8 to 19 kWh/m^3, which is quite high compared to other water related activities.

Table 8. Assumptions per groundwater recharge % and energy intensity of water (Source: Own elaboration)

Water use in consideration	Total (annual)	Minimum (monthly)	Maximum (monthly)
Only potable water use (P) (kWh/m^3)	24.32	7.83	33.51
P + groundwater recharge 2%	19.17	-	23.38
P + groundwater recharge 5%	15.48	-	22.10
P + groundwater recharge 7%	13.72	-	21.32
P + groundwater recharge 10%	11.72	-	20.25
P + groundwater recharge 15%	9.43	-	18.68
P + groundwater recharge 20%	7.89	-	17.34

Last, the major problem detected in the field visit was that saline water, after backwashing the filters, was released directly to the sewage network. The influx of saline water into wastewater treatment plants increases the conductivity rate, resulting in more energy needed in the tertiary treatment plant preparing water for irrigation or gardening where conductivity is an important parameter. Thus, this operation system had adverse impacts on the overall energy intensity of the water cycle not only in Benidorm but also in the nearby areas.

5) Discussion and Conclusions

The results illustrate the various processes within the hotel and recreational sectors that require both energy and water. We have explored the regional context of the Water Energy Nexus (WEN) and have identified some of the challenges observed in terms of WEN in the mass tourism activities of Benidorm. As part of the WEN approach, the measurement of the energy intensity for water (especially in terms of fossil fuel use) is proposed for a better understanding of energy transitions. WEN-based analysis reveals the fossil fuel dependency for water heating and steam production, which is considered as one of the most energy intense water use at the demand end. Due to the mild climate of Benidorm, the use of energy for hot water may not be as large as in hotels in other regions. However, the popularity of water intensive activities such as spas or climatized pools, requires more attention as they imply water uses highly energy intense.

At the demand end, WEN analysis also highlights the limitations of using energy intensity for water (kWh/m^3) since it cannot be a single indicator but should be accompanied by water or energy use intensity (m^3/gn and kWh (or MJ)/m^2 or J/gn·m^2) in order to evaluate environmental impact. Energy intensity for water may signal false performance improvements for example, when energy consumption is constant and water use increases. Or, in relative terms, the electro domestic appliances tend to have much higher energy intensity compared to other WEN activities such as heating or pumping water. This could be read as a sign of worsening of environmental performance but, on the other hand, may have reduced energy and water use intensity in overall with the input of more energy per water used.

However, in the long run, focusing on the measurement of environmental management practices using the WEN approach will provide coherent and reliable data to measure and compare efficiency in the hotel sector. The current tendency of environmental performance management centered around cost control presents limitations in addressing the efficiency due to price fluctuations of resources. Considered alone, energy or water use also fails to address the significance of WEN in providing the comfort and convenience so central to the hotel sector.

Moreover, HVAC systems based on efficient heat exchangers using water as medium, are increasingly chosen as sustainable technological option instead of traditional air-conditioning and furnaces. In terms of WEN it reduces both energy and water consumption for the same comfort level providing a win-win situation. However, as seen in the case of Benidorm, a careful evaluation is required on the source of the medium (water), whether it is open or closed system, and how and from where it is extracted and returned. Hotels with access to groundwater are increasingly adopting GSHP based on the highly efficient titanium heat exchangers. If applied to a larger number of hotels, there is a danger that there will not be a sufficient water flow and natural capacity for heat dissipation. In cases of deficient operation, it may even cause further seawater intrusion into the aquifer. It is foreseen that GSHP installations are likely to spread out quickly in the hotel sector of Benidorm.

The WEN approach also reveals a trend of incorporating unconventional energy and water sources in different economic sectors. This also shows the shortcomings of quantitative measures of sustainability based solely on the energy intensity of water. For example, the energy use for clean surface water extraction may have lower *energy for water* compared to recycled water that requires tertiary treatment. However, the use of recycled water reduces water stress in the region providing opportunity for other sectors to have potable water. Therefore, along with quantitative measurements important questions are for example, what resources are being used to provide what type of comfort and services, by mobilizing which part of the water cycle, and through what (social, technical, and ecological) processes. In general, the transition from WEN based on fossil fuel use and potable water generation to

WEN based on renewable energy and reclaimed water sources should be evaluated as a positive sign for the environmental performance of mass tourism.

In the same line of thought, reducing the energy costs of reclaimed water is considered essential for the hydrosocial cycle of Benidorm. Thus, the Canal Bajo Algar is concerned about the water quality of urban effluents, particularly, of salinity as the cost of reducing conductivity in tertiary treatments is directly related to higher energy inputs. Initially, GSHPs were blamed as some hotels did not reintroduce the groundwater extracted to the aquifers and released it to the urban sewer network. However, recently, all existing GSHPs have installed additional pumps to ensure reinjection of groundwater into the aquifer. Therefore, it seems most likely that the cause of increased conductivity found in the waters entering the treatment plant is coming from the aquatic park that uses saline water to run its facility during the summer months. Moreover, uncontrolled groundwater use in swimming pools and toilet flushing in hotels contribute to increased salinity levels in wastewater. This reveals how recreational facilities and activities may have an impact on the whole cycle while environmental externalities are neglected by the responsible stakeholders. Consequently, the costs of higher treatment are passed on to the population and the environment whereas those responsible remain benefit from the exploitation of groundwater. In this sense, WEN approach may be able to assign responsibilities regarding the increased conductivity and point out externalities which have not been considered before.

Perhaps the major limitation of the WEN approach is the low awareness of this in the hotel and recreational sectors. The WEN is rather a new concept and maybe a challenge for mass tourism to recognize the term, where the presumed greater efficiency of the high-density city is proudly perceived. Even though our study has found a good potential for the consideration of the WEN within the hotel and recreational sectors, the current socio-technological regime in Benidorm seems to be far from prepared to challenge the idea as their main focus lies in cost savings rather than environmental friendliness. Only a few hotels have developed a vision of improving their environmental performance, but others admit that their interest remains in profit and providing the services to tourists regardless of environmental matters. This unequal interest explains to an important extent the current state of data management of energy and water use. Technical managers often keep their water and energy logs disconnected from guest nights. Moreover, rarely energy and water are managed per sector in hotels. Moreover, bigger facilities such as luxury hotels seem to perform better due to their scale. However, for smaller hotels, the environmental approach to hotel management is still far from being perceived as attractive and feasible. Therefore, it makes it difficult to quantify the impact over the choices on different services and functions and the externalization of some activities in terms of WEN. The complexity of choosing technologies and managing the workers' daily practices also proves difficult to gauge which solution would bear the most sustainable solution for the hotels.

The conservation nexus must be highlighted to visibilize the transition to green energy as it reduces greenhouse gas emissions and furthermore contributes to reducing the water use for energy. Therefore, solar thermal energy, biomass and geothermal energy, found in Benidorm, result in overall water savings. For example, according to the analysis by Hardy et al. (2012), solar thermal energy only requires 8 % of the water required for nuclear energy. In the same line of thought, WEN in reclaimed water use is seen as one of the most promising the socially and environmentally options to reduce the water stress for potable water. The propagation of use of reclaimed water contributes to the conservation of energy as their energy intensity for water is lower compared to other water sources that are sourced, such as desalination. In the Benidorm area, the energy consumption of desalination plants can be six times higher than the energy required for reclaimed water (Yoon et al., 2018).

On the institutional dimension, stronger top-down institutional initiatives for improving the sustainability of the tourism sector are needed. During the recent years, some pioneering hotels have adapted innovative technologies looking at synergies between cost reduction and environmental performance improvement. Technological uncertainty still holds some hotels in doubt even though they are keen on the topic of conservation. The exploration of new and unconventional technologies led by some of the innovative hotels is driving the change in WEN, while other hotels maintain facilities based on fossil fuel, largely diesel boilers. However, sociotechnical changes in the region with the installation of natural gas the removal of bureaucratic hurdles for new technologies and the continuance of mass tourism flows puts pressure on the more conservative hotels.

The WEN as a concept highlights the interconnectedness of water and energy that is less visible in current management practices. However, units such as kWh/m^3 must be used with caution along with questions to value different technologies and energy carrier choices that emphasize win-win solutions between water and energy refraining from possible (and not so positive) trade-offs.

Supplementary data

Fuel type	Value	Unit	Category
Diesel	9.85	kWh/L	Low calorific value
Propane	12.83	KWh/Kg	Low calorific value
Butane	12.44	KWh/Kg	Low calorific value
Natural gas	11.24	kWh/Nm^3	High calorific value
Biomass (Olive seed)	4.48	kWh/Kg	Low calorific value

Table A. Conversion to calorific value used for different type of fuels (i.e. LPG 0.51kg/L) cf. 1 kWh =3.6 MJ (Source: IDEA 2014)

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4 The WEN of Water and Energy Vulnerability – The Case of Barcelona Metropolitan Area

4.1 Politicization of Energy and Water from the Vulnerable – The Case of Energy Poverty and Water Poverty in Barcelona[10]

RESUMEN

En los últimos años, la sensibilización sobre la pobreza energética e hídrica – una situación de indisponibilidad de energía y agua suficiente para mantener las condiciones de vida básica o estándar en el hogar– ha comenzado a ser reconocido como un problema social en Cataluña. En 2015, los movimientos sociales promovieron una Ley de Iniciativa Popular (ILP), consiguiendo la promulgación de la primera legislación autonómica en España que reconoce el derecho a los servicios básicos para la población vulnerable. Este éxito deriva de contextualizar la pobreza energética y hídrica desde un problema individualizado hacia un problema socio-económico y político. En este trabajo intentaremos ampliar el espectro del estudio sobre la pobreza energética incluyendo la pobreza hídrica (o hídro-vulnerabilidad) para obtener una perspectiva holística y crítica que se basa en la ecología política. Según este enfoque el metabolismo doméstico de la energía y del agua debe entenderse como resultado de procesos multi-escalares y multifactoriales, por ejemplo, la gestión de los recursos en el hogar, la privatización de los servicios públicos de agua y energía, la crisis de la vivienda en España, y la discordancia de los medios de comunicación y las iniciativas institucionales entre de diferentes escalas de gobernanza. Se trata por tanto de una lucha continuada de la población vulnerable para politizar la energía y el agua. Como ilustraremos para el caso de Barcelona, este proceso conlleva consecuentemente un cambio ascendente en la distribución desigual de los recursos.

Palabras clave: pobreza energética, pobreza hídrica, movimiento social, ecología política

ABSTRACT

In recent years, the awareness on water and energy poverty - the situation where one is not able to have sufficient energy and water at home to maintain basic or standard living conditions - has dramatically turned around in Catalunya and begun to be recognized as a compelling social problem. Strong social movements initiated a citizen-led law and conduced the first regional legislation recognizing the rights to basic utilities for the vulnerable, the first of its kind in Spain. This success infers from contextualizing water and energy poverty as an individualized problem to a socio economic and political problem. The case study allows us to expand the spectrum of the energy poverty study to include water poverty (or water affordability) and to gain critical perspective rooted in political ecology on understanding the domestic metabolism of energy and water as a confluence of multi-scalar and multifactorial process such as resource management at domestic level, privatization of water and energy utilities, Spanish housing crisis, lack of awareness or political will and discordance of institutional means and initiatives across different scales of governance. Moreover, it is a continued process of vulnerable population to politicize energy and water and to consequently bring a bottom-up change in the unequal resource distribution.

Keywords: energy poverty; water poverty; social movement; social movement; political ecology;

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1. INTRODUCCIÓN

Una de las condiciones para una vida digna en una sociedad moderna del siglo XXI es la disponibilidad de unos recursos básicos como energía y agua en los hogares , en ciertos casos considerados como derechos humanos (IDHC, 2004). La privación de energía en los hogares ha llamado la atención de los académicos desde la década de 1980, empezando en el Reino Unido, pero siguiendo rápidamente en otras partes del mundo, a partir de distintas metodologías de trabajo (Boardman, 1991; Bouzarovski, 2014; Brunner, Spitzer, & Christanell, 2012; Devalière, 2007; Healy, 2003; Hills, 2012; Walker, Simcock, & Day, 2016). En Europa, a la mayor parte de estos estudios se han centrado en los países septentrionales aunque la sensibilización sobre dicho problema ha aumentado también en los del sur como España, especialmente durante los últimos cinco años. La pobreza energética se refiere a una situación en la que un hogar no puede asegurar un servicio energético suficiente, debido condicionantes sociales y materiales (Bouzarovski, 2014). Esta situación provoca una escasez doméstica que obstaculiza la participación en los estilos de vida, costumbres y actividades que definen la pertenencia a una sociedad (Buzar, 2007). De manera similar, la pobreza hídrica, en este estudio, se refiere a una situación en la que un hogar no puede mantener el servicio de agua doméstica.

En España, la pobreza energética e hídrica está reconocida como un problema social enmarcado en un contexto de bajos ingresos e inestabilidad laboral derivados de la crisis económica y el aumento de precio de la electricidad desde 2008 (Tirado Herrero & Jiménez Meneses, 2016). Según el estudio de Tirado Herrero et al. (2016), un 15% de la población española gasta más del 10% de sus ingresos para pagar sus facturas de electricidad y un 11% afirma que tiene dificultades para mantener la temperatura adecuada en su hogar. En Cataluña, se estima que un 18.7% de la población catalana gasta más del 10% de sus ingresos para pagar sus facturas energéticas (Sabes-Figuera & Todeschini, 2016). En el caso del agua, no existe un análisis a nivel español ni catalán, pero un 8,3% de los hogares del Área Metropolitana de Barcelona cuyo suministro de agua está gestionado por Aguas de Barcelona, filial del grupo AGBAR dedica más del 3% de sus ingresos a mantener el consumo de agua vital de 100 Lpcd (litros por persona y día)(Todeschini, Casado, Sabes, & Sanz, 2015). El reconocimiento de estos problemas ha aumentado en Barcelona debido al incremento del número de hogares que sufren carencias de energía y agua y a raíz de varios incidentes mortales ocurridos en Cataluña , que han dado un fuerte impulso al lema 'la pobreza energética mata'.

Uno de los principales actores detrás de la sensibilización sobre el tema de pobreza energética e hídrica en España es la Alianza contra la Pobreza Energética (APE), un movimiento social nacido en 2013 formado por varias organizaciones como diversas Asociaciones de los Vecinos, Plataforma Afectados por la Hipoteca (PAH), Unión de Consumidores de Cataluña, Observatorio de la Deuda en la Globalización, Agua es Vida y Red por la Soberanía Energética. A pesar de que la APE actúa en Cataluña, está liderando discusiones sobre el tema con un impacto estatal. Destaca su visibilidad en los medios de comunicación a través de sus acciones directas o intervenciones que desculpabilizan a los afectados. Este articulo trata de explicar el ascenso de la sensibilización sobre la pobreza energética e hídrica en los discursos, tanto a nivel coloquial como a nivel político, haciendo hincapié en el papel de la APE.

El trabajo utiliza una metodología-mixta, que consiste en observación participante, entrevistas semi estructuradas e investigación acción para realizar un estudio, inspirado en dos estrategias analíticas: 1) el binomio agua-energía (Voinov & Cardwell, 2009) y 2) la ecología política (Hilbert & Werner, 2016) con el fin de aportar una visión crítica sobre la pobreza energética e hídrica.

Los dos marcos teóricos nos permiten acercarnos al problema de energía y agua de una manera global, por cuanto ambos recursos tienen una importancia vital en el metabolismo socio natural del ámbito doméstico (Kaika, 2004). A través del caso de estudio, se trata de ver como un movimiento social está logrando visibilizar la pobreza energética e hídrica como un problema multi-escalar y multi-factorial que provoca una situación de escasez de recursos construida en el hogar, al tiempo que refleja el problema directamente en la experiencia vital de los afectados (Brunner et al., 2012; Middlemiss & Gillard, 2015). Para explicar el caso de los afectados de Barcelona, utilizamos el concepto de lo 'ominoso' (uncanny) en el ámbito doméstico (Kaika, 2004), describiendo una situación *unhomey* en el hogar en términos de inseguridad o incomodad. Este argumento nos sirve para dar impulso a la politización de la pobreza energética e hídrica.

El artículo consta de seis secciones. En la siguiente sección introduciremos el papel de la APE en dar visibilidad y contextualizar la pobreza energética e hídrica. En la tercera sección, nos concentramos en la complejidad y los matices en la vida cotidiana de los afectados. En la cuarta sección, explicaremos el éxito de la iniciativa legislativa popular (ILP), el proceso 'bottom-up' que ha conducido a la primera ley catalana que aborda la privación de energía y agua en los hogares. En la quinta sección, trataremos discutir el empuje de los afectados y su potencial de lidiar con el modelo energético e hídrico y acabamos este artículo con una conclusión.

2. VISIBILIZAR Y CONTEXTUALIZAR LA POBREZA ENERGÉTICA E HÍDRICA

La invisibilidad de la pobreza energética e hídrica constituye un gran enigma, ya que se trata un problema que los miembros de familia padecen en un espacio doméstico, percibido como un lugar de protección, el cual se define con las características de seguridad e intimidad. Por tanto, nos referimos a un tipo de pobreza muy oculta. Por ejemplo, la mayoría de las veces, los afectados no quieren mostrar sus problemas hasta al punto que éstos se vuelven crónicos. Muchas veces sienten vergüenza y miedo a exponer su problema de pobreza energética e hídrica en público; síntoma común que también se ha observado desde la 'experiencia vivida' (lived experience) en otros países (Middlemiss & Gillard, 2015).

> "… el 2014 (donde) me quedo sin luz, sin agua, sin gas, y me asusto, pero me asusto mucho porque te genera mucha impotencia, se te hunde el mundo, por eso cuando ves en las reuniones, en las asambleas, la gente que te dice: qué miedo, que esto y lo otro, es que es verdad, es verdad… Si encima de eso hay personas que no tienen personalidad o carácter, o empuje, o no tienen para ir pa' delante, peor…te encierras en ti mismo, te entra el miedo de tal manera que ni te moverías de la cama, y estarías allí a ver qué pasa." (J. Entrevista)

Además, un país como España donde la relaciones familiares son muy importantes, muchos de estos problemas se comparten entre familias, para ayudar a cubrir pagos y deudas, de modo que tardan más en ser visibles.

La APE, con su práctica del asesoramiento colectivo, ha creado un espacio abierto en el que los afectados pueden exponer sus problemas, ayudarse mutuamente, y participar en acciones reivindicativas directas que transforman a los afectados y los empoderan (Casellas & Sala, 2016) actuando cada uno como un agente de cambio y monitores de su propio entorno. Cuando se da la bienvenida a nuevos afectados, se dedica tiempo a cambiar la percepción del problema y desculpabilizar a las personas afectadas. En dicho cambio, el problema que antes pertenecía a la esfera individual pasa a convertirse en un problema estructural y colectivo.

Este intento de contextualizar y cambiar discursos se muestra en una acción que se llevó a cabo en 2015 (ver figura 1), culpabilizando al gobierno de Cataluña que tomaba una posición pasiva a la hora de abordar la pobreza energética e hídrica. En la misma línea de la campaña, la APE también ocupa las sedes de las compañías eléctricas para exigir el derecho a disponer de suministro eléctrico en los hogares.

Figura 1. 'El gobierno de la Generalitat marioneta de las empresas suministradoras' desde La campaña #oscurasmarionetas, 12 Marzo de 2015 (Fuente: Facebook APE)

Por tanto, la APE está visibilizando una realidad más compleja sobre la pobreza energética, desde una perspectiva '*bottom-up*'. De esta manera, esta organización logra formar discursos que desculpabilizan y desindividualizan el problema, exigiendo una mayor responsabilidad al sector eléctrico e hídrico, y tratando de transmitir esa información a los afectados y a la sociedad.

3. INTRODUCIENDO COMPLEJIDAD Y MATICES AL PRIVACIÓN DE SERVICIOS DOMÉSTICOS BÁSICOS

La corriente principal de la teorización de la pobreza energética proponía tres factores causales - ingresos bajos, (in)eficiencia energética y precio de la energía (Pye, Dobbins, Baffert, Brajkovic, & Grgurev, 2015). Sin embargo, en realidad la experiencia de un hogar es mucho más compleja y sus necesidades presentan muchos matices (Bouzarovski, 2014).

Las dinámicas de la pobreza energética e hídrica en el hogar parten de que la energía y el agua forman parte de los presupuestos de un servicio básico para una vida digna. Además, asegurar ambos recursos es muy necesario para tener una vida cómoda, considerando que casi 45% del uso de agua doméstica se destina a obtener agua caliente. Por lo tanto, no solamente llegan con casos de privación de energía sino que comparten también problemas con el agua. Para los afectados de la APE, el problema se expresa directamente en la dificultad de pagar la factura desde el principio, aunque en el proceso de asesoramiento surgen otros factores causantes: instalación eléctrica obsoleta, mala condición de la vivienda, problemas con los electrodomésticos, mala contratación del servicio, falta de información o problemas financieros (Brunner et al., 2012).

La mayoría de los afectados se dirige a la APE por la dificultad de asegurar el suministro de electricidad por su coste más elevado en comparación con el agua o el gas. Al tener también la ayuda del fondo solidario del AGBAR, la carga de pagar agua se alivia bastante. Sin embargo, con el bono social de la electricidad, que se aplica solo al coste del consumo y no a los otros costes, las familias no notan el impacto del descuento, al tener un nivel de consumo de energía muy bajo, llamado 'Hábito de la modestia' (Habitus of modesty) (Brunner et al., 2012). El nexo entre agua y energía, en la experiencia de la APE, ayuda a los afectados a llegar a entender la gestión de dos recursos de dos maneras diferentes. Pero sobre todo, esta noción de nexo agua-energía expone la privatización del sector eléctrico y el sistema oligopólico de la empresa contra el que se incentiva la oposición.

Los afectados por la crisis de la vivienda – que residen en una casa ocupada o por un fraude no disponen de un contrato en vigor – destacan como los casos más difíciles de resolver. La compañía eléctrica se niega a poner la luz, cuando en realidad los hogares no tienen otra opción de vivienda, ya que no disponen de un contrato. Además, los trámites para conseguir una cédula de habitabilidad o un boletín azul[11] suponen muchos obstáculos. En una situación sin salida, los hogares muchas veces consiguen una conexión ilegal ("pinchar la luz") y entran conflicto con las comunidades de vecinos, viviendo con la amenaza constante del corte de suministro bajo ansiedad, vergüenza y estrés. La mayoría de las veces, se quedan en una zona muerta, invisible, porque la administración actúa con indiferencia y entran en un círculo vicioso porque la conexión ilegal está sujeta a multa, que, a su vez, significa una barrera económica costosa para conseguir la reconexión.

Así, la experiencia vivida por los afectados muestra una dinámica compleja en el entorno doméstico por cuanto el suministro del agua y energía está plagado de factores sociales, tecnológicos y económicos. En la siguiente sección explicamos cómo la sensación de urgencia y la campaña del movimiento llevaron este problema social al terreno de la política y la legislación.

4. INICIATIVA POPULAR Y LA NUEVA LEGISLACIÓN

El primer caso de politización de la pobreza energética fue presentado en 2013 por primera vez en el Parlamento español y pareció que la vulnerabilidad energética había entrado en el debate político de manera muy rápida (Tirado Herrero, 2013). En aquel momento, PSOE e Izquierda Plural, propusieron unas mociones ante el parlamento en las cuales, aunque cada uno con diferentes palabras, abordaban el tema de la pobreza energética. Especialmente, la moción de Izquierda Plural, demandaba una tarifa social para la electricidad, gas natural y el gas butano, así como y una auditoria en el sistema de establecimiento de la tarifa eléctrica, más ambiciosa que la del PSOE. Lamentablemente, ninguno de las dos mociones resultó aprobado y la discusión sobre pobreza energética desapareció del parlamento hasta una fecha muy reciente. Así, el primer intento de politizar la pobreza energética desde una perspectiva '*top-down*' había fracasado.

En 2015, un movimiento '*bottom-up*' logró politizar la pobreza energética e hídrica en Barcelona a través de la denominada Iniciativa Legislativa Popular (ILP), objetando que la regulación a nivel estatal de la pobreza energética no se correspondía con la recomendación de la directiva de la UE (ver tabla 1). Dicha iniciativa ha sido difundida por tres organizaciones – la PAH, la APE, y la Observatorio DESC, a través de unas campañas llamado ILP Vivienda (*ILP Habitatge* en catalán) en las cuales han propuesto mesuras contra desahucios y la pobreza energética. Por lo que se refiere a la pobreza energética e hídrica, se propuso una legislación que paraliza los cortes para garantizar el acceso a la energía y agua. Para aumentar la concienciación ciudadana y para reflejar el problema de los cortes a la escala autonómica, la campaña en su página web daba indicación del número de cortes del suministro que la ILP podría frenar.

[11] Es un documento oficial emitido por un electricista autorizado en Cataluña, que certifica que la instalación cumple con todos los requisitos necesarios para el suministro eléctrico. Es necesario para pedir una alta nueva de la electricidad, o aumentar de potencia eléctrica y se caduca después de 20 años.

Tabla 1. Regulaciones sobre la pobreza energética a diferentes niveles

Nivel de escala	*Leyes de referencia*	*Contenido*
EU	2009/72/EC, 2009/73/EC MS, 2010/31/EU, 2012/27/EU	- Se recomienda desarrollar un plan de acción nacional u otro marco de referencia contra la pobreza energética - Se recomienda definir los consumidores vulnerables - Se recomienda invertir en la mejora de la eficiencia energética con prioridad para ayudar potencialmente a erradicar la pobreza energética
Estatal	Ley 24/2013, de 26 de diciembre	- Menciona consumidores vulnerables sin definir - Aplica el bono social a los consumidores vulnerables en el mercado regulado - El coste del bono social está en discusión
Cataluña	24/2015 de 29 de julio	- Prohíbe los cortes según su vulnerabilidad económica - Derecho al suministro básico - Con principio de precaución, los suministros no se puede cortar si no les confirman su situación de vulnerabilidad los Servicios Sociales a la compañía

Las tres organizaciones lograron recoger en conjunto 143,380 firmas entre la población catalana, tres veces más de la cantidad mínima necesaria para poder presentar una ILP en el Parlamento Catalán. Posteriormente, las negociaciones internas entre los partidos con representación parlamentaria han tenido como resultado la promulgación del decreto 24/2015 de 29 julio de 2015, bajo la medida de emergencia. Esta ley defiende el derecho a la vivienda y los suministros básicos, abordando el acceso a la electricidad, el gas y el agua. Además, prohíbe el corte de los suministros de las familias en riesgo de exclusión social. Progresivamente, la ley también demanda que las empresas creen y doten económicamente un fondo social para ayudar la población vulnerable.

Por otra parte, la promulgación de la ley catalana derivó en un proceso político influido por el conflicto entre el gobierno español y el catalán. En el principio del proceso de negociación, la mayoría de los partidos representados en el parlamento (CUP, PSC, ERC, ICV-EUiA y Ciutadans) confirmaron sus apoyos a la ILP. Sin embargo, el Partido Popular se opuso y CiU (el partido nacionalista catalán) no demostró una posición clara ante la propuesta. La comisión ILP, con apoyos de la APE y la PAH, lanzó una campaña fuerte contra estos dos partidos políticos durante sus campañas electorales para dañar sus imágenes sociales. Como consecuencia, PP y CiU cambiaron su posición, aunque en ello también intervino por parte de CiU el interés político derivado conflicto con el gobierno español. La culminación del conflicto coincidió con la campaña y así, el proceso legislativo de la iniciativa popular tuvo lugar en el momento oportuno.

La legislación marcó una nueva etapa para la APE en establecerse una comunicación de colaboración con el gobierno catalán, cuya acción administrativa tomó en consideración el conocimiento de la APE, implicada directamente en este tema. Además, ya que el decreto 24/2015 impone la firma de un convenio entre la administración y las empresas eléctricas estas últimas estarán sujetas a comunicar y llegar a un acuerdo con las condiciones que establece la comunidad autónoma, aunque la electricidad dependa de la ley estatal.

La agencia política de la ILP es importante por su poder de proyectar el tema a nivel estatal. La ley catalana llamó la atención de las empresas y de los políticos, y el PP la llevó al Tribunal Constitucional alegando su inconstitucionalidad. Consecuentemente, una parte de la ley catalana esta invalidada hoy en día, aunque la parte que aborda la pobreza energética e hídrica sigue en vigor.

Respecto al bono social, la APE ha criticado el Real Decreto ley 7/2016, de 23 de diciembre donde se regula el mecanismo de financiación del coste del bono social y otras medidas de protección al consumidor vulnerable. La discusión está en marcha: el coste del bono social ahora está en duda, porque la empresa eléctrica, enfáticamente, se niega a cubrir el coste total involucrando la administración pública, rechazando la plena responsabilidad cuando la APE requiere que el fondo sea una contribución de las empresas tanto de distribución como de comercialización y se incluyera una población vulnerables más amplia desde el principio. Sobre todo, la APE demanda que se aplique el principio de precaución para determinar la interrupción del suministro a consumidores vulnerables tratando de transmitir la experiencia de la ley catalana.

Por otro lado, las empresas de agua mantienen una posición mucho más ágil para responder a la necesidad de los afectados debido a la gestión de los recursos que siempre ha sido reconocido como una cuestión local. AGBAR cumple su responsabilidad social a través de Fundación AGBAR, pagando la mayor parte de la factura de las familias afectadas desde el Fondo de Solidaridad de Aigües de Barcelona. Así que en el discurso sobre la ley catalana, el conflicto se concentra mucho más en las empresas eléctricas, especialmente Endesa y Gas Natural.

5. LO ‘OMNIOSO(UNCANNY)’ DOMESTICO A POLITIZACIÓN DE LA POBREZA ENERGÉTICA E HÍDRICA

En esta sección trataremos de discutir los impactos sobre los afectados y su potencial de lidiar con el modelo energético e hídrico basándonos en el caso de Barcelona. Desde el enfoque de la ecología política, el espacio domestico se contempla como una plataforma donde se metaboliza agua y energía (Kaika 2004). Como explica Kaika (2004), el espacio doméstico, está segregado del exterior pero con una división porosa que permite la penetración de los flujos materiales desde el exterior, aunque ideológicamente los espacios interiores se hayan constituido de manera independiente y desconectada de procesos naturales. Debido a esta esta porosidad, vivimos en un entorno doméstico donde los equipamientos y las tecnologías del suministro del agua y energía, como, por ejemplo, las bombas, cables eléctricos, etc. están todos escondidos. De igual manera, los procesos necesarios para suministrarlos a la ciudad están separados de los hogares.

El proceso socionatural responsable de los recursos básicos no queda reflejado en los hogares, así que fácilmente olvidamos que se tratat de recursos que necesitan unas redes materiales y sociales extensas (Kaika, 2004). Cuando un hogar empieza experimentar la pobreza energética e hídrica, en el espacio domestico se crea una situación ‘ominosa’ como explica Kaika (2004) que, apropiándose del Freud(1919), convierte lo *homely (*Hogareño*) en unhomely* (o no hogareño). Así, en el hogar se empiezan a experimentar dos situaciones diferentes de privación. Una, puramente física, de carencia de energía y/o agua y otra, más psicológica, de privación de lo hogareño y del derecho a una vida digna, que crea una situación ominosa en el hogar.

En la APE, cuando un afectado empieza exponer una situación inusual e incómoda de pobreza energética e hídrica, no solo expone su situación dentro del hogar sino también se refiere implícitamente a redes materiales y sociales y al modo de gobernanza en torno a la energía y el agua. Principalmente, la toma de conciencia del afectado se inicia cuando empieza a entender y a cuestionar diferentes conceptos de una factura o una comunicación del corte o deuda – potencia contratada, el coste de peaje, impuestos, cánon para tratar las aguas residuales, el coste del alquiler del contador, empresa de cobro, fusibles etc. En una situación más grave de corte de suministro, los afectados empiezan a rebelarse en las redes por su necesidad de salir de una situación ominosa, instalando conexiones ilegales para conseguir los recursos necesarios. Por esta razón, las discusiones en el asesoramiento colectivo de la APE suelen ser muy extensas y técnicas.

A través de la estrategia de la APE de hablar caso por caso y de compartir cada paso, los afectados suelen discutir no sólo sobre los bonos sociales, sino también sobre temas más profundos del proceso político, por ejemplo ¿quién ha creado el sistema?, ¿quién debería ser responsable del coste del fondo solidario?, ¿por qué el precio de la factura no se baja a pesar de consumir poco?

La disrupción de flujos de energía y de agua trae consigo un impulso y un interés para entender los factores a otras escalas. Por ejemplo, la relación con los servicios sociales tiene un mayor impacto por el hecho de poder aprovechar fondos supra-municipales y autonómicos. Sin embargo, los servicios sociales tienen menos influencia sobre las compañías eléctricas porque éstas obedecen a la regulación estatal.

Así, los afectados y su experiencia revelan aspectos multifacéticos que empujan el proceso '*bottom-up*'. El caso de Barcelona muestra como las campañas de sensibilización han dado la voz a los afectados a través de un movimiento social que ha luchado para una población vulnerable. Sus reivindicaciones han logrado la aprobación de una ley de protección, aunque la lucha continúa para conseguir la reforma de las tarifas, la condonación de la deuda de los afectados, para eliminar las malas prácticas de las empresas, etc.

6. CONCLUSIÓN

Vivimos en una época donde las necesidades pero también los estándares de vida han aumentado gradualmente desde hace unas décadas (Brunner et al., 2012). Sin embargo, los hogares de la pobreza energética e hídrica viven en una situación de privación de los servicios esenciales que les proveen estos recursos y que crean una situación de vulnerabilidad económica y dificultades para pagar.

En el debate actual sobre la pobreza energética e hídrica en Barcelona hemos llamado la atención sobre las condiciones de vida de los hogares vulnerables destacando el derecho de tener los suministros básicos, para mantener una vida digna. APE, un movimiento social liderando el discurso de la pobre energética e hídrica, ha expuesto los casos visibles a la sociedad y ha llevado a cabo un discurso que extrae el problema desde un punto de vista individual y lo define como asunto colectivo por la responsabilidad de las empresas privadas de suministro de energía y agua.

Los afectados de la APE, resaltan la complejidad de la pobreza energética y los varios matices de las necesidades en un hogar y han logrado politizar el tema. La Ley 24/2015 de 29 de julio 2015 ha parado el corte del suministro para las familias vulnerables según el principio de precaución. Esta acción legislativa es un trampolín para el reconocimiento al derecho de tener luz y agua en casa.

Este artículo recalca la experiencia de los hogares afectados y como su impulso llega a una discusión global al tiempo que muestra otras redes sociales, económicas, y políticas de una situación 'ominosa'. La pobreza energética e hídrica saca relaciones ocultas y nos ayuda entender un problema de gran calado en la gestión de la energía y agua. A través del asesoramiento colectivo, la reforma de la tarifa o la denuncia de las malas prácticas de las empresas continúan en discusión.

A escala municipal, la experiencia de observar conjuntamente la pobreza energética y hídrica han demostrado las diferencias entre el modelo de gestión de recurso al nivel estatal y a nivel municipal. Como consecuencia, el Ayuntamiento de Barcelona está planteando una comercializadora de electricidad municipal. Al nivel estatal, la politización ha estimulado a las compañías eléctricas a empezar un proceso de redefinición del bono social. Por un lado, la sensibilización sobre el tema ha aumentado de manera relevante, pero, por otro lado, la politización ha empujado a la empresa a proporcionar medidas en contra de la pobreza energética sin todavía llegar a un consenso social o una definición de estos conceptos en España.

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4.2 The Water-Energy Vulnerability in Metropolitan Area of Barcelona [12]

Abstract

This paper focuses on the water-energy nexus in low income households. Water, electricity and gas constitute fundamental resources for households that interplay throughout many daily activities. However, in studies on household poverty, there is a tendency to treat water and energy separately. In this contribution, we argue for the joint consideration of both forms of deprivation and present empirical evidence for the Metropolitan Area of Barcelona (AMB). In Barcelona, the dynamics between water and energy poverty in households widened the scope of institutional measures on energy poverty by incorporating water poverty as part of guaranteeing the 'right to basic utilities'. We document the interactions between the two resources through the water-energy nexus approach by combining quantitative and qualitative methodologies. Apart from presenting the expenditure-based analysis of the Spanish Survey of Income and Living Conditions, which reveals that a significant part of the population is both water and energy poor, with the results from our semi-structured interviews, we are able to demonstrate how much importance and value the affected households give to their thermal and hydric (dis)comfort, which in turn, exerts a direct impact on their daily hygiene and health. The paper also highlights how the differences in ownership and regulatory status of both resources cause discordances in public efforts to alleviate the status of the water and energy poor.

Key words: water-energy nexus; water-energy vulnerability; water poverty; energy poverty; Barcelona.

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1) Introduction

Only recently in Catalonia, and other parts of Spain, water and energy (WE) poverty has surfaced as a social problem confirming the findings of earlier studies showing high excess death rates in winter and limited affordability of vulnerable households [1,2]. At the same time, analyses conducted on income, expenditure and living conditions at regional and national levels have increased focus on energy poverty studies [3–7]. This growing visibility mainly correlates to the rising number of households incapable of securing energy and water in the aftermath of the Spanish financial and housing crisis of 2008, echoing the very ordeal and hardships faced by countries hit by financial crisis, such as Portugal and Greece [8–11]. Despite the fact that water and energy are managed and regulated by different authorities, numerous entities are speaking up more and more about WE poverty (Interview #26 18/2/2016, expert in the private sector). The vulnerability of households has reached such critical proportions that water poverty and energy poverty have caused social services to face near collapse, as suffering households poured in with unpaid bills, letters of notice of arrears, or more dramatically, cutoffs. Currently in vulnerable households, these symptoms have become chronic over time[13].

In this article, water and energy are treated as two fundamental flows for household metabolism [12]. This approach stands in contrast with most the energy and water poverty studies which tend to treat these two flows separately. Only few studies have focused on water and energy vulnerability together [13–16]. However their approach has been partial and limited to addressing either affordability [16] or accessibility [13], notwithstanding the fact that domestic hot water (DHW) use has been given considerable importance in energy studies [17–23]. Applying a mixed methodology, water poverty and energy poverty or water-energy

[13] The economic situation has improved but the majority of families in vulnerable situations have not seen any benefits. It is true that unemployment has dropped but it is still high. There have been many households which have survived and still survive with savings, unemployment subsidies, and especially family support. The problem is that many people come to Social Services when their situation of deprivation has become chronified. “In this country we have been in a situation of

vulnerability [13] is explored with the aim to unravel the complex dynamics of water and energy use in vulnerable households. In this vein, and by using the insights derived from the energy vulnerability approach, the study also attempts to expand water poverty studies to address the global phenomenon on insufficient water in various forms regardless of the level of economic development of countries – Global North or South. Furthermore, we intend to understand better how WE vulnerability is affected by the socio-technical arrangements of water and energy as commodities and, reversely, how WE vulnerability has induced changes in socio-technical arrangements by reimagining water and energy governance through community struggles. Our view aligns with recent studies that draw upon political ecology [24] to disentangle the role of social, cultural, political and economic conditions and the institutions that accompany them as WE vulnerability becomes a multifactorial and multiscalar problem [12].

The intrinsic links between water and energy have gained academic interest in the water-energy nexus (WEN) studies, which address the importance of understanding the interdependencies of WE throughout their respective cycles: acquisition, processing, transportation and end use phases. Globally many governments and international organisations have agreed on the importance of WEN to capture the positive synergies between the two resources, opt for win-win situations and avoid negative trade-offs. However, due to locked-in administrative practices, inertia that slow down innovation in administration, and lack of an institutional (public or private) architecture for information sharing between the two sectors, integrated planning for energy and water still remains a challenge. Particularly, the WEN at end-use stages underscores the challenge faced in demand management, as the studies have revealed 72% of the total water cycle requires energy [25, 26]. Concerning end-use stages, domestic resource use is particularly implicated

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economic crisis from 2008 until today. It is true that now the situation is improving, but we will not notice it in a few years because we started from very low incomes. (Interview #22, 08/02/16, Head of Social Services, Barcelona) in everyday practices, where the home becomes the place in which the metabolism of WE takes place [12, 27]. Table 1 shows various activities, technologies and energy intensities in the domestic environment of developed countries – which are crucial for thermal comfort and health. Among the various activities present in the nexus, DHW use plays a pivotal role in WE vulnerability as previous studies concluded that water heating comprises 97% of total water-related energy use [28, 29].

Table 1. Water-energy nexus in the domestic environment

Type	Activities	Appliances	% of water-related energy	Energy intensity (MJ/L)
Bathroom use (Shower/bath/ hand basin)	Hot water use for personal hygiene	Boiler or heater	100%	0.019-0.2628
Cooking	Cleaning, boiling, cooking	Stove, range, oven, microwave, electric kettles, blender etc.	35%	0.0016-0.0022 (rice)
Wet cleaning	Dish washing, floor cleaning	Dishwasher or hand washing	95%	0.130-0.145 (sink) 0.157-0.164 (machine)
Laundry and ironing	Use of water in cleaning and ironing clothes	Washing machine or hand washing, iron		0.072-0.162 (washing machine)
Drying	Removing water with energy	Hair dryer, tumble dryer	100%	778-3,615(kwh$_e$/yr, clothes dryer)
Space heating and cooling	Reduce or intensify indoor humidity	Central heating, individual heating: electronic, gas (butane, or propane), natural gas, bio palette heater, fireplace, etc.	11% (steam; indirect use)	0.1393-0.6292
Recreational use	Water service and amenities	Hot tubs, spa, swimming pools, electric waterbed	100%	5.004

Source: adopted from [19,25,30–34]

Studies conducted in Spain on residential buildings have found that 47 percent of energy demand went to heating; 21.7 percent to electric appliances; 18.9 percent to DHW; 7.4 percent to kitchen use; 4.1% to lighting and 0.8 percent to air-conditioning [35]. Compared to other parts of Spain, the AMB requires less energy for DHW in zones having a Mediterranean climate mainly due to higher indoor water temperature [36]. Studies show that apart from any geographical factor, energy consumption for DHW also depends on habits, time of the year and the purpose of building, and above all consumer lifestyle [18,36]. Winters in the AMB are considered mild compared to Northern European countries or other parts of Spain with Atlantic or continental climates. However, during the summer, hot and humid weather poses other challenges. Moreover, predictions of temperature increases and precipitation decreases due to climate change [37] raise the questions of a vulnerable household's resilience to droughts and heatwaves [38].

The quality of both WE is also important. Water impurities must be removed and water should be provided at an adequate temperature. Energy may be provided from various sources but it requires efficient, reliable, and continued supplies to guarantee quality service [26]. In the Global North, where quality is well-controlled, ensuring the vital amount of the resource in efficient conditions and at affordable costs to meet the comfort of residents is the key to solving the WE poverty problem. Efficient use mitigates the impact of climate change by reducing consumption. Moreover, nexus thinking further implies that reduced consumptions would result in saving *energy for water* or *water for energy*. There is extensive literature addressing energy and water efficiency in built environment, where various practices, innovative technological options are examined and solutions are proposed [15,32,34,39–51]. However, vulnerable homes find it difficult to afford costly retrofits or opt for technologies that require relatively high initial investments. Moreover and often due to the fact that vulnerable families live in rented flats, after renovations, landlords tend to increase rents, which can result in displacing the tenant (known as "renoviction") unless public regulations prevent such incidents [52].

Conceptually, energy poverty studies [53,54] have expanded their foci from addressing a situation where a household is unable to access physically and socially sufficient levels of energy services in the home to address commonalities in the driving forces of 'energy vulnerability' from the supply chain to end-uses [55]. The probabilistic character of 'energy vulnerability' accounts for the dynamics of households in changing time scales, as said households may experience different phases of energy poverty along their life spans. However, the concept of water poverty has been traditionally addressed separately [56–58]. As such, indicators on water poverty, e.g. the Millennium Development Goals Indicators or the Water Poverty Index, chiefly focus on the access to potable water and improved sanitation services that are inadequate for developed countries, such as Spain, where 100% access to water is guaranteed [59]. Feitelson & Chenoweth [56] highlighted the importance of domestic water supply and defined water poverty as 'a situation where a nation or region cannot afford the cost of sustainable clean water to all people at all times'. However, their assertion referred implicitly to the Global South. Contrary to energy, domestic water deprivation in the context of the Global North has garnered insufficient academic attention. Rather, studies have focused on water pricing with the objective of recovering the full cost of the water supply chain. In the review by Walker [60], the water poor are defined as 'people who may not have a sufficient supply of water at a price that they can afford'. Additionally, there is some consideration for a fair tariff design that would permit equal access to water [16,60–64]. Only recently, climate change and its adverse impact on water availability has highlighted the problem of water poverty in the households of the Global North, as increasing tariffs were predicted to add extra economic burdens on low income households [38,60,61,65], which contrasts with the comprehensiveness of energy vulnerability studies. March and Sauri suggested water poverty to be a driver behind the significant decrease of water consumption in the poorer districts of Barcelona during the crisis and post-crisis years, thereby alluding to the possibility of households with difficulties in securing the appropriate water needed for sustaining the livelihoods of these households [66].

This article expands the energy vulnerability concept to water vulnerability in order to address the problem of household water deprivation. The nexus perspective of the WE vulnerability provides an in-depth understanding of the interrelatedness of two resources at the supply level as well as the lived experiences of poor households in the AMB. Furthermore, we focus on how the socio-ecological and socio-technical characteristics of WEN affect the WE poverty of households at specific times and administrative scales [67], and how WE has helped in politicising energy and water [68] towards the (re-)municipalisation of energy and water in Barcelona. The rest of the paper is organised as follows. Section 2 briefly explains the methodology used. Section 3 contextualises the role of the water energy nexus in the WE vulnerability in the AMB. Section 4 explores the empirical evidence of WEN in the study areas. Finally, the paper discusses results and concludes with the main relevant points of this research.

2) Methodology

In order to investigate WE poverty in households as well as its causes and implications, we apply a mixed methodology, i.e. qualitative and quantitative, to process the information compiled in the AMB. [69]. The AMB consist of 36 municipalities around Barcelona with a total of 3.2 million people. In 2016, 21.2 % of the AMB households faced the risk of poverty or social exclusion. Domestic water consumption reaches an average of 103.5 litres per person (capita) per day (lpcd) [70], while domestic electricity consumption amounted to 1,131.86 kWh per person in 2014 [71].

The quantitative analysis was conducted using secondary data collected from the Spanish Survey of Income and Living Conditions [72]. Expenditure-based indicators on WE poverty were calculated to understand the extent of population facing WE poverty in the area. Water poverty was measured with the benchmark of households that dedicate more than 3% of their income to pay water bills. The expenditure on energy services is measured using the benchmark of 10% of income, including electricity, natural gas, and other fuel costs in the calculation. At the same time, it is important to note that the benchmarks applied in this study have some limitations, as they are based on the aforementioned Spanish Survey, which only offers data on actual consumption without including the desired WE consumption. Therefore, it is difficult to detect those households that reduce their consumption to meet their ability to pay, which is observed to be a common practice in vulnerable households. Households with no income would also be left out in the calculation due to computation problems. Various methodologies based on expenditure have proven to be incomplete because they overlook some segments of the population [3, 4]. We focus on the households that are at risk of poverty, namely those whose household income is below 60% of the median income. The aforementioned survey also addresses household perceptions towards the capability of maintaining adequate indoor temperature in winter as well as structural challenges related to the lack of heating and cooling.

The applied qualitative methods consisted in administering 33 semi-structured interviews conducted with key actors and experts from public administrations, utility companies, non-profit sectors and people suffering from WE deprivations (see Table A). Twelve of the 33 interviews were conducted with affected households, six of which participate in the Alliance Against Energy Poverty (APE, see below) and six who had experienced the housing crisis but are not participants of the APE.

3) WE vulnerability *nexus-ed* in the AMB

Barcelona is currently leading the discussion on water and energy poverty issues in Spain and disseminating its situation nationally and internationally. The town council of Barcelona, which is governed by the progressive left political party *Barcelona en Comú* since 2015, is taking the deprivation of energy and water in vulnerable households very seriously. Recent studies reveal that 170,000 persons (11% of the city population) are in energy poverty, either because they cannot afford the bills or they are unable to maintain adequate indoor temperatures [73]. Beyond the institutional actions of town councils, which might be limited, grassroots movements have played a critical role in raising awareness. In the Metropolitan Area of Barcelona (AMB), the Alliance Against Energy Poverty (*Aliança contra la Pobresa Energètica,* APE), a social movement created in February 2014, plays a pivotal role in raising the general awareness not only concerning the rising problem of energy poverty, but also of water poverty. Their motto 'no thirst, no cold, no darkness *(ni sed, ni fred, ni foscor* in Catalan)' aptly captures the importance given to domestic metabolism of WE for dignified livelihoods. This was influenced by the partnership with another social platform, Water is Life (*Aigua és vida* in Catalan), which works on water rights. Moreover, it also based on observing the mounting number of households suffering from the two problems. APE raised awareness on both topics with the participation of affected households, wherein they are transforming their voices into direct action by claiming rights to energy and water. The first Catalan law that prohibited electricity, gas and water cutoffs (Law 24/2015 of 29th of July) was enacted by a citizen-led initiative promoted by APE and other social entities. The law proved to be a successful case of politicising the energy and water issue experienced by the vulnerable households. Specifically, this law protects 30,000 families from disconnections as of October 2017 [68,74]. It was also the only legal instrument that considered WE poverty together. One of its most immediate effects was to force the Spanish Ministry of Industry and Energy to reform national regulations on social tariffs for essential resources [75].

4) Results

4.1) Indicators of WE poverty

The indicator based on the affordability of energy and water was conducted for the AMB population in order to estimate the extent of affected households based on the Spanish Survey of Income and Living Conditions of 2016. For energy services, expenditure for electricity, natural gas and other fuels was included in order to take into account all energy sources in households. Households that dedicated more than 10% of their income to energy services were considered to be affected households. For water services, the households that dedicated more than 3% of their income were considered to be affected. One of the primary shortcomings of the indicators based on the proportion of utility costs over total household expenses is that households with high incomes, consuming large amounts of water or energy for non-essential purposes (exceeding the benchmarks), could also be considered to be water or energy poor.

Table 2. Indicators on water and energy poverty

	Total population			Population at risk of poverty		
	Households	% of total households	Average spending in utility services (€/year)	Households	% of total households	Average spending in utility services (€/year)
Water poverty	116,089	8.86	490	95,720	7.31	345
Energy poverty (1)	93,487	7.35	1,182	88,489	6.96	1,157
Water and energy poverty, both combined	65,028	4.96	1,360	63,357	4.83	1,338

Note: (1) It includes electricity, natural gas and other fuels.
Source: [76]

In order to overcome this limitation, the population above the threshold limit, which, at the same time, were at risk of poverty or social exclusion were finally defined as affected households (AROPE)[77]. According to this criterion, 8.86% of all households in the AMB were affected households in the case of water spending at an average of 490€ per year. With regard to energy, 7.35% were affected, whereby they spend an average of 1,182€ per year. Households suffering from both water and energy poverty represented 4.96% of the total households with an average total expenditure of 1,360€ per year. Furthermore, the task of considering low-income households only reduced slightly the number of affected households. 7.31% of the total households were classified as water poor, with a mean expenditure of 345€ per year, and 6.95% were classified as energy poor (1,157€ per year). The affected households suffering from both water and energy poverty and are at risk of poverty remained around same level of 4.85% of the total households with a combined expenditure of 1,338€ per year. In other words, around one third of those households in risk of poverty in the AMB are identified as water and energy poor (34.5 % and 31.9 %, respectively), and 22.8 % suffer both water and energy vulnerability at the same time.

The result shows that most affected households were households at risk of poverty (83% for water, 95% for energy and 97% for both). The average annual expenditure in both resources was lower in the households at risk of poverty compared to that of the total households. While the tendency is more apparent for water consumption, it nevertheless implies the possibility of limiting the use of all basic commodities to reduce the household budget[14]. This is a common attitude observed in these households, which are also called 'habitus of modesty', where households restrict their use in order to avoid financial burdens [81]. The tendency to reduce their consumption may also mean that there could be households that are not detected as energy poor because they spend less than 10% of their income. As one project officer on energy renovation in social housing (RELS project) said in an interview, the problem they faced in the initial phase of the project was 'monitoring no consumption because households were not using energy' (Interview #11, 15/12/15, Housing Agency of Catalonia).

Regarding the indicator of declared thermal comfort, 8.9% of households expressed that they experienced thermal discomfort during the winter months. This correlated with the availability of central heating in households, but showed low correlation with household income. In the AMB, a significant proportion of households live with insufficient domestic equipment for thermal comfort: 35.4% of households live in houses without central heating, 2.1% without hot water for showers and 54.4% without air conditioning [82]. Due to limited affordability, many more households may not be using this resource, which suggests that official statistics may not always reflect the 'lived' experience of residents. Deteriorated living conditions that can be either a cause or consequence of energy poverty are observed as well with 17% of households reporting problems related to humidity (leaks, damp walls, floors, ceilings or foundations or rotten floors, window frames or doors), and 10.6% have limited natural light at home. Additionally, financial difficulties also impact access to appliances, such as a refrigerator, which again may not be covered by the official data. Such needs are also considered vital and are provided for by social service funds. According to one interviewee:

> *We have various help programs for these people. From what [we] have seen here, maintenance could be buying appliances. We decide in cases of urgencies and emergencies. If a person does not have a refrigerator, he/she cannot live. […] The services of the city councils of Barcelona try to the extents of their possibilities [so] that people have a minimum coverage and we help you to get out of the situation. (Interview #22, conducted on 08/02/16, Head of Social Services in Barcelona)*

The increasing problem of energy and water poverty can also be inferred from the significant reduction in domestic energy and water consumption per capita in the AMB. Domestic energy consumption for both electricity and natural gas has decreased at an average of 20% in 2014 compared to 2009, when the population began experiencing the negative impact of

[14] In Spain, there are 2.414 million consumers (as of September 2015) with social vouchers, each household spending on average 1,657 kWh per year. A household in a free electricity market spends on average 2,620kWh per year, which is about 1,000 kWh more than the average social voucher beneficiaries [78–80].

the economic crisis. Similarly, water consumption decreased 9% during the same period in the AMB area.

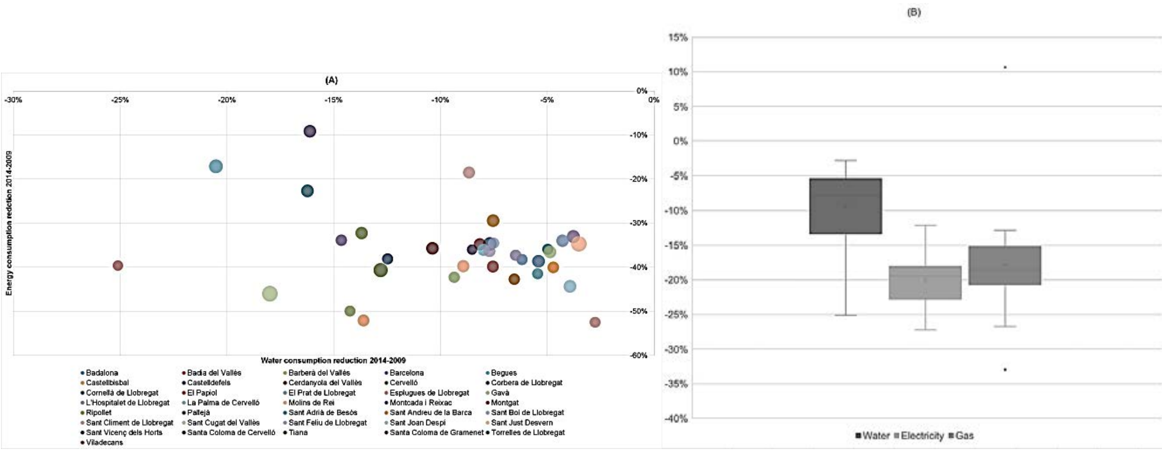

Figure 1. (A) % of reduction in utility consumption in the municipalities of AMB from 2009 to 2014 (the larger size of the bubble corresponds to the higher average of declared income before the economic crisis) (B) Summary of % reduction of consumption per inhabitant in box plot. Horizontal line in the box indicate the median, the boxes the interquartile range (Q2 and Q3). The upper whiskers extends to maximum (Q4), and the lower whiskers to minimum (Q1). × represents mean and dots represent outliers. Source: [71]

The quantitative results derived from the available data provide us a snapshot of the extent of WE poverty problem in the AMB. However, the lack of detailed information on energy poverty and water poverty in Spain still limit the quantitative analysis for the scale applied in this study [83]. Results from the qualitative analysis provide us with insights on the dynamics and the multifactorial character of energy and water poverty, and on their impacts on daily practices.

4.2) The water-energy nexus lived-in experience

WE uses are deeply intertwined in daily activities, since their objective is to increase comfort levels and fulfil the basic needs of households. According to one interviewee:

> *…people must have their basic needs covered, such as food, housing, and at this moment, we also believe that the basic supplies are also needed like water, electricity and gas; education, health, etc. (Interview #22, conducted on 08/02/16, Head of Social Services Barcelona)*

Not being able to secure energy and water causes the lack of DHW. We highlight this use at the nexus of WE, as it exerts a significant impact on the water use comfort level. Conversely, little or lack of hot water enormously challenges the basic reproduction functions of households. Hot water use in the household is directly related to life, as it serves fundamental sustenance, hygiene and sanitation needs, for example, cooking, cleaning, washing and showering. Hot water is also a factor in making water use at home energy-intensive [7]. The average annual energy consumption for DHW use in the Mediterranean area is estimated at 1755.9 kWh per household [84]. Considering that in Barcelona households that have a social voucher and consumed on average 1657 kWh yearly [79,80], it seems very likely that heating must be reduced if water is heated with electricity. The participants of APE emphasised the lack of hot showers as one of the most indignant experience of their livelihoods. Sometimes the tradeoffs are between which energy apparatus to rely on, making a strategic choice of turning off the radiator for space heating, but keeping the water boiler on. This is an inconvenience felt by every family member, from young to old. An interview with an affected household with irregular water supply opened a discussion on water for showers, where kids jumped in with enthusiasm demonstrating the high satisfaction they feel when they could have a good shower at their grandparent's house.

> *Mother: […] The day we can have water, we're going to freak out. Sometimes when they [daughters] go to my mother's house, they say: "Oh! [Satisfying expression]"*
> *Daughter 3: When I go to Grandma's house, it makes a difference because here, there is water to take a shower, but... [makes a face of dissatisfaction]*
> *Mother: there are seasons that you hear: "Mom, there is not enough water for the head!"*
> *Daughter 1: At Grandma's house, I sometimes get lost [in the shower] but Grandma tells me: "Come, Betty, wake up!"*
> *Mother: [In my mother's place there is] real water, and it is paid by my mother. But well, we have become accustomed to what we have and all we are going to learn is that, if one day things change, we have become accustomed to saving here and there. (Interview #8, 07/12/15, Affected household)*

Hot water is sometimes an alternative way of heating up:

> *Sometimes we put an electric heater in the bathroom, but it scared me how much it's going to increase [the bills]. So I didn't put the heater. [Instead] We bathed two at a time instead of taking a shower… We warmed with the hot water in the bath; moreover we saved because two were bathing at the same time. (From Interview #29, 3/6/2017, Affected household)*

Moreover, in some municipalities, WE vulnerability is manifested by the increased water consumption at the municipal sports facility, as households try to externalise WE use for essential activities, such as the shower On this, a municipal environment officer in charge of energy and water poor households answers that:

> *Also many people come to you saying: water and gas, I have it more controlled because we take showers at the municipal swimming pool. Of course, the municipal swimming pool has increased water consumption a lot (I. Did you notice it in this period of crisis?) Yes. They say it, that they shower there, they go to the gym, and at home they don't shower. (Interview #7, 01/12/15, Technical Officer in the AMB)*

Households also limit cooking as they have to control energy costs (Interview #24, 09/05/2016), Affected households). Moreover, considering that preparing large quantities (by mass) of water-intensive food is less energy-intensive [85], single households with limited cooking resources are inclined to cook with higher energy intensity, which means spending more energy per unit quantity of food. Often these households rely on a social kitchen, products from humanitarian organisations, canned food or microwave, or opt for quick cooking even though food costs clearly have more priority over electricity or water bills (Interviews #3, #8, #17, #25 Affected households).

Generally, limited affordability causes households to reduce their daily water and energy practices to minimum usage to avoid high bills [86]. The inconvenience of not having sufficient energy is expressed throughout the entire year; not only in winter, but also during the long, hot summer that characterises Mediterranean climates. According to one interviewee:

> *In summer, it's a problem that you can't keep things fresh; you cannot get anything fresh or it all goes bad. In winter, you are freezing to death […] When I had nothing to pay, from that day, I started controlling, turn off this, turn off that, turn off the other. You are left with the minimum, for example, the refrigerator. […] I intend to*

> *save the maximum. Now look, I have electricity (at home), but I cannot have the luxury of turning on the air conditioning or heaters during the winter. We are in the poverty threshold. (Interview #4, 27/05/2015, Affected household)*

Thus, the impact of WE vulnerability is expressed in vital reproduction services that directly impinge on the health and hygiene of citizens.

4.3) The socio-technical regimes of water and energy in the AMB

The WE poverty issues result from distinct socio-technical regimes. Table 3 summarises the different social policies that utility companies provide for vulnerable households. The tariff structure has significant influence in relationship with domestic flows. In Barcelona, water consumption is charged according to a block tariff system to promote water savings and environmentally friendly behavioursbehaviors. It includes the compulsory purchasing of water of the first block, which may help recover fixed costs but disfavours the vulnerable households with consumptions lower than the level established in this first block. Despite this, the water sector has been in close cooperation with social services in the AMB in order to reach vulnerable populations.

Thus, AGBAR, the major water company in the AMB is actively proposing various social measures for water services. A social tariff is applied guaranteeing 66 litres per capita per day with a tariff on the first block, which could mean going back to 2011 levels (0.3999€/m^3). The local social services, AGBAR and the Catalan Water Agency promote the direct application of a social voucher or online (web or phone) services, which would make the process in principle more accessible for vulnerable populations. Regarding solidarity funds, giving discounts of a maximum of 28€ per bill, discretionary decisions are made by the local government's social service agency or by charitable organisations, such as, *Cáritas* and *Creu Roja*, which help expedite assistance. As part of their social responsibility program, discount schemes are paid by the water company. This differs from the position of energy companies that claim that the government should pay half of the cost of social vouchers. Thus, public institutions may end up subsidising private companies by paying these companies what the energy poor cannot pay.

Table 3. Comparison of socio-technical regimes for energy gas and water vulnerability households

	Electricity	**Gas**	**Water**
Benefits for affected	Social voucher provided by 8 companies	No progressive pricing (application of the lowest tariff)	Social tariffs (water company) Solidarity funds (Agbar Foundation) Social tax (Water Agency of Catalonia) Wastewater treatment tax (AMB)
Criteria of vulnerable consumers	**After reform RD897/2017** Different benefits are applied depending on the income level: vulnerable customers receive a 25% discount; severely vulnerable customers receive a 40% discount. Discount per annual electricity consumption depending on the household size	No benefits, but gas companies accept social services reports on economic vulnerability or social exclusion	Rely on social service's criteria and decision Contributory pensions or permanent disability, retirement or widowhood Unemployment Social Integration of Disabled Persons Act Basic needs Non-contributory pension Minimum income
Application for the benefits	**Before** Directly presenting document by the contract holder or the social service (Law 24/2015) **After reform RD897/2017** Via web, email, telephone, or mail	Directly presenting document by the contract holder	Application online, phone, application through social service, or directly presenting an application form (Solidarity fund also through charitable organisations)
Renovation for benefit	Requires renovation process after two years by vulnerable households	NA	Automatically renewed by the company
Client service	Outsourced to service company	Outsourced to service company	Mostly directly managed by the water company

Comparatively, the electricity market is much more complex than the water market. To begin with, it is divided in two segments: regulated and free markets. Usually, in a regulated market, the bill is calculated by a simple function of unit price and a passage fee for the amount of power contracted and does not reward any energy-saving efforts. Off peak discounts provide households with an option to control their energy use in order to lower the bill. In the free market segment there are various service contracts promoted by different companies. Thus, prices may vary creating confusion among many vulnerable households. Moreover, the social voucher is only applied in the regulated market, and acquiring this benefit is considered to be slow and confusing due to the passive attitudes of electricity companies. The latest reform provides greater discounts, as it applies to the final price. However, a cap is put on the annual electricity consumption, for which the discount is applied, without taking into account different energy services and devices required at home. Electricity companies only open a narrow window for the vulnerable, as they make it difficult to change power contracts over the phone or they force consumers to apply for social vouchers only by directly visiting their offices. For gas, a discount scheme does not exist despite the fact that the energy poor in Catalonia rely on natural gas for most of the hot domestic water (66%) and heating (49%) [87].

Since the Catalan regulation 24/2015 mentioned above, both water and energy companies cannot order cutoffs for vulnerable households. This has allowed these households access to energy and water despite the inability to pay. However, social services were given the task to sort out vulnerable households from long lists of households with arrears. As a result, not only did the situation of understaffed social services worsen, in terms of delaying making reports available to vulnerable households that need them to obtain social vouchers (which in worst cases, took up to four months), but also created hostility against electricity companies, and altogether a setback to the overall efforts in improving energy poverty. As another example of the unjust, opportunistic, and oligopolistic character of the Spanish electricity market, two years later, the Spanish law RD897/2017 reformulated the social voucher for electricity. This reform not only made it even more difficult for vulnerable households to apply for social vouchers, but it also further reduced the responsibility of electricity companies, since they changed the 'rules of the game'. Instead of finding a way to expedite the administrative process, what the reformed regulation provided was in fact the opposite. Bearing the general socio-technical regime of vulnerability in mind, the following parts reveal the intrinsic link between WE vulnerability by focusing on tariffs, economic vulnerability and efficiency.

4.3.1) Increasing resource prices against vulnerability of households

Vulnerable households in socio-economic terms highly correlate with the energy poor households [88]. In the daily practice of households, energy and water as commodities are recognised in terms of bills, in other words, in order to have these commodities, you have to pay the bills. This also justifies a joint analysis of the two resources. Considering the household budget from a holistic perspective, a water or energy tariff increase imposes a threat on the affordability of the other bill. APE recognises that increases in the water tariff would affect energy poor households 'in a moment when neither income nor pensions are increasing [by] even a single euro' [89] despite the fact that only a part of most vulnerable households tend to suffer both water poverty and energy poverty. Further considering the economic impact on the vulnerable population in the AMB, it seems reasonable that WE poverty is being discussed chiefly to address the low-income households. In the AMB, 26.1% of households in 2011 expressed economic difficulties in making ends meet. This figure had risen to 28.6% in 2016[15].

When combined with the evolution of energy and water prices during the past decade, economic vulnerability brings to the fore the challenges that households must face (Table 4 and Figure 2). Between 2007 and 2016, while the price of electricity and water in Barcelona increased by 70% and 66%, respectively, the purchasing power of residents declined by almost 10% (Idescat). Moreover, energy prices have increased more for the smallest consumers, further disfavouring vulnerable households and their saving habits. This implied an enormous burden for vulnerable households. AGBAR, the major water company in the AMB, admits that the water poor have increased since the crisis, and that the number of households benefitting from social tariffs is rising steadily since the creation of this program. Moreover they remain sceptical that these numbers would decrease any time soon (Interview #27, 02/06/2016, AGBAR). According to AGBAR, some 17,000 households in the AMB are unable to pay their water bills and the company assumed €6 million of the debts incurred between 2012 and 2016 [90].

Table 4. Evolution of domestic energy prices (PPS/kWh) from 2007 to 2016 (all taxes and levies included (€))

Electricity consumption	Price Increase (2007 vs. 2016)	Gas consumption	Price Increase (2007 vs. 2016)
Consumption < 1 000 kWh	71%	Consumption < 20 GJ	58%
1 000 kWh < Consumption < 2 500 kWh	73%	20 GJ < Consumption < 200 GJ	48%
2 500 kWh < Consumption < 5 000 kWh	64%	Consumption > 200 GJ	24%
5 000 kWh < Consumption < 15 000 kWh	56%		
Consumption > 15 000 kWh	42%		

Note: Figure B.1, B.2 for graphical information
Source: [77]

[15] This does not include households that expressed some difficulties to make ends meet, which account for 28.4% in 2011 and 32% in 2016.

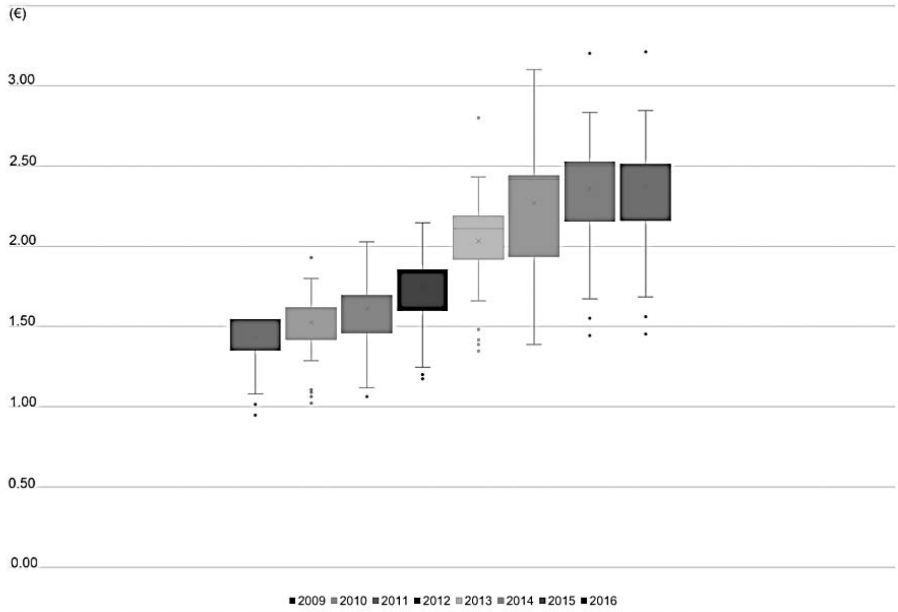

Figure 2. Box plot on the evolution of water price in the municipalities of AMB from 2009 to 2016. For explanation of box plot, refer to Figure 1 (based on consumption of 12m3/month, €/m3 VAT not included) Source: [91]

The continuous rise of Spanish electricity costs respond to several factors that derive from the peculiar structure of the electricity system in this country. Firstly, the high dependence on fossil fuels makes the electricity market vulnerable to world price fluctuations, as Spain has to import most of its energy resources. The electricity auction system does not allow customers to pay different electricity prices depending on sources. Thus, renewable energy does not benefit from reduced cost and electricity is overpriced. Secondly, price increases are inevitable due to the tariff deficit arising from the liberalisation of the electricity market. Third, deficits have also resulted from overcapacity in electricity generation and the failure of some large projects. Spain has a generation capacity of 25,000 megawatts annually, of which only 18,000 are actually consumed.

Water prices and taxes in Barcelona have also increased substantially since 2008, partially as a result of privatisation of the regional water company Aigües Ter-Llobregat (ATLL) in 2012 as well as the investments in new infrastructures, such as desalination to increase water supply. As an emergency source, desalination is an attractive source, as it taps seemingly endless source of water that free the population from climatic and hydraulic limitations [92]. The desalination plant of El Prat serves the population of AMB since 2009. However, it has been operating at a minimum capacity because cheaper surface and groundwater resources have been available. In this sense, desalination increases water security but at high costs, which translates into costly water bills that poor households can barely afford and in some cases, eventually lead to their limited access to water. According to one interviewee:

> *In the last 10 years, it [water price] has gone up a lot. Before 2009 … the water was taken directly to the user from wells, but that water was excessively saline. From 2009 it was necessary to introduce desalination through reverse osmosis to improve the quality. That has very high energy costs, so the entire cost of the investment had to be passed on to the water bill… to be able to balance the fees, the income, the expenses. […] In fact, in El Prat today, 70% of the water is produced by the company itself, the rest is bought outside, but all that is desalted undergo osmosis, and this has a high cost. [It is] a radical change. Although the percentage [of the] water we buy outside is small (25% or 30%) this water costs us a lot. It comes from what would be the high network, which today is managed by a company that has recently been privatised, ATLL, which is one of the companies that manages the water produced in the desalination plants in the marshes. Especially since it has a very high fixed quota, no matter if we consume more or consume less, the guarantee of the supply is very expensive and that has a very high impact on the bill. We have no alternative. (Interview #19, 02/02/2016, Aigües del Prat (public water company))*

In both energy and water, the value added tax (VAT) has increased as part of a package of measures presented by the Spanish government to increase revenue [93]. Today VAT is charged at 21% on electricity and gas and at 10% on water.

A large portion of affected households have expressed difficulties in confronting unexpected high bills due to, for example, additional maintenance costs, incorrect metre readings, or leakages. Most of the detected malicious cases reflect the bad practices of some electricity companies of changing the contract of household from the regulated market to the free market without obtaining an informed consent beforehand. This certainly impacts the increase in bills, and in some cases, has taken away the right to use a social voucher. Where flexible company policies, such as payment through instalments, could alleviate the stress of households, many companies do not provide a regularised policy for these flexible measures.

As a result, households are pressed to make decisions that might jeopardise spending on essential items, such as food. When rigid company policies are applied to recover arrearage, the affected households' decision becomes fraught with dramatic trade-offs.

4.3.2) Interconnection between efficiency and poverty

Efficiency is considered an important factor that allows resource use and comfort at lower costs, which also brings benefits in reducing environmental impacts. Energy (in)efficiency in built environment is considered one of the three main causes of energy poverty. On the other hand, the synergies achieved in alleviating climate change by improving energy poor households have been largely highlighted as resilient actions [94,95]. Programs targeting energy efficiency have gradually increased, in recent years in the AMB, but not at a level sufficient enough for the local municipality to take major initiatives. Water efficiency measures for reducing toilet flows, shower time and the like have also been often implemented. According to one interviewee:

> *I believe that the most important thing at this moment is to make a task of improving the energy efficiency and the quality of the houses. The payment of bills is palliative; the remedies are to improve the housing stock of Barcelona […] I think these are the measures we would have to address not from Social Services but from the Environment of Barcelona; ... especially old, old houses in poor conditions and the forethought, because if this bulb saves me 25% of the cost, it's worth it, right? (Interview #22, 08/02/16, Head of Social Service, Barcelona)*

The problem with energy efficiency is the low insulation of much of the housing stock built in Spain during the 1960s and 1970s. According to one interviewee:

> *Here what was done is to comply with the regulations in force at that time [the period of construction boom]. At the time the administration has always been a bit more advanced in the subject of what would now be the letters of energy efficiency, A and B, C, and all these things, than the private ones (sector). The private wanted to build and did not think about the subsequent consumption. […] Before the energy was free..., not free, [but rather] cheap. Before the regulations, the technical codes were enforced, and at the time of construction, the minimum was done. And that is how we are [here] now because the minimum was done. [As] I already told you, the most we did here is to try to recover rainwater at the time. There are many municipalities that are already incorporated in their regulations, the recovery of grey water and the minimum energy efficiency mandated by the regulations, which are double discharges in the toilets, diffusers in the taps. Because the Generalitat at the time began drawing*

rules in this regard, the minimum was met. (Interview #20, 02/02/16, Housing Department, Barcelona Province)

Over 70% of the housing stock in the AMB was built before 1980. Most apartments and houses with Energy Performance Certificates (EPC) in the AMB have a certificate level E (54%); houses with a certificate level above C added to around 5%, among which A and B merely represented 0.1% and 0.8%, respectively. Poorly built environments inherently bear the problem of inefficient energy use, which trigger unsustainable metabolism patterns in the city with important social impacts, as poor households tend to occupy housing in the worst conditions. Only 37.5% of households in the AMB have double glazed windows; 15.3% rely on electric heating; and 51.5% on natural gas for heating, among which only 6% had central heating [96]. A recent study found out that EPCs are still not effectively reflected in the rent or in the housing market in Spain [97]. Therefore, the deprivation of vulnerable households in the future may worsen when the EPC's impact on housing prices and rents becomes normalised. All in all, apartments and houses with improved energy efficiency become more difficult for vulnerable households to afford.

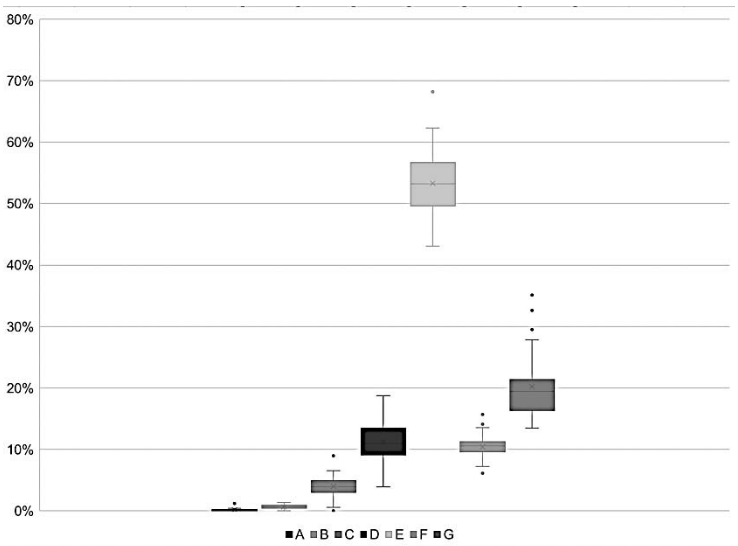

Figure 3. EPC certificate distribution in the municipalities of AMB. For explanation of box plot refer to Figure 1. Source: [98]

The direct impacts of the built environment on the daily lives of vulnerable households is felt more severely in households recently moving to new flats having worse conditions than the previous ones. In our interview of a household comprising of a single mother (Interview #33, 26/07/2016, Affected household) who had recently moved to a social housing unit provided by the city council, she noted problems in the new flat due to reduced energy efficiency and lack of light. Her previous flat was better located with plenty of sun reducing the energy bill, which gave her enough margin to afford water bills. However, in the new flat, the electricity bill increased to the point of making her worry about how to pay the incoming water bill (not yet received at the time of the visit). Her flat had a large single glazed window with wood frame, where a finger could pass the gap between the window and the frame. Lack of efficiency is expressed as problem of affordability in the dynamics of WE household vulnerability, as these households suffer from insufficient economic means of covering extra costs.

Table 5. Comparison of administrative scale and characteristics of energy and water

	Energy (electricity and gas)	**Water**
Type of management	Private service by energy companies Oligopoly of the 'Big 5' (Endesa, Gas Natural Fenosa, Iberdrola, EON España and EDP)	Concession made by municipality or direct management by a municipal water company (Mixed (24*), private (9*) or public company (3*))
Legal boundary	State regulation	Municipal and regional regulation
Data availability	Protected as confidential information of the company	Depends on the type of management but mostly treated like municipal data
Price regulation	Market State law	AMB

Note:* number of municipalities

4.4) Lack of institutional coordination

Hilber and Werner's recent study on energy poverty showed the multiscalar character of energy vulnerability [24]. The differences in the ownership and regulatory status of energy and water cause discordances in public efforts to alleviate WE vulnerability (Table 5). In the AMB, these problems are also detected as causing difficulties in daily operative tasks, particularly the lack of coordination arising from managing the different forms of commodification of energy and water.

Affected households rely primarily on support from municipalities, either from the technical manager of environment or social services, depending on the arrangement of each municipality. The difficulties arising from institutional incoordination manifests mostly in the inaccessibility of customer services. As one technical manager explains:

> *I: Do you also work with a private supplier, with Endesa, Iberdrola? P: Not much, I try to avoid it because it is choking (cumbersome). It is very difficult. […]When you have to change the owner, I tell them: "call here". And I avoid being transferred to an operator [referring to the operator of phone customer services for electricity companies] that does not understand anything, and waiting. I cannot. I have to manage my time. (Interview #7, 01/12/15, Technical officer in the AMB)*

Moreover, electricity companies remain highly uncooperative regarding the provision of data, which causes important difficulties in estimating the impact of energy poverty at the municipal level. In this way, all the responsibility for detecting the problems is passed on to the public administration lacking the sufficient means or resources to protect vulnerable households.

> *There is not much data. It is one of the problems and one of the demands too because it is not being reported. And I suppose you know the law that was approved in Catalonia on energy poverty. Now in theory, there should not be so many cuts. ... Even so, there are cuts of people who are users of social services. So one of the demands is that companies give information about the supply cuts. For water, there is data; the difference between energy and water is that most of the powers are at the state level, and water is at the municipal level, and since it is a municipally owned service, it is much easier to manage certain things and also the municipalities have access to these data. With energy, it does not work like this. For this reason, with energy, it is much more difficult to have certain cut data, etc. (Interview #26, 18/2/2016, Expert in private sector)*

However, in the extreme cases of occupied housing, access to these vital resources may be limited with some exceptions in case of water where a separate agreement is signed with the municipality. Houses without contracts cannot ask for a legal arrangement, and are thus forced to establish illegal connections. In old houses with obsolete electric hardware, threats to life may be present, as there is a fire hazard from potentially overheated electric wires. In the case of one affected house that we interviewed, similar strategies of preventing any connection with the municipality and the utility company are pursued. As one affected explains in the interview:

> *The issue that concerns us with energy poverty is as a result of living here. We find a house abandoned for more than five years, without basic supplies of electricity and water… They were not contracted. There was no water metre or electricity metre. Logically, we illegally connected, we did a job. Within the three months of being connected, they [the municipality and water company] did an inspection and removed the water supply from the house in September 2013. They lifted the sidewalk and covered it [water service pipe]. From the electrical part, I put a power strip[…] The problem is that it is a very obsolete installation, not adapted to the new regulations and the cables are overheated from using electric stoves in winter. With the consequent danger that these cables can burn… It can cause fire. And so we live with the light (electricity) and water illegally connected (pinchado in Spnish). (Interview #8 07/12/15, Affected household)*

On behalf of the affected households, the APE exposed and emphasised the dubious practices of these utility companies. At the same time, the Catalan public's and public officers' awareness evolved over a short period of time to recognise these utility companies and their policies as major causes of suffering for these households. Thy also demonstrate different degrees of criticism towards water and energy companies based on the companies practices.

> *… I am very critical of the companies because the supply companies immediately threaten to cutoff the supply, so people get scared and ask for help pay for it… I suppose you know the Generalitat's decree of energy poverty. This was very good because it assured us that they were not going to cut anyone's supplies. […] We have many problems because sometimes, we [pay] here but they [the company] do not know and cut the light. There are many intermediaries. There is a distributor, marketing, the one who is going to remove the meter or cut the gas. Then as there are so many people in the middle, sometimes the information does not arrive, so they also cut. We have many discussions with the companies because they want profit and want to make money, and they do not care. I think that on top of that, we are paying with public money the deficit of a private company. They would have to be more understanding. I'm talking about gas and light. They do not contribute any money, they could do social work, social collaboration, but they do not make any effort, or they make very small efforts[…] The water is different because in Barcelona it is a semi-public company. And for a long time, they have a social tariff, a solidarity fund*

> *and other aid, although in the end, like all companies, they want to collect the debts. They [water companies] are much more aware and much more cooperative [compared to energy companies]. (Interview #9 10/12/15, Social Service in the AMB)*

4.5) Solutions for vulnerable to citizens

Currently in Barcelona, WE vulnerability has resulted in fostering a re-imagination of energy governance, including a discussion of the municipal electricity company as a possible option for creating a fairer electricity service for all citizens. According to one interviewee:

> *A key element is to be able to influence the market, to be able to influence the supply conditions through a public and private energy operator. We are also working on this, in creating a metropolitan energy operator that controls the public (Interview #14, 18/01/16, Barcelona Advisor to Mayor)*

As the WE poverty issue persists, the acknowledgement of this situation as a problem of households suffering economic and housing crises is evolving into a problem that affects the general population as well. Vulnerability is seen as a question that stems from the lack of an energy culture, whereby people are not aware of how to interpret the bills. Hence, this involves what lies in the contractual terms that may influence our daily interaction with these flows of materials.

> *Now we want to make a leap towards a larger scale, and we want to do it with the public because it is a broad spectrum problem. It affects the whole world. Nobody understands the bills, nobody. Because some see it as impossible, and others do not devote the time it takes. [We need to] create a little network. People like you, ordinary people, who show you that you can make changes with the company. (Interview #7, 01/12/15, Technical Officer in the AMB)*

Therefore, WE poverty has become politicised not only to find solutions for poor households, but also to address the problem arising from the (poor) energy culture and the current economic model that is promoted at the European level. Thus, the case of the AMB moves beyond the actions that simply focus on WE vulnerability, as it questions the dominant energy and water model based on the commodification of both resources by private companies that work under the ‘benefit imperative’. According to one interviewee:

A last reportage that I saw was that Endesa wants to divide the dividends of the benefits, among them until 2019. They are benefiting. And they are abusing citizens unbeknownst to them because they are taking public aid […] That money, that comes out of the public coffers, are given to the vulnerable families. They make a small bridge, and in the end the money is always taken by the companies. Yes, citizens benefit because they pay a little for the debts, but that money comes from the public money of all taxpayers. The energy companies do not assume their responsibility to alleviate these needs. The fight is against these new great giants. We are fighting and we will continue fighting. [Like] David against Goliath, Goliath fell. Endesa will fall. (Interview #8 07/12/15, Affected household)

5) Discussion & Conclusions

This article focused on the deprivation of energy and water in vulnerable households of the Metropolitan Area of Barcelona (AMB). The Water Energy Nexus (WEN) at various scales suggests that Water and Energy (WE) vulnerability deserves more attention from those studying energy poverty, so as to take more into account the dynamics in domestic metabolism that impede vital activities, and at extreme cases, can cause fatal consequences. From the supply angle, WEN affects household vulnerability, as energy and water are subject to increased tariffs. Deteriorated or non-existent efficiency measures for energy and water are also pointed out as one of the main features of the built environment, especially in low-income neighbourhoods; these factors worsen WE vulnerability. Lastly, the case of the AMB also offers an example of how social movements have risen to address WE vulnerability; specifically declaring that water and energy are basic rights and vital resources, and are therefore not commoditised goods.

Our study on the understanding of WE vulnerability based on Living Condition Surveys, is limited due to the lack of information on the desired energy and water consumption, the actual water and energy consumption (in m^3 or kWh), water and energy efficiency data, and the links between energy efficiency data and data on living conditions at the household level. For example, the data on EPC are managed by Catalan Energy Agency and is not linked with the Spanish Living Condition Surveys. Establishing a new survey framework encompassing various aspects of vulnerability for both energy and water, and linking built environmental data (efficiency of houses, appliances, climate, etc.), user practices and behaviour (required and actual) and water and energy affordability, is essential for enhancing our understanding of WE vulnerability in Spain. Despite its limitations, the study intended to contribute to the understanding of WE vulnerability in Barcelona by employing quantitative and qualitative methodologies.

More than 10% of households of the AMB are experiencing difficulties with either water or energy costs. The results derived from the affordability indicator for energy and water in the AMB are alarming, as a significant percentage of vulnerable households are overwhelmed with water and energy bills. Somehow surprisingly, a slightly higher number of households were identified to be water poor compared to those that were energy poor. But this corroborates the observation from interviews. For instance, staff from social services confirmed having detected initially both water and energy poor (and not only energy poor) as an emerging social problem. Consequently and despite the lack of academic conventions or precedents in this respect, in this paper, we considered the two resources together.

Around 22% of those at risk of social exclusion in the AMB are identified as being more susceptible to being both water and energy vulnerable. Among the many adversities in their lived experience, the need to have DHW for vital activities for sanitation and hygiene cause these households to subsist in and endure undignified living conditions. We observed that their lived experience creates various dynamics in the practice of WE use and saving practices within their homes. Often WE vulnerability is bound to have wider ramifications, as the households make strategic decisions to outsource their shower from municipal facilities, to use water from municipal fountains or in extreme cases, to illegally connect to water and electricity networks.

In the Mediterranean climate, where the winter thermal discomfort is perceived to be less important, or could be overcome with more layers of blankets, often households decide to leave on the water boiler, but turn off all heaters in order to control the utility bills. With less than 5% of houses with the EPC above C, the AMB presents the challenge of deteriorated housing stocks that imply important challenges to the general population. Old stocks constructed before 1980, constitute 70% of total housing stocks in the AMB. Since WE vulnerability has evolved to the point of households being incapable of affording utility services, they are perceived as a poverty problem in general. As a result, compared to other European countries, discussions on energy efficiency measures seem to foster less public interest.

The findings of this study may have important implications for future practices in current public administration. Specifically, they highlight that the problem of severe vulnerability of households is compounded by the lack of coordination between different scales of governance, whereby clear and expedient communication lines are difficult to achieve. In some countries, social vouchers applied to water bills may serve as proof for applying for an energy social voucher, since water bills tend to be lower. In the AMB, where water vulnerability tends to be managed in a much more efficient manner, energy companies might use the water bills as a mean to expedite the application of their own social vouchers.

In broad terms, targeting both WE vulnerability could turn into win-win strategies for households, as they are alleviated from financial burdens by being offered an economical tariff. Having to pay less for electricity would allow more affordability for water, and vice versa. Needless to say, WEN synergies from reducing energy use via improved efficiency results in saving water, and reducing water use via improved efficiency implicates energy savings in the urban water cycle. These nexus relations are valuable in an area usually burdened by water scarcity, such as the AMB. The AMB has experienced significant increases in the water tariff during the past years, which have put an extra burden during the crisis period, as water security requires new infrastructures. Desalination was favoured in the

AMB. However, this modern infrastructure, while increasing water security for the general public, resulted in diminishing the capability of vulnerable households to afford paying their utility bills due to the high costs of desalination.

Currently social movements are continuing their struggle to address accumulated debts and non-financial obstacles, i.e. the lack of housing contracts, fraud, citizen registration, obsolete installations, etc. that impede access to resources. Finally, the WE vulnerability discussion in the AMB contributed to the initiation of the (re-)municipalisation movement for these resources, as the lack of coordination in the administration scale revealed general interests in finding an alternative way of managing water and energy. Our findings suggest that a large potential lies in rethinking the water- energy metabolism of households for the vital functions that these resources perform at the nexus level. A better understanding of the complex dynamic between WE under different socio-technical regimes would help broaden the view on WE vulnerability as well as address more thoroughly the difficulties of vulnerable households in their daily lives.

Supplement data

Table A. Summary of interviews conducted

Category	Sub Category	Number of interviews	Subtotal
Affected households	APE participants	6	12
	Non APE who experienced housing exclusion	6	
Public administrations (City council, Municipalities, Barcelona Metropolitan Area, Barcelona Provincial Council, Housing department and agency)	Environment sector (includes officers from environment, climate change, energy & water departments)	5	15
	Housing sector	4	
	Social service sector	3	
	Consumer and resident rights (includes Consumer's Agency, Ombudsman and social advisory for city council)	3	
Utility companies	Agbar (No script)	1	2
	Aigües de El Prat	1	
Non profit	APE	1	2
	Habitat3	1	
Other expertise	Academia	1	2
	Private company	1	
Total			33

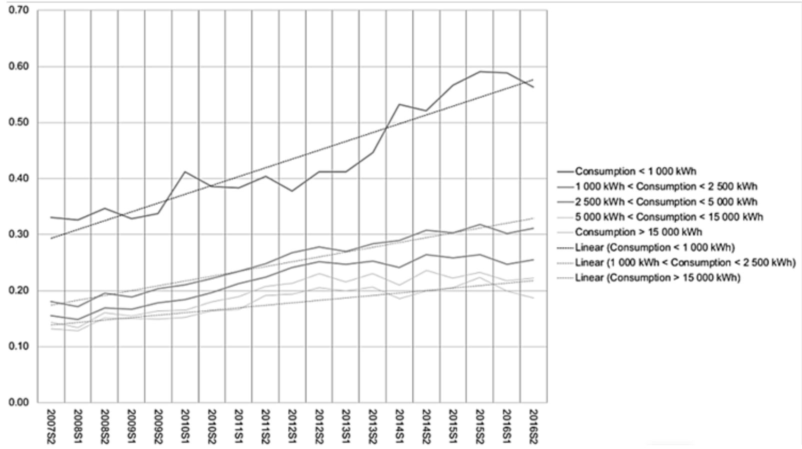

Figure B.1. Evolution of domestic electricity price in Spain (PPS/kWh, Source: eurostat)

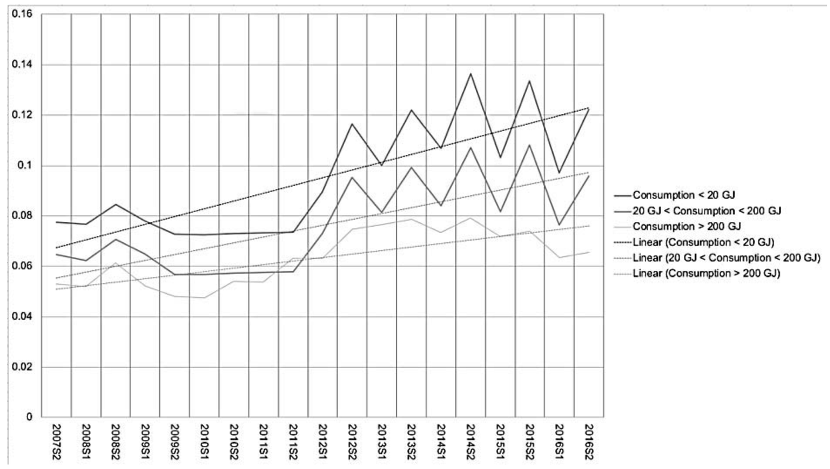

Figure B.2. Evolution of domestic gas price in Spain (PPS/kWh, Source: eurostat)

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4.3 '#No more thirst, cold, or darkness' - The co-production of knowledge of water and energy vulnerability[16]

Abstract

Water and energy vulnerability (WEV) in Barcelona continues to stir up social debates in Spain, as the social movement known as the Aliança contra pobresa energètica' (English: Alliance against Energy Poverty; hereafter referred to as APE) champions the cause and raises awareness of water and energy rights of vulnerable families in Catalonia and beyond. In the urban space of the metropolitan area of Barcelona and on top of the heavily unequal social fabric that the city cultivates, APE has been at the forefront of initiating new discussions on water and energy services and their governance. This is interpreted as a new form of water-energy nexus (WEN) addressed by end users and arose from posing fundamental questions on political ecology to participants, such as: '*Why are water poverty and energy poverty approached and managed differently from each other by companies and administrations?*'; '*Who decides the regulations of water and energy vulnerability programs and what are the criteria of vulnerability?*'; and '*Who pays the costs involved?*'. Using a mixed-method research approach, including participant observation, action research and quantitative analysis, we investigate the case of the APE, particularly how they deal with WEV and demonstrate their guiding principle of 'co-production of nature and knowledge'. APE's guiding principle places WEV deep into the sphere of people, (urban) nature and power. We conclude that exploring water poverty and energy poverty together in an extensive and open manner reveals the lived experiences and struggles of households and brings a more holistic understanding of human and nature relationship at the household level.

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Prologue

#LlumperAntonio (#LightforAntonio)

Location: Meeting room, Federació D'Associacions de Veïns i Veïnes de Barcelona (FAVB) (English: 'Federation of Neighbours' Associations of Barcelona), Gothic Quarter, Barcelona

An old lady slowly stands up from her chair. She takes her turn to tell her story at a bimonthly *asesoramiento* (English: "counselling" session of the APE. She had come from Parets del Vallès, a town 23 km north of Barcelona that is being run by a young mayor from the Socialist Party of Catalonia (PSC). One late autumn evening in 2015, as the cold white lamp illuminates her silver hair with fading blonde dye, she starts narrating carefully yet anxiously her story to the gathering listeners:

> *'I've been living in the house without electricity for a year. Last year when they first cut my electricity off, I rushed to SS in tears… but they sent me back home, telling me to come back two months later… I never went back. But I found a neighbour who helped me reconnect the fuse (this is commonly referred to as 'luz pinchada'* in Spanish*).'*

Her way of handling the situation hardly surprised the group listening to her case in the room, since they are aware that many vulnerable households experiencing cut-offs usually resort to similar measures. On the contrary, people nodded in agreement or added sympathetic responses, such as: '*That's normal'* or '*Of course, what else would you do*'. She continues talking, brushing off the ethical burdens of confessing her wrongdoing.

> *'Some days ago, a technician hired by the power company came to install a new meter and found out that I was illegally connected. He said that by reporting her case, he would get a compensation of €50. He left me without light. I live like in the 1950s. I have two candles. I am alone, I am afraid, I am cold'.*

After hearing her story, APE quickly decided to launch a campaign on Twitter. The next day, a photo of her sitting on her table with two candles surrounded by darkness goes viral under the main hashtag '#LlumperAntonia', at the same time tagging Endesa (the electricity company in charge), PSC, the mayor, and the city council. The Catalan regulation 24/2015, which was officially passed a few months earlier on July 29, 2015 via a citizen initiative called 'ILP Habitatge' and campaigned by APE, PAH and DESC, prohibits electricity, gas

more thirst, cold, or darkness' - The role of social movements in the co-production of Water and Energy Vulnerability) and water cut-offs, unless the company can prove that the household in question is not vulnerable according to their economic situation. After numerous Twitter message exchanges, phone calls, account blocks, attempts at appeasement and threats from the mayor and city council of Parets del Vallès, on November 17, 2015, Antonia got her electricity back. This was resolved within a week after the APE's campaign started.

Unfortunately, there are many more Antonias. This is merely one of numerous fights that APE has led. Also its mission includes fighting water poverty. e.g. #AguaparaEster (#WaterforEster), #AguaparaSalem (#WaterforSalem), etc. (see supplemental data A.1. for the timeline of all major actions).

1) Introduction

The term 'energy poverty' refers to 'the inability to attain a socially and materially necessitated level of domestic energy services' (Bouzarovski and Petrova, 2015, p. 31). In a similar vein, energy vulnerability in the context of households refers to the risk of households facing deprivation of energy services (Bouzarovski, 2014). It is generally recognized that today energy vulnerability is increasingly blurring the divide between the Global North and the Global South terminology-wise, thereby overcoming the limitation that energy poverty or fuel poverty was hardly an issue in developed countries. In this paper, water poverty and water vulnerability are applied and referred to in a similar manner, even though water poverty generally refers to the lack of water services in terms of quality or quantity in developing countries. However, there is increasing evidence that, as energy poverty, water poverty understood as lack of affordability rather than lack of access may start to become an issue in the developed world as well (Mack and Wrase, 2017). Nevertheless, in acknowledging the growing interests of scholars concerning the issue of the WEN emphasizing political, socio-ecological and socio-technological processes (Allouche et al., 2015; Browne et al., 2018; Williams et al., 2014), in this paper, we will use the terms 'water-energy vulnerability (WEV)' to analyze the case of Barcelona.

The story of Antonia was reconstructed to provide a snapshot not only of the experience of households struggling with energy poverty but also the ongoing social movements against energy and water poverty in Barcelona. Since the founding of the APE in 2014 in Barcelona, similar campaigns were or are being initiated to secure electricity, gas and water connections in vulnerable households. Various social movement groups forming the APE include the *Plataforma Afectados por la Hipoteca* (English: 'Platform for People affected by Mortgages'; hereafter referred to as 'PAH'), *Aigua es vida* (English: 'Water is Life'), *Engineria sense Fronteres* (English: 'Engineers without Borders'; hereafter ESF) and the *Observatori de Drets Econòmics, Socials i Culturals* (English: 'Observatory of Economic, Social and Cultural Rights'; hereafter DESC) play pivotal roles in APE's everyday practice along interacting with the affected households. Bi-weekly counselling sessions attract water-deprived or energy-deprived households in Barcelona as well as cities and towns nearby, where open assemblies provide practical tips and know-how on how to face their situations. APE has obtained outstanding results in exposing the problem and changing the discourse that stigmatizes the affected individuals, redirecting the spotlight towards utility and energy companies through direct actions. Today APE is seen as a key actor in Catalonia that plays a significant role in politicizing water and energy poverty (Yoon, 2017). Moreover and very relevant for our work, APE is one of the few organizations that work on addressing the lack of both water and energy at the household level.

This article examines the role and the strategies of the social movement focusing on the co-production of knowledge in politicizing WEV, which has revealed the WEN in the lived experience of vulnerable households. The conducted research addresses the following questions: How has APE politicized water and energy vulnerability in Catalonia? What has APE mobilized towards strengthening their agency. Who are the actors of this agency and what means do they use to realize their goals? Here we attempt to provide multidimensional insights into the topic of energy poverty by carefully following APE’s recent history with regard to their approaches in combatting ‘accumulation by dispossession’ (Harvey, 2004) as a major factor in energy and water poverty. Focusing on the co-production of knowledge, we describe APE as an agency and its practices of going beyond the separation between water poverty and energy poverty, and provide evidence on how this approach could reveal the potentials of developing bottom-up contributions to WEN research.

The study focuses on Barcelona and is organized as follows. After this introduction, Section 2 introduces theory and context while section 3 describes the methodology. The results are presented in section 4, which is followed by the discussion and conclusions.

2) Theory and Context

WEV brought attention to the vulnerable ‘home’, a place of everyday activities, where biological reproduction, care and maintenance of the workforce (Moser, 1993) takes place. According to Tuan (Tuan, 2018), a ‘place’ is defined essentially in the repeated process of everyday activity, and therefore, the daily use of energy and water gives meaning to the idea of a place as *a field of care*. On the other hand, the ‘home’ as a basic unit of the community is also a public space to a certain degree. Hence, there is a ‘porosity’ between the private and the public spheres, where flows become consumed, dissipated and disposed of, while necessary services are provided to the home (Kaika, 2004). According to Kaika’s understanding of home, energy and water poverty refer to insufficient metabolic flows of water and energy affected by public policies on water and energy.

Additionally, outside the home, water and energy are increasingly conceptualized under the WEN framework, highlighting their intrinsic and interwoven relationships. In facing the global challenges of climate change, resource scarcity, the increasing disparity of wealth between social groups, and the accruing global ecological debt, the need to comprehend

WEN better in human activities is emphasized by scholars and practitioners alike. Most commonly, WEN is approached quantitatively, where *energy for water* and *water for energy* are reduced to kWh/m^3 or m^3/kWh, respectively. Although quantification allows us to grasp the relation expeditiously, it nevertheless does not help us comprehend the complexity of the water- and energy-scape knitted by political, ecological, social and economic agents. As William and colleagues (Williams et al., 2014) explore the co-production of the WEN, they call for the politicization of WEN. They explain that WEN is insufficiently analyzed due to contradictions appearing in the processes of modernization, industrialization and the historic development of capital that prefers technocratic forms of environmental managerialism (Williams et al., 2014). Moreover, Cairns and Krzywoszynska (2016) claim that WEN is at the early stage of conceptualisation and therefore characterised by the heterogeneity and ambiguity of the term. In this sense, WEV studies provide opportunities for addressing WEN from a bottom-up perspective.

Previous studies analysed the influence of WEN on the availability of resources at the domestic level, and consequently its influence in the vulnerability of households (e.g. China, see Browne et al., 2018). In addition to this, we attempt to contribute to bringing a social perspective to WEN from the perspective of political ecology. This alternative pathway for WEN research opens the possibility to 'explore the interaction of ecological, social and technological systems across scales; considers the role of science and technology, and technological choices; highlights the importance of local context and diversity of ways of knowing; acknowledges the value of plural ways of understanding problems and solutions, and defining development and its objectives; and recognizes the highly political nature of associated decision-making' (Allouche et al., 2015, p. 619).

We borrow the concept of 'co-production' from Science and Technology Studies (STS). In Jasanoff's words, co-production explains a 'bricolage' rather than an idealized scientific method by ‘opening conversations with other approaches of social and political enquiry’ (Jasanoff, 2005). There are several reasons for combining this theoretical approach with political ecology. Firstly, by recognizing the ‘co-production of socionatures’ where humans and non-humans alike participate and are influenced by a bricolage of social, economic, cultural and technologic interventions, co-production captures the complexities of the nature-human relationship, and at the same time, it highlights the importance of knowledge. In this case, knowledge of how utilities work and what kind of neoliberal logic they are subscribed to is very relevant when this knowledge coalesces into sociotechnical structures. Therefore, the significance of social movements lies in their capacity to address the status-quo knowledge on the water and energy landscape, amongst other dimensions of activism. Moreover, co-production is rooted in the notion that power is not static, but continuously ‘reinscribing itself in our communities, institutions, practices, discourses and scientific production’ (Jasanoff, 2005, p. 36). Conde (2014) notes that social movements can be a place for the co-production of knowledge contesting existing power relations. Furthermore, whether local, scientific, or co-produced, knowledge always becomes a political tool for expressing and exercising power (Conde, 2014).

In an increasingly urban, neo-liberalized and globalized world, political ecologists have been critically studying the relations between the human and physical environments. In the urban environment, households receive water and energy through hidden infrastructures, which in our daily experience cause us to see nature in an externalized and objectified manner (Smith, 2007). Since the expansion of neoliberalism from the 1980s onwards, energy and especially, water have become more ‘commodified’ or ‘mercantilized’ (Bakker, 2002). The relationships between these resources and humans are reduced to commodity-consumer relationships based on contracts. In turn, this causes a deficiency of ‘self-reflexivity’ on how the natural world is transformed through our activities (Smith, 2007). Recently energy poverty studies have been proposing a new analytical approach based on urban political ecology by emphasizing the multi-scalar aspect of the issue encompassing regional labour market restructuring and urban disinvestment, geopolitical and geo-economic struggles, resource extraction conservation policies as well as social movements (Hilbert and Werner, 2016). With this approach, energy poverty is foregrounded as 'the product of uneven socionatural development'. Moreover, energy poverty is understood as a multi-dimensional problem expressed as 'a geographical assemblage of networked materialities and socioeconomic relations' (Harrison and Popke, 2011). On the other hand, the concept of energy vulnerability has adopted an inclusive approach that addresses the risk of insufficient energy services at home due to internal or external factors, such as access, affordability, flexibility, energy efficiency, and needs and practices in both developing and developed societies (Bouzarovski et al., 2014).

The Metropolitan Area of Barcelona (AMB)

At the center of our argument lies the issue of utility management, i.e. electricity, gas and water. The Spanish energy market has undergone a long process of privatization since the approval of the Royal Decree 54/1997, which complied with the European Directive 96/92/EC. More recently, the Spanish government restructured policies on vulnerable customers. Although, they still have to confront a complex market system. Two categories exist, i.e. regulated and free markets; confusing to most customers. In terms of water, *Aigües de Barcelona*, which is in charge of supplying water to more than 80% of municipalities in the AMB, is a mixed company where 15% of stocks are owned by the local supra municipal public agent AMB, and the rest by private entities, most notably AGBAR. There is only one company that commercializes water per municipality. Even though water companies may be more sensitive to vulnerable populations (Yoon et al., forthcoming), their accumulation strategies bear similarities in many ways to the energy companies, as their practices also create conglomerates that are expanding globally and prioritizing profit generation.

The Catalan regulation 24/2015 is one of the first regional regulations that provide protective measures for preventing cut-offs in WEV households. The process requires Social Services (SS) to assume an important role, as they are the first contact point for vulnerable households and are entrusted to diagnose socially vulnerable, 'who are: at risk of poverty or severely materially deprived or living in households with very low work intensity' (Government of Catalonia, 2014, p. 16). Furthermore, in Catalonia, there are various actors working on WEV, such as the Consumers Agency, City Councils, Ombudsman, AMB, and the regional governments, who have all developed a direct contact with APE throughout the last years.

3) Methods

The article draws on a set of quantitative and qualitative data collected from March 2015 to March 2017. We follow the concurrent mixed method approach (Morse and Niehaus, 2009), which include surveys and participant observation, and sequentially evolves as participatory action research (Table 1). These methods were selected in order to gain an in-depth understanding on the affected households and APE's role, given the limitation of data availability (Johnson et al., 2007), as we were dealing with 'unseen' problems laden with stigma and therefore, purposedly, "invisible". Surveys were conducted in order to gain a first personal contact and understanding of the socio-economic status of the households participating in the social movements. We attempted to collect data on the three indicators of energy poverty i.e. income security, energy price and house efficiency. A total of 61 households participated in the research, which covered about 40% of the participants who came to APE meetings during the aforementioned period of March 2015 to March 2017 (Table 2).

Table 1. Research methods applied during the fieldwork period including evolution to action research

Research methods	2015	2016	2017	Description of activities (n=)
Participant observation				Observational notes (12)
Survey				Face-to-face and online surveys (62)
Participatory action research				Participation in various types of actions (e.g. marches, silent picketing (*escrache*), papering companies (*empapelar*), occupation) (5)

Table 2 Demographic information of APE participants (n= 61, significance = 0.10)

Profile Category	Details
Sex	Female 61% Male 39%
Place of residence	Metropolitan Area of Barcelona (AMB) 80.33%
Origin	Spain 76% Latin America 20% Other 4%
Family size	3.1 (Max. = 7)
Family composition*	One person household 13% Households with minors 54% Households with retired members 12% Households with at least one disabled member 27%
Age of respondent	Under 40 36% 40 to 49 30% 50 to 59 20% Over 60 2%
Education	Primary 33% Secondary 41% Above 26%

Participant observation, inspired by ethnographic approach, helped the first author to become immersed in a new research environment in social, political, cultural and geographical terms. This method allows direct access to meaningful experiences, emotions, intelligence and activities (Jorgensen, 2015). In the 'knowledge-practices' of social movements, political activists are engaged in 'analyzing, envisioning and elaborating new ways of knowing and being in the world' (Casas-Cortés, Osterweil, & Powell, 2008, p. 28). Not only are they 'epistemic partners', but also they themselves are analyzers and citizen scientists. As Lozano argues 'within ethnographic settings populated by this type of actors it is simply too arrogant, or too naïve, to try to maintain the fiction that the scholar is the only one invested with the authority and expertise for complex analysis and interpretation' (Arribas Lozano, 2018, p. 2). Sequentially and gradually, the fieldwork developed into an activist-type of research (Taylor, 2014) in APE, which meant participation in counselling sessions, daily activities, such as handing out flyers and accompanying the affected households to the service centers, as well as direct actions – online and offline – from planning and building strategies up to their execution and evaluation. The information that was shared internally within the APE group helped substantially in shaping the arguments for this research. Such information includes bills, letters from companies (arrears and cut-off notices), and other documents on the status of affected households or general discussion on energy and water poverty in the region, and workshops and conferences in which APE participated.

The survey was conducted under the participants' consent and by ensuring confidentiality. The observational notes used in this article ensure the anonymity of the participants, whereby initials or pseudonyms were used. However, the hashtags reveal real names, as they have previously been made public on Twitter.

4) Results

4.1) Contesting Accumulation by Dispossession

APE has been able to politicize the issue of WEV in Spain (Yoon, 2017); Politicization has been based on debunking the individualization of WEV in order to eliminate the personal stigma. In the process, APE has opposed several common accumulation strategies applied by energy and water companies to build on the commodification of both resources. As Prudham (2007) explains, the focus is on the commodification of energy and water as an analytical frame for exploring the common strategies of accumulation observed and contested by APE in Barcelona.

One of the core aspects of the commodification of water and energy is that WEV is increasingly being treated as a financial problem. For example, Spanish energy regulations define ‘vulnerable consumers’ by solely measuring their economic vulnerability. A recent amendment (Royal Decree 897/2017) proclaimed two categories of customer vulnerability depending on the financial status of households: ‘severe vulnerability’ and ‘vulnerability’, whereby severe vulnerable customers are offered a 40% discount and vulnerable customers a 25% discount from the power bill, with maximum consumption allocated according to household composition (Ministerio de Energía, Turismo y Agenda Digital, 2017). So far, social vouchers constitute the only policy measure for addressing energy vulnerability. This financial focus has caused the state to shift away from more substantial causes of WEV, such as job insecurity, contractual and bureaucratic barriers and household efficiency.

Moreover, making a practical decision regarding which commercial power company and contract to choose becomes confusing because it is difficult for households to compare the various plans offered in a complicated market structure. Whereas transparency should be guaranteed for all aspects, the imprudence of energy companies in this regard has been continuously questioned over the past years by the media, grassroots organizations and ombudsmen. Therefore, social movements are playing an increasingly important role in this respect by bringing the non-financial perspectives of WEV to the foreground.

The situation is not very different concerning water vulnerability. In the case of the AMB, funds and discounts are applied to the direct payment of the bills to support households at risk of social exclusion to guarantee water services at lower prices. In practice, the risk of social exclusion is justified by SS according to the household’s socio-economic situation, which is reduced solely to the financial status. Likewise, other problems, such as difficulties in comprehending the water bill, the presence of other taxes and the levies being charged, and understanding the reasons for rising water prices remain unaddressed.

In the same line of discussion, the unpaid utility bills are often seen as a chronic symptom of WEV (Boardman, 2012). After securing the rights to energy and water, as stipulated by the Catalan Law 24/2015, many vulnerable households have accumulated debts to the utilities companies, as their ability to pay has not improved. The campaign organized by APE to demand debt cancellation lies at the center of questioning and breaking down the accumulation strategy that puts socially weak populations in a state of dispossession of basic resources. The campaign for debt clearance is one of many occasions that compelled APE to organise strong responses to both energy and water companies. It is also the only case where APE activists were charged for occupying the customer offices of companies.

Similar to mortgages (García-Lamarca and Kaika, 2016), energy and water debts affect everyday life as well as human-nature relationships taking place in an intimate domestic environment. Commodified energy and water resources represent a profit for energy and water companies, for which cost recovery is considered a priority. In contrast, indebted vulnerable people are intimidated by debt collectors, threats of cut-offs, and rejected requests for power and water supply reconnections. Such politics of 'live and let die' causes physical and psychological pain and loss of lives (Blanchar, 2015). The energy companies pass on the cases of debts to law firms or collection agencies in charge of debt collection. These agencies make persistent phone calls (even up to five to six times a day) and threats of cut-offs to provoke fear.

APE's campaign '*#AcosadasPorLasDeudas'* (English: #HarassedforDebts) reveals the strategies of commercial power companies, including: 1) claiming interest on delayed payment; 2) filing a case of delinquency; 3) taking the case to the court, which involves additional costs; and 4) cutting off power supply, which may incur additional costs related to reconnection fees. On the phone, the collector does not hesitate to coerce payment from customers. For instance, they claim '*Yes, we can take away the [electricity] meter'* or ask

‘*Can anybody lend you money, or do you have a flat or something else? If you have the flat, we could claim it for security purposes’*. Collectors have various tactics to besiege customers to find other sources of money (Aliança contra la Pobresa Energètica, 2018, 31", 55").

In worst cases, households tend to resort to illegal connections as they succumb to WEV. These may happen as a result of being denied an official connection due to accumulated debt, lack of a house contract or other relevant documents, such as a report on security measures that requires payment. These households do not only face danger in their everyday life, they are also charged the maximum electricity bill based on an estimation of the annual usage exceeding 2 000 €. This makes legal reconnection even more difficult, as debt and fines accumulate, thereby creating a vicious cycle. As mentioned above, APE confronts these situations using direct action. As a result, the electricity company, Endesa, has reduced the debt of some families, but does not extend the same consideration to others as a general policy. In contrast, AGBAR has taken a more generous position in announcing a new policy, by which the debt of vulnerable families will be completely written off.

The financial aspect of WEV also brings an important discussion to the surface, i.e. who is responsible for paying the arrears of WEV households? Before the amendment of the Spanish law RDL 7/2016, the provision of social vouchers was limited to the electricity companies operating under a regulated market; this involves the big five multinational power companies i.e. Endesa, Ibedrola, Gas Natural – Fenosa, EDP, Viesgo. However, today various companies in the free market are also responsible for providing these vouchers. This possibility allowed vulnerable households to be able to raise benefits without relying on the previous oligopolistic market.

In the past, the responsibility of paying the social costs connected to voucher policies fell in the grey area of the regulation, while, power/water supply companies refused to take responsibility from the debtors. APE claimed that companies should bear full responsibility of these costs. In the case of Catalonia, where Law 24/2015 is in force, the Barcelona city council proposed that energy companies should agree on the responsibility of 50% of the social cost in paying the bills. The soft position of the city council was criticised by APE, but even the offered proposal was not accepted by the power companies, and the question as to who will pay for this figure remained unanswered. At last, the decision taken at the Spanish ministry level provided the same result, as proposed by the Barcelona City Council: 50% the cost would be covered by the administration and the rest by the companies.

Regarding water poverty, the AMB holds a more pluralistic opinion, clearly stating that the responsibility on the arrears lies on all taxpayers, in that the debts should be divided and paid by taxpayers to recover the cost of water supply. Their logic supports that the water supply business should be for profit, not for charity. Meanwhile, the AMB also highlights AGBAR's dedication in financing a solidarity fund to pay the bills of vulnerable households to guarantee minimum access to water, with the idea that water should be provided to everyone as long as they are not wasting it. AGBAR's engagement with vulnerable households by means of a solidarity fund strongly contrasts the attitude of power supply companies probably because the water market is more regulated than the electricity market, thereby in principle more sensitive to social problems. Moreover, it should be considered that although AGBAR concentrates most of the shares of the metropolitan water company, this company is a private-public venture.

4.2) Co-production of WEV knowledge

4.2.1) Science and Technology entering homes and campaigns

Socio-technological arrangements in relation to domestic appliances, meters, electric installations, etc. constitute important reasons why affected households go to APE for help. Households have incorporated various domestic appliances in everyday life during the last decades. For example, the research on minimum income standards (MIS) (Walker et al., 2016) revealed that TVs, computers, broadband and domestic appliances are considered necessities rather than wants, as everyday life technology have evolved incorporating higher services (Table 2). Studies in the US (EIA, 2015) have also observed significant increases of residential electricity use during the last two decades, whereby appliance use accounted for the largest share (personal computer and microwave ovens represent the highest increases). As the energy services that are perceived to be essential at home increase in number and tend to augment themselves in scope, vulnerable households feel the lack of appliances more substantially now when compared to past years. For instance, TVs and refrigerators are increasingly considered common and essential parts of the household, as they provide various social functions. In immigrant households, a TV, especially when equipped with a satellite dish, has an educational role (e.g. on language, culture, and news on the country of residence as well as the country of origin). The lack of electricity for the refrigerator causes acute concern, as it is directly related to food security, especially during summer. For families with children, refrigerators are essential for their care, as can be observed in the following when describing O’s and U’s households:

> O’s household has the electricity supply cut off for one month and two weeks. O has not connected to the grid illegally because she is afraid that something bad will happen. Fines can go up to EUR 3 000. Now she has reached a limit. She has kids who want to watch TV, and they are nagging about it. But at the same time, they are maturing too fast. Her 4-year-old daughter tells her: '*I don’t need anything for my birthday, but I will give you a present. I will buy you light*' (O, 5.4.2017 field notes)
>
> U lives in a social housing. However, the former owner's debt is affecting her electricity supply. She said that they [the power company] already came three times to cut the electricity supply off. For her, it is important to have the fridge, as she has kids. She tried many things in the past to have the electricity supply fixed, but was unable to find a solution. She is avoiding paying a debt that does not belong to her. All the bills add up to EUR 800. (U, 30.11.2016)

Increased dependency on energy services through various domestic appliances is perceived as a challenge, as these embedded social norms need to be challenged in order to contribute, among other objectives, to less pollution and to climate change mitigation (Walker et al., 2016). However, vulnerable households from APE express a different approach in understanding the technology and its political agents.

Table 3. The list of energy use categories considered essential in minimum income standard research in 2014 (adopted from Walker et al. 2016)

Energy use category	Necessity in every households	Necessity in certain households
Heating	Central heating (for heat and hot water)	Upright fan heater (pensioners; single working age adults) Electric fan (pensioners)
Lighting	Electric main lights, side lights, nightlights	
Entertainment and communication	Landline telephone, 32-inch TV screen, computer and broadband, mobile telephone (one per adult, and each child in secondary school) and Freeview box, CD player, DVD player	Landline phone removed (working-age adults without children), paper shredder (pensioners), extra laptop (households with more than one school-aged child), no printer (households without children), computer and printer (families with school-aged children)
Cooking	Fridge, freezer, cooker, kettle, toaster	Steamer (single female pensioner; single male pensioner), handheld blender (couple without children), microwave (all except for couple without children), slow-cooker (pensioner couple)
Cleanliness and personal care	Vacuum, iron, washing machine	Hair straighteners (working age females with and without children; secondary school female children), hairdryer (adult females; secondary school female children), tumble dryer (family with over three children)
Gardening and transport	None	Lawnmower and trimmer for garden (families with children), car (families with children)

Firstly, they have the right to have energy and appliances at home despite some critics remarking that vulnerable households have acquired luxury goods beyond their purchasing power (i.e. mobile phones). However, such criticism ignores that a dignified life is a basic constituent of society, and that vulnerability should not imply deprivation of technological benefits. Communication services, including a smart phone, internet and a computer, are essential for job search, education and various types of paperwork as well as emerging forms of social participation. APE also mobilises much of its campaign via online platforms, such as Google groups, Telegram, Twitter @APE_Cat, Instagram @ape.cat, Facebook @AlianzaContraLaPobrezaEnergetica etc.; all forms make internet access an essential component of the organization. According to fieldwork observations:

> Twitter and Telegram, which are popular social media applications, are emphasised as important tools for the movement. They were able to secure electricity in one day with a Twitter campaign. Telegram is an important tool to communicate when they have some urgent cut-off to solve. (13.1.2016 Field Notes)

Moreover, outdated technology is often a cause for higher energy or water consumption due to smaller and falling efficiencies resulting in higher bills. However, households with old domestic appliances are quite common. For instance, refrigerators have improved their efficiency in energy terms using on average 40-60% less energy than 20 years ago (Kim et al., 2006). However, a refrigerator is one of the priciest household appliances, and WEV households can only afford to replace their non-functioning old refrigerators with a second-hand, low energy efficiency machine. With relatively high percentage of households without central heating, the use of old electric heating devices also increases energy vulnerability. One of the few households that we could interview during the winter of 2015 had picked up an electric heater from the street. It was the only heating device present in the home and placed in the middle of the living room, where most daily activities occur.

Secondly, deteriorated electricity installations are jeopardizing safety. WEV households cannot cover the high costs of installations and renewal even though it is mandatory. In such cases, households cannot sign a contract with a power supply company, thereby leaving them in the dark. Having often only access to obsolete technologies, households are thus left in the most vulnerable position.

Lastly, the incorporation of new technologies has the side effect of making energy vulnerability more visible, as can be observed from the adaptation of digital meters in Spain. As companies are obligated to change all meters, technicians visiting apartment buildings detect households that are illegally connected. Illegal connections are subject to penalties. However, households are left with no other choice after companies deny them legal connections. Moreover, penalties do not help in normalizing their situation as long as substantial economic and administrative support needs to be provided. Over and over again, we observed their uncertainties and doubts regarding the credibility of the digital meter reading, for which they strongly believe further investigations should be conducted. Various households go to APE, claiming that they received much higher bills after changing the analogue meter to a digital meter even though they were limiting electricity consumption to the minimum as usual. According to recent research (Leferink et al., 2016), electromagnetic interferences were found to have caused inaccurate readings with documented errors being as high as 582%. However, the clear and common causes of these errors still need to be revealed and confirmed by further data and research.

4.2.2) Consolidating agency from everyday WEV

WEV, often socially unseen, has been exposed by APE. Before introducing every meeting, APE members affirmatively declare to its audience: ‘You are the testimonies’. With this statement, they seek to encourage newcomers, who are usually affected households, to let go of their sense of shame, and regain confidence with the help of the APE family. According to our survey, most participants in APE meetings consist of those at risk of social exclusion (Table 2). There is a high concentration of female participants and single parent households, who on average have larger families compared to the Catalan average of 2.1 members per household. Among the respondents, 64% were living on monthly household incomes of less than EUR 750, and 36% lived on less than EUR 450 while 21% declared incomes higher than

EUR 1 050 per month. Among the respondents, 45% were unemployed without compensation, 28% were unemployed with compensation, and only 2% had permanent jobs. Single-parent families were especially vulnerable, as 21% of them did not have any income.

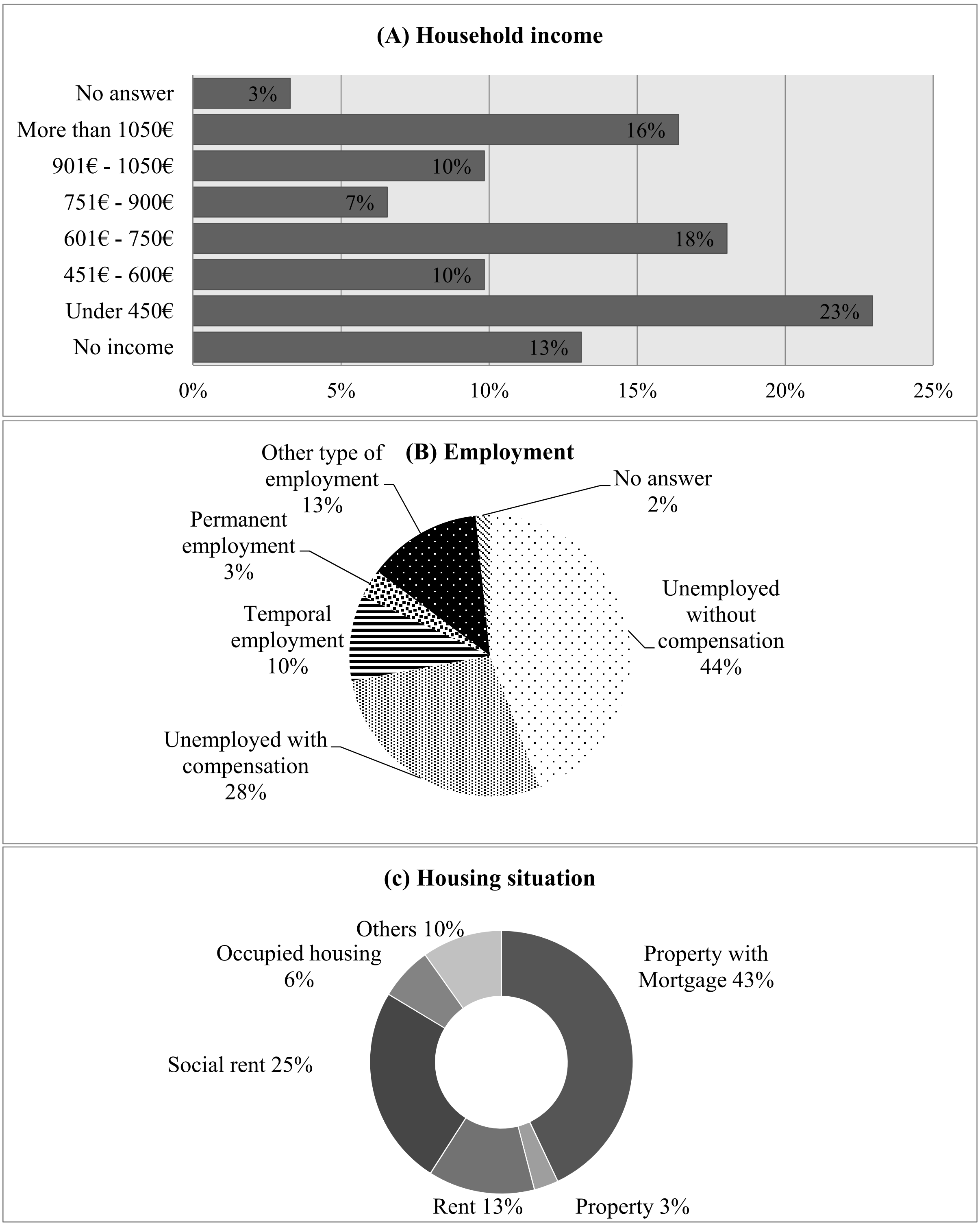

Figure 1. Socio-economic status of APE participants (a. Household income; b. Employment; c. Housing situation)

The high percentage of participants in housing regimes with mortgage stands out, since many families (84%) are also part of the sister social movement PAH. Determining which households are dealing with both energy and water problems resulted in bringing together a number of other social movements directly related with water such as *Aigua es Vida* to constitute a social movement dedicated to WEV. The observation of WEV was not unique to PAH, as other organizations (non-profit and public) also confirmed observing the same. However, APE was unique in the sense that it created a platform based on the PAH's practice of open counselling, empowering and direct action with a militant style, e.g. occupying banks, not fearing to camp there until their request is fulfilled, or in another situation, protestors were forcefully removed by police (see also García‐ Lamarca, 2017; Suarez, 2017).

The organizations forming part of APE and those collaborating as a team of spokespersons for APE have very critical actors. These actors are at the intersection of different organizations that are themselves network nodes on issues ranging from globalization, and unemployment to development and the environment. Organizations, such as ESF and DESC, contribute to the co-production of WEV discourses in Catalonia. Concerning the issue of political economy of energy and water commodification, they have a long history of working with specialists in developing countries. Spokespersons for APE work or have had experience working in these organizations. Thus, their dedication to APE contributes directly to expanding discussions on domestic energy and water problems towards greater concerns involving energy and water rights. These activities provide greater insights into connecting vulnerable actors with activists and academics having scientific and practical knowledge. As a consequence, such connections contribute to forming agencies that enable APE to comprehend and deal with both the political economy and actual empirical findings from the lived experience on WEV at the local scale. Although these activists confirm that the challenges are daunting, as counsellors, they aim not only to provide a wider perspective for addressing the injustices of the energy and water markets, but also sustainable practical management tools for the households.

Organizations such as ESF and DESC also invite external experts, academics, and practitioners from other European countries to do workshops and seminars. All these activities require further organizational power (funding, etc.). These workshops act as platforms for knowledge-sharing and discussion and provide opportunities for sharing and testing. The expertise mobilized confirms the legitimacy of their advocacy and contrasts the experience of APE with other European experiences. We particularly observe from the lived experience that the direct impact of social care on WEV tends to be felt more thoroughly than merely providing technologies that could improve household comfort. Therefore, the social care structure involving administrative and bureaucratic arrangements (paperwork, work flow, policy design, social welfare design, etc.) can prove to be more beneficial. Such knowledge is acquired in the organizations by inviting experts on social care to the workshops and through case studies. Therefore, the founding members of APE are significant actors in co-producing knowledge and mobilizing power that confronts the dominating agendas of energy and water companies.

Moreover, within a short time, APE was able to build a platform, wherein WEV was openly discussed and had the power to impact policy. Thanks to the Barcelona City Council hiring a former APE activist, the council has begun listening carefully and siding with vulnerable households. Moreover, this also meant that APE was able to share its knowledge in a much more open manner with the council.

4.2.3) Affected households as actors

Although WEV does not exclusively imply households at risk of social exclusion, much of APE participants are vulnerable households. As with PAH, APE empowers people and turns them into activists and actors, who can help other households in similar situations. However, due to the urgency and speediness of the solution for WEV cases in comparison to the housing crisis, APE has experienced more difficulties in building critical mass compared to PAH, as the eviction process is much more complicated and takes a longer time to confront and resolve.

Nonetheless, by borrowing strategies from PAH, APE employs a militant style of insurrection for declaring water and energy rights. This highlights the importance of co-production, as the experience from other social movements reinforce knowledge-sharing in the daily practice of such movements. Not only do the empowered actors become active voices in increasing awareness, but they also become pertinacious scrutinizers of policies. The collective agency of affected households transforms APE into an agent that addresses WEV while working with various institutions. For example, the Barcelona City Council has opened new offices to address WEV. T, who is a fervent participant of APE and an affected person himself, analyses system errors and reports accrdingly in the counselling sessions (Figure 2). He analyzed the current structure of '*punt d'asesorament energetic'* (English: Energy Advice Points') and its workflow in order to address the loopholes in the process, whereby affected households were being directed from PAE to SS and SS to PAE, and back and forth. These observations are delivered to the city council at the next periodical meeting and help create changes to correct the inconveniences or wrongdoings of the offices.

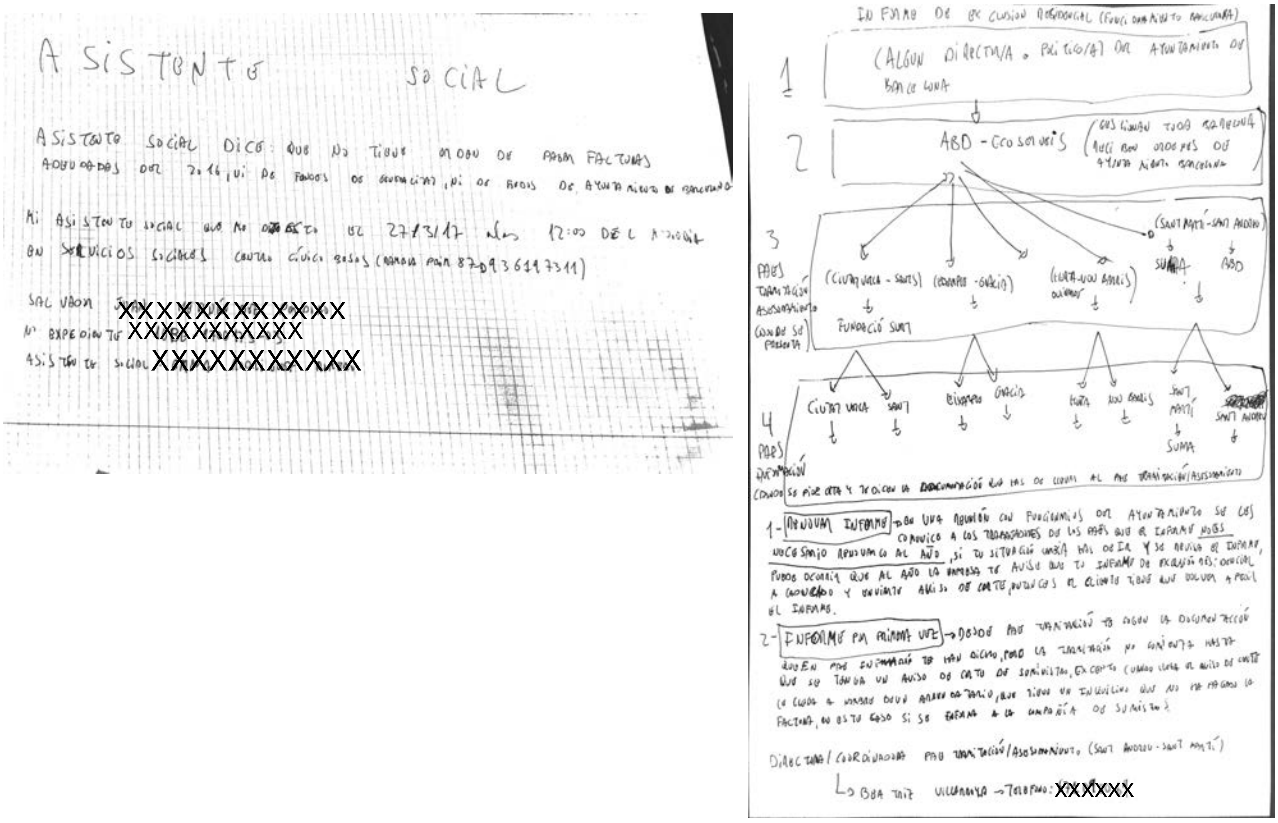

Figure 2. A schematic analysis conducted by T on the socio-technical structure of WEV in the City Council of Barcelona (supplementary info.B)

APE has the agency to address both water and energy problems, whenever affected households knock on their door to attend the counselling sessions. The coexistence of both problems and the impacts on daily life has compelled and empowered affected households to address and tackle these problems together. Previous studies revealed that WEV affect 7.31% and 6.96% of households in AMB, respectively (Yoon et al., forthcoming). This also explains why water had to be part of APE's activity and how water vulnerability has become such a vital consideration.

More crucial than ever before, the lack of knowledge puts households in a weak position, as they are limited in their attempts at obtaining the necessary tools in overcoming their difficulties. Among the problems these households face is that many do not have sufficient knowledge to understand how to read their utility bills, which companies and tariffs to choose, and what type of taxes are to be paid through such bills. To further develop and strengthen

APE's position through a reciprocal process, an increasing number of affected households participate in APE and remain active members, who build the routine of knowledge-sharing and contesting the current agendas of utility companies. During the aforementioned practices, APE carefully follows the state-of-knowledge, by utilizing it as a means of redirecting power towards APE's cause. However, in terms of efficiency, APE does not actively share knowledge. Rather, this role is taken care of by the PAE, as it involves costly interventions. The knowledge shared by affected households in this field is limited to minimizing use, to leaving all appliances unplugged, learning to cook more efficiently with an electric kitchen, recycling shower water for cleaning, etc.

4.2.4) Other actors

Law 24/2015, which seems to be the only legal text within Spain that recognizes WEV, remains valid in Catalonia after disputes over its legitimacy in the Spanish constitutional court. Approved on July 29, 2015 by the Catalan Parliament, Law 24/2015 was enacted by popular request, which was promoted by APE, DESC and PAH to address WEV along with housing issues. This regulation is one of the strong actors in the WEV landscape, since it states that vulnerable households must have continued services despite their incapacities to pay their water and energy bills. It is one of the most advanced forms of regulations that protects vulnerable households and supports APE's agency (see the Spanish campaign '#La pobreza energética mata. La Ley 24/2015 salva vidas!'; in English: '#Energy poverty kills. Law 24/2015 save lives!'). Since its approval, it has prevented water and energy cut-offs in 30,000 households in Catalonia (APE, 2017). This legislation has proven to save lives in contrast to the previous policies in Catalonia, which had left houses without water and energy. By considering Foucault's concept of biopolitics, it can be understood that when putting it in the context of vulnerable households, life becomes disassociated or abstracted from the pure physical limits of individuals (Foucault et al., 2004). In the case of WEV, the utility companies demonstrate the power of possession by imposing cut-off policies and threatening the lives of vulnerable households. Altogether, they are exercising measures of "*letting die*". This claim is also supported by the fact that there have been various domestic fire cases, wherein energy poverty has been identified as the main cause of these fatalities. The changing governmentality of water energy vulnerability in Catalonia signify how life is not a basis or the object of politics, but rather a border to politics that should be 'simultaneously respected and overcome', and in this vein, 'both natural and given, but also artificial and transformable' (Lemke, 2011, p. 5). Altogether, this propels participants of APE and the affected households to be at the core of influencing the change.

At the same time, Law 24/2015 has a great power in protecting vulnerable households. In Spain vulnerability is formally determined and recognised by means of filling out and submitting a form to utility companies called 'Informe de Riesgo Exclusion Residencial' (in English: 'Report on the Risk of Residential Exclusion') It was previously known as the 'Informe de Vulnerabilidad' (English: 'Vulnerability Report'). Presenting this form to utility companies is a concrete measure for households to avoid cut-offs. Therefore, vulnerable households need to be inscribed in SS registers in order to receive approval for their Informe de Riesgo Exclusion Residencial. Thus, official registration allows other social funds to help pay the unpaid bills of vulnerable households. According to one respondent's experience:

> One Saturday while S was preparing all the paperwork to get the *Informe de Riesgo Exclusion Residencial* from SS, the natural gas supplier cut her household off. S complains that on top of this, SS do not have any understanding of the Law 24/2015, and they kept asking for more documents. In the counselling session, APE decided to contact the regional government in order to solve this problem. (S, 22.3.2017 field notes from the biweekly counselling session)

In many cases, the life of vulnerable households becomes conditioned by the relationship they have with the municipal SS. Some schedule monthly visits to update their status as a way of maintaining their cases active. Therefore, life becomes bound to SS funding on energy and water while meeting their assigned social worker becomes a strategic act. According to one respondent's experience:

> J entered a housing provided by the city council and the house did not have any water, electricity or gas. She was complaining that in a case like this when she is receiving housing, she needs to fight to get her electricity, gas and water - all the basic utilities. She had five electricity bills to pay off in order to obtain electricity supply. She said that after moving to this new house, she had to change her branch of SS. Since then, the work was not the same. She had felt that it is a whole new process. She said 'before, they [Social workers] knew me, and they had good relations, but now it is not the same' […] She needs to build trust with SS all over again. (J, 16.11.2016 field notes)

Changes in WEV policies sometimes add to the confusion of SS workers, which in turn imply new administrative and bureaucratic hurdles for WEV households. In some cases, knowledge gained from APE empowers affected households to become actors with stronger arguments for demanding the correct application of Law 24/2015. These households learn to confront the administration and demand their rights by testing various tactics, which is shared in the assembly later on. According to one respondent:

> She shared her story of how she had to tenaciously insisting on getting the Informe de RER. She made a bit of a commotion, mentioning that she had the right to get the document because the law says so. SS asked back "What law?" Upon hearing this, she said that she left the office with a bang on the door, so that the boss could hear. She got a phone call 40 minutes later, and they told her to come by at 16:30h. The social worker who previously attended to her told her, 'I'll give it to you but I have no idea (what it is)' (N, 27.01.2016)

Under the nexus perspective, the ever-changing characteristic of energy and water services may result in implications for other issues affecting food security, health, and everyday life. First and foremost, the price fluctuations of water and energy can cause greater impact in terms of household budget trade-offs between food, transportation and other costs. Physical and psychological distresses induced by WEV in everyday life are beginning to gain more attention in health studies. In APE, many have also expressed emotional distress as they struggle to secure water and energy.

5) Discussion

The article focused on two main topics. Firstly, it analysed the struggle of vulnerable households in AMB and APE's activism by addressing the 'accumulation of dispossession' to reveal the complexity of WEV. Secondly, the co-production of knowledge observed in APE's practices has also been highlighted as we analyzed the role of key actors in creating APE's agency. We argue that empowering affected households through participation, sharing practices, and further developing the discourses through the involvement of other social actors and their expertise culminates in mobilizing power that supports APE's discourse on the 'rights approach' concerning WEV in Spain. The lack of domestic energy services, installations, and the introduction of digital meters are seen as the main technologies reinforcing WEV discourses within APE.

APE has succeeded in fostering a discourse that defends the right of vulnerable households, thereby driving the WEV discourse at the regional level. So far, the limitations of physical access to energy or water have been addressed thoroughly in APE. Law 24/2015 guarantees the physical access to water and energy and this has been the major approach for energy and water companies in term of social vouchers. However, it is clear that there is limitation, as we observe a void on renewable energy or in the incorporation of unconventional or innovative technology in WEV discourse. The focus on the lived experience of the households still limits the capacity of social movements to address decentralised renewable energy systems. The financial vulnerability of the households approaching APE also limit their ability to access more efficient products or domestic appliances due to path-dependency issues. In other words, they rely on the resources that they already have at home. Likewise, creating zero emission houses also requires large amounts of investments that are totally beyond the capabilities of vulnerable households.

Moreover, until recently, regulated markets only provided social vouchers, which also limited vulnerable households to contract green energy companies. Back then, Somenergia, a local energy cooperative endorsing sustainable energy supply had approached APE for possible cooperation. After a discussion in the assembly, the potential collaboration was suspended, since the social voucher program could not be offered by Somenergia. Moreover, financing also supposed a problem since a cooperative can only rely on a limited number of members, and APE saw it unjust that only a limited number of 'good' people had to take care of the cost of providing the social vouchers. At the end, APE chose to challenge conglomerates forming the oligopoly, which have the power to shift the energy market comprising mainly of commercial and distribution companies.

In the long run, deprivation of renewable energy or of alternative water sources (grey water, rainwater harvesting) might further put vulnerable households at a relative disadvantage, as they will have no other option than to purchase conventional energy and water. The challenge remains in finding the right pathways for more equitable technologies or decentralised systems. It should be only a question of time that a discussion takes place on the WEV regarding renewable and decentralised technology implementation. In Spain, it seems that various socio-technological structures involving a renewable and decentralized systems are beginning to be implemented.

6) Conclusions

The article followed the trajectory of APE, a social movement in Barcelona working in issues of WEV. Our approach involved using a political ecology framework and borrowing the concept of co-production from STS in order to focus on the strategy of this social movement for creating knowledge that could be deployed as an agency for practical action. APE confronted the utility companies' tactic of 'accumulation by dispossession' practiced by utility companies, through the co-production of knowledge, their biweekly assembly and other practices, and the participation of affected households and spokespersons connected to other non-profit organizations in the region. Their discussion touched on politics, administrative, technological, and social aspects around WEV forming a *bricolage* that represents the advocacy of APE.

Most importantly, APE's foreground for treating WEV is rooted in the lived experience of the households participating in counselling sessions. WEV is repeatedly analyzed, whereby such analysis greatly helps in actively comparing the two resources; Moreover, it also contributes towards fostering proactive knowledge on the commodification of both (Yoon, forthcoming). Affected households empowered in APE together with leading spokespersons of this organization create a reciprocal process based on mutual support, whereby knowledge is shared and discussed in counselling sessions and direct actions. The shared knowledge allows APE to strengthen their strategy and discourses, gaining a powerful position to lead arguments on WEV at the regional level.

This perspective of WEV developed by APE shows an alternative path to the concerns on WEN, namely 'attending to questions of power is a crucial but often underplayed aspect of proposed integration' (Cairns and Krzywoszynska, 2016). The vulnerable households experience WEN in particularly fragile situations, not only economically but also socially. Therefore, APE as a social movement demonstrates how various actors join in co-producing knowledge in addressing WE security for these vulnerable households. Moreover, as APE became influential, various actors at the local, regional and national level came in contact with them with the motivation to collaborate in creating periodic meetings, in which the knowledge could be shared. This allowed affected households to have direct influence and become active scrutinizers of the socio-technical engineering of WEV regime in Barcelona.

In our view, the vulnerable households' experience in dealing with energy and water supply brings new insights to WEN, energy poverty and water poverty studies. Energy vulnerability studies have started addressing the problem of fuel poverty and energy poverty in developing and developed countries. Along with the concept of environmental justice and by following three essential tenets, i.e. procedural, participative, and distributional justice, our understanding on energy use have revealed the complexity of the problem. However, water poverty is still perceived as a distinct field due to materiality conditions, inertia, limited attention on affordability, etc. Rarely are the two discussed together holistically as an issue for environmental justice. Even though scholars have researched persistently on technological alternatives, consumptions, and savings related to domestic hot water (DHW), there are still very few articles addressing the needs of DHW services for vulnerable households compared to those focusing on the technological aspect of DHW. Rather, the attempts at integration come from social movements trying to include water and energy as part of universal basic services, along with transportation and housing. It is therefore very interesting to note that WEN studies at the household level have begun with cases focusing on household vulnerability and deprivation.

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Supplementary graphical information

A.1. https://www.tiki-toki.com/timeline/entry/1051625/Nexus-ed-Water-Energy-Vulnerability/

A.2. https://youtu.be/56GR7fvfR2M

B. Translation of Figure 2

Social assistant

Social worker says s/he has neither the order to pay bills due from 2016, nor funds from the Catalonian government, nor funds from the City of Barcelona.

My social worker told me this on 03/23/2017 at 12:00 noon at Social Services, Besos Civic Center (Rambla Prim 67 - [0000000000])

[Name]
File No.: [00XX-0000000-00]
Social worker: [name]

Residential Exclusion Report (Operation Barcelona)

1. Directive / City Council of Barcelona
2. ABD-Ecoservei (Manage all of Barcelona, receive orders from Barcelona City Council)
3. PAE Processing /advice (Where [document] is presented)
4. PAE Information (Where an appointment is requested and they tell you the documentation you should take to the PAE Processing /advice)

1- Renewing a report → in a meeting with city council officials. It is communicated to PAE workers that the report does not need to be renewed every year.
If your situation changes, you should go and review the report. It might happen that the company informs you that your residential exclusion report has expired and you receive a cut-off notice, then the client must request the report again.
2- Report for the first time → from PAE processing, you hand-in the documentation

indicated in the PAE information, but the processing does not begin until you have a notice of cut-off supply. [In case] a cut-off notice arrives in the name of a landlord, who has a tenant not paying the bill, the supply company is informed [directly].

[Name] Telephone [000-00000]
Director / Coordinator PAE Processing / Advisor (S.Andreu-S.Martí)

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5 Conclusions

5.1 Summary and final conclusions

The thesis examined the water-energy nexus in urban environments through two case studies: Benidorm and Barcelona. Inspired by political ecology and science & technology studies, the thesis attempts to contribute to Water-Energy Nexus (WEN) studies by exploring the nexus at the municipal scale. WEN in the hotel and recreation sector was evaluated by conducting an *energy for water* analysis. The energy and water used at the micro scale (e.g. water heating and steam generation, laundry, kitchen, swimming pool and spa) were estimated to determine the impact of these activities on *energy for water*. The case of Barcelona attempts to develop a social perspective of WEN. It focused on the importance of having, both water and energy, to fulfil the necessary services that enable households to achieve the optimal functions of sustenance, care and reproduction. The processes involved in the politicization of WEV in the social movements were analyzed based on the observation and action research conducted in collaboration with 'Aliança contra Pobresa Energètica' (English: Alliance against Energy Poverty (APE)).

First and foremost, the case of Benidorm demonstrates various implications of WEN on the 'sea and sand' mass tourism. The thesis analyzed the urban water cycle of Benidorm and recapitulated that energy has always had a central role since the 1970s. Tourism development in Benidorm entailed increasing water demand, which intensified water stress during dry periods. When urban water was secured under the agreement with farmers in the 1970s, the cost of energy played an indispensable role. This agreement allowed drinking water to be prioritized for urban use. In exchange, farmers were provided with reclaimed water from a tertiary wastewater treatment plant for irrigation. This required higher energy inputs compared to secondary wastewater treatment but significantly less energy compared to desalination.

Moreover, the energy intensity involved in water provision plays an important role during drought periods, when the scarcity of water intensifies. There is a difference in the extent of energy intensity required depending on the water source chosen for provision. The most energy-intense water comes from desalination. Even though the Muchamiel plant operates with excellent efficiency using state-of-the-art energy recovery technology, the input required for water production in the desalination plant would be around six times higher than the input from other available water supply options. Although local authorities are aware of the new water source available, the high financial and energy costs involved make it an unattractive supply option. Unfortunately, the desalination project, which was planned with the political interest of ending the water conflict at the national level, transferred this conflict to the lower scales of water governance. Today, the local water consortium must deal with political pressures to incorporate costly sources for urban use.

At the micro scale of hotel and recreational activities, WEN appears at the core of their management practices and daily activities in providing comfort and services to customers. Although it is still perceived as a new concept by the hotel owners in Benidorm, various tasks in the nexus justifies the possibility of incorporating *energy for water* indicators, along with energy use intensity and water use intensity, which are commonly employed as indicators of environmental performance. This is especially useful for the case of Benidorm since swimming pools, cooking and in some cases, spas are at the core of services provided involving WEN, along with hot water provision. Incorporating renewable energy would significantly reduce energy intensity. However, the appropriate technology choice for reducing energy consumption presents a challenge for many hotel managers who think primarily in terms of cost efficiency.

The hotel sector has shown interest in the ground source heat pump system, which uses groundwater as a medium for providing HVAC. An ‘open system’ is preferred to a closed system due to lower capital investment, as it directly extracts water from the aquifer and reinjects it to the same aquifer, thus creating a flow of groundwater. However, there is a risk of depleting the aquifers, as more hotels opt for this technology due to higher energy efficiency and lower costs.

Seawater intrusion in the local aquifers is highlighted as an uncontrolled environmental cost and has an impact on the WEN in Benidorm. This problem affects the hydro-social cycle by increasing energy use and therefore the treatment costs of the urban effluent. Some hotels use groundwater for pools and toilets, which is not strictly regulated or managed. Moreover, waterparks also rely on groundwater. In both cases, groundwater is discharged to sewage and mixed in the urban effluent, which contributes to augmenting the energy input needed for the reclaimed water.

The case study of Barcelona demonstrates another interesting example of WEN manifestation, as it highlights the water and energy metabolism in the households of the urban environment through the lenses of the most vulnerable population. Based on affordability measures, the case study showed that a substantial percentage of households experience critical difficulties in paying their water and energy bills. The households studied have unstable housing, economic situations and employment status; altogether, these circumstances seem to have a major impact on the households' ability to pay their energy and water bills. The Barcelona case study provides a unique example of an arena, where social movements have taken an active role in problematizing and raising awareness of water and energy vulnerability as clear social problems. The dissonances between administration and regulations over water and energy poverty had been used to avoid responsibilities for solving poverty issues. Three social movements including APE initiated a Popular Legislative Initiative that resulted in the promulgation of a Catalan legislation that protects vulnerable households in securing energy and water flows, regardless of the household's affordability.

This initiative increases the comfort levels and consequently allows the household to function as a place of care and sustenance.

The everyday practices of APE brought up crucial questions for understanding water and energy governance in the urban environment. Particularly, the experience of vulnerable households in their struggle against utility companies and social services highlights the importance of knowledge and organization. Water and energy, as commercialized goods managed by private companies, are regulated with the objective of profit generation, and they work according to the principle of accumulation. They often practice the reverse logic of spending more money to cut off households by means of dematerialization (e.g. getting rid of water pipelines, taking meters), which costs significantly more than what households actually owe the company. Social movements, such as APE, therefore tackle the problem of the privatization of water and energy by condemning the market norms as one of the main causes for the vulnerability of households.

Although water and energy companies act in accordance with the market logic, some differences can be observed in the attitudes toward acknowledging social responsibility and addressing the unequal distribution of resources. At face value, they claim to support 'water for all' despite the dilemma, in which they penalize fraudulent users, which in turn, also becomes the argument they use to legitimize their concession in the region.

An open platform, which was initiated under the umbrella of APE and other social movements, actively involves vulnerable households. Their seminars and activities, which are aimed at increasing awareness and building strategies, became a process for the co-production of knowledge in the urban WEN. As a result, the households are empowered to imagine different energy and water governance systems and encouraged to be an effective watchdog of society.

Overall, focusing on the diverse urban WEN issues observed in Benidorm and Barcelona, the research aims to induce thinking along water and energy, supply and end-uses and the complexities involved in the ecological, social and political processes transposing the management of water and energy.

5.2 Key highlights

Four key highlights stem from this research:

- **WEN is dynamic and discloses complex ecological, economic and political decisions within the hydro-social cycle.**

The hydro-social cycle examined from the WEN perspective demonstrates that *energy for water* measures reflect the politics of water in Benidorm, where tourism became the main economic driving force of the city. Water scarcity due to physical limits was overcome by obtaining water from more distant sources, which required more energy inputs. Moreover, the new desalination plant in Muchamiel, which was conceived as a typical large-scale national infrastructure, involves significant energy costs for Benidorm.

- **Caution is imperative in WEN trade-offs at various scales and across scales**

The WEN trade-offs refer to situations where solving the problem of water supply results in energy problems (vice versa also applies when energy solutions create water problems). The case studies used in this thesis demonstrated that these water-energy interactions appear across scales, whereby the 'losers' may not be clearly observed. Therefore, the WEN trade-offs do not only require careful multi-actor examination at each scale, but also across scales, whilst focusing not only on the actors causing such trade-offs, but also the affected actors.

- **WEV unveiled the weakest actor and the true character of water and energy governance in the urban area.**

Water and energy are highlighted as two main flows that influence household activities. WEV addressed the reality of the urban water and energy crisis, where many households are denied access to resources due to regulations favoring profits for water and energy companies. Therefore, commodified water and energy controls people's lives, in that water and energy companies cut connections and refuse access. This dynamic reflects the governance crisis at the urban scale and reveals the true character of water and energy companies. Moreover, the passive attitude of the companies compounded by the inefficient support from local, regional and national governments clearly demonstrate the limitations of the current state of water privatization (i.e. concession to private-public companies) and energy (i.e. privatized market under oligopoly).

- **WEV experience has a transformative power to change the governance of water and energy.**

The Barcelona case study demonstrated how vulnerable households, which are considered one of the weakest actors, have politicized and transformed the discourse on energy and water poverty. Strengthening their agency through social movements, vulnerable households were able to shift the WEV paradigm. Empowered WEV actors address the loopholes in a variety of aspects, such as social services, customer services and the housing agency. Furthermore, the movement entailed juridical change and continues to address the limitation of the current governance model by collaborating with other social initiatives, such as the movement for water municipalization. Regarding changes in the energy sector, the Barcelona city council is establishing a municipal energy company to explicitly address the energy needs of poor households.

5.3 Future research

Firstly, the issue of *water for energy* at regional or municipal scale requires further attention. In Spain, and due to the private character of the energy market, water withdrawal and consumption data from energy facilities is often not available. This is a common issue in many other countries where transparency is not considered to be important and data are undervalued. In other cases, data are overvalued and treated as private information so as to have control over a topic that is controversial. In order to complete WEN analyses for Benidorm, a detailed study on energy facilities in Marina Baja comarca and Alicante province is required. Conducting research on such a focus would considerably help to address the effects of different energy mixes at the regional scale.

Secondly, there is a need for longitudinal hydro-social cycle studies on accounting *energy for water* that could provide further insights on the dynamic character of the WEN. Analyzing the evolution of *energy for water* could provide important data for preventing negative WEN trade-offs. Further analysis on the power relationships between the hotel and recreation sector, on the one hand, and the farmers, on the other, could help to better understanding the change of water use linked to land use changes. This is an intriguing link that has been detected during the fieldwork, but could not be explored in detail due to time limitations. As the economic activities of the farmers change from cultivation to tourism, this would bring a considerable impact on current water uses.

Thirdly, water and energy vulnerability during the summer season deserves further research. During heat waves, water is often used to cool down: at the household level, individuals meet this need either by drinking or by taking showers. However, this could be a problem from the perspective of vulnerable households, and as such, this question is yet to be addressed properly. Especially, *ad hoc* analysis using geographical information systems could provide meaningful results for local policymakers by identifying geographical hot spots.

Lastly, the explorative nature of the thesis imbues each case study with a distinct focus on addressing WEN at various scales and dimensions. The case study of Benidorm could provide a more holistic result if it were supplemented with a study on the WEN at the domestic end-use level. On the other hand, the case study of Barcelona could be completed with the WEN from the supply perspective (*energy for water* and *water for energy*). For example, Barcelona is increasingly becoming a popular destination for cruise tourism. However, little is known about the WEN of a harbor with large passenger ships in relation to equity and justice in water and energy access and costs. This aspect could be explored by examining the water and energy access disparities between Barcelona residents and the harbor.

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Annex I. Letters of coauthors

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A qui correspongui,

David Saurí, profesor del Departament de Geografia de la Universitat Autònoma de Barcelona amb DNI 46323312R,

FA CONTSTAR

que els següents articles:

- "Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain" publicat en la revista *Sustainability* elaborat juntament amb Hyerim YOON i Antonio RICO AMORÓS

- "The Water-Energy Nexus in Hotels and Recreational Activities" enviat a la revista *International Journal of Hospitality Management* elaborat juntament amb Hyerim YOON i Antonio RICO AMORÓS

- "The Water-Energy Vulnerability in Metropolitan Area of Barcelona" en revisió a la revista *Energy and Buildings* elaborat juntament amb Hyerim YOON i Elena DOMENE GÓMEZ

- "#No more thirst, cold, or darkness' - The role of social movements in the co-production of Water and Energy Vulnerability" enviat a la revista *Energy Research and Social Science* elaborate juntament amb Hyerim YOON

no han format part anteriorment de cap altra tesi doctoral, i RENUNCIA a presentar-los com a tal en el futur.

Bellaterra, 12 setembre de 2018

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A qui correspongui,

Antonio M. Rico Amorós, Director de l´Institut Interuniversitari de Geografia de la Universitat d'Alacant amb DNI 21463610X,

FA CONTSTAR

que els següents articles

- "Shifting Scarcities? The Energy Intensity of Water Supply Alternatives in the Mass Tourist Resort of Benidorm, Spain" publicat en la revista *sustainability* elaborat juntament amb Hyerim YOON i David SAURÍ

- "Water-Energy Nexus in Hotels and Recreational Activities of Benidorm, Spain" enviat a la revista *International Journal of Hospitality Management* elaborat juntament amb Hyerim YOON i David SAURÍ

no han format part anteriorment de cap altra tesi doctoral, i RENUNCIA a presentar-los com a tal en el futur.

Alacant, 6 de setembre de 2018

A qui correspongui,

Elena DOMENE GÓMEZ, Cap de l'Àrea de Desenvolupament Urbà Sostenible de l'Institut d'Estudis Regionals i Metropolitans de Barcelona (IERMB) amb DNI 43436718E,

FA CONTSTAR

que l'article "The Water-Energy Vulnerability in Metropolitan Area of Barcelona", elaborat juntament amb Hyerim YOON i David Saurí, en revisió a la revista *Energy and Buildings*, no ha format part anteriorment de cap altra tesi doctoral, i RENUNCIA a presentar-lo com a tal en el futur.

Bellaterra, 6 setembre de 2018

Annex II. Field notes[18]

1) Benidorm

1. Fieldwork Schedule

Date	Schedule
Tue. 2 June 2015	Office work with Prof. Antonio Rico
Wed. 3 June 2015	10:30 AM Desalination plant in Muchamiel 12:30 PM Fenoller-Amadorio connection pump station
Thu. 4 June 2015	9:00 AM HiDRAQUA Benidorm Office 12:00 PM Tertiary treatment plant of Benidorm 13:00 PM Wastewater treatment plant of Benidorm
Fri. 5 June 2015	Morning - Embalse Amadorio 12:00PM Estacion de Bombeo Algar, Consorcio de aguas de la marina baja

2. Field notes

2.1. Introduction

The hydrosocial cycle of Marina Baja is focused on the water supply management in order to secure water to the municipalities including a legendary city of Benidorm where skyscrapers welcome tourists from Spain and overseas. On the other hand water is supplied to farmers who have had power on water use traditionally to irrigate to their avocado and loquat fields. Benidorm's success in tourism owes to the measures taken to supply water to the booming number of tourists that came in search for the beach and sun in from the late 1970s.

Consorcio de Aguas de Marina Baja (Consortium from here forth) was established in the 1977 to be in charge of water supply and sanitation in the Marina Baja area. It consists of municipal of Alfaz del Pí, Altea, Benidorm, Callosa d'Ensarriá, Finestrat, Polop, La Nucía and Villajoyosa. The rest of the municipalities that are not part of the Consortium represent around 3% of the total population and water consumption of Marina Baja.

Table 14 Inhabitants and water consumption in 2014 per member municipalities to consortium (Source: Spanish Statistical Office, Cosortium)

Municipality	Inhabitant	Water provided by the consortium (m^3)	Water provision per inhabitant per day l/inhab./day
L'Alfàs del Pi	21,357	2,392,755	306.95
Altea	22,518	1,819,165	221.33
Benidorm	69,010	10,111,705	401.44
Finestrat	6,265	668,070	292.15
La Nucia	20,029	1,538,041	210.39
Polop	4,313	524,610	333.25
Villajoyosa	33,951	2,285,000	184.39
Callosa d'en Sarrià	7,370	0	0.00
Total	177,443	19,339,346	

[18] More field notes are available upon request

The province of Alicante is located in the semi dry region in the south east of Spain. Every few years this province experience periodic drought that lasts two or three year. Since 1970, there have been total six drought periods (Table 2). Since 2014, the sixth dry period started and the region is experiencing a difficult situation to combat the water shortage. As of 10 June 2015, there is only $3Hm^3$ of water left in Guadalest reservoir[19], and $0Hm^3$ left in Amadorio reservoir[20].

Table 15 History of dry years in Marina Baja region

	Year
1st period	1968/69 – 1970
2nd period	1977/78 – 1979/80
3rd period	1981/82 – 1984/85
4th period	1995/96 – 1996/97
5th period	1998/99 – 2000/01
6th period	2014 –

As Marina Baja area historically has been strong in farming, water provision to Benidorm meant that water resource that was previously used for agriculture was met with a competition. A measure was needed in order to meet the spiking demand for water for tourism industry as water that was used for irrigation, which the farmers owned, now had to be supplied to Benidorm. As the result an agreement between the Consortium and irrigators were signed in 2001 to confirm irrigators' cooperation to supply water to the towns in return to a promise that treated water from the wastewater treatment plant will be provided for reuse in irrigation (Real Decreto Legislativo 1/2001, de 20 de Julio). This convention includes the Irrigators' Community (comunidad de regantes) in Canal Bajo Algar that uses water treated from the tertiary treatment plant of Benidorm and irrigators community in Villajoyosa that uses water treated from Villajoyosa. Other communities in areas such as Polop and Callosa d'en Sarria also hold convention with Consortium for similar type of cooperation. Even so, when there is a drought, conflict with the farmers becomes visible as irrigators' community become more reluctant to share their water to urban consumption than irrigation. Marina Baja has emergency water supply system to transfer water in dry years through inter basin transfer Fenollar-Amadorio. A desalination plant at Muchamiel, which is an alternative water source for Benidorm, is still yet to be connected to supply water to Benidorm as the project for pipeline are in delay.

2.2. Hydrosocial cycle of Benidorm

The key to water cycle of Marina Baja is in the Algar aquifer that has capacity bigger than Guadalest and Amadorio reservoir - the two main surface water sources - combined. The calcite land contributes to outstanding quality of aquifer that fills up quickly when it rains, and releases water. The water in Algar is pumped to Guadalest reservoir from Algar Pump Station. Another ground water source, Benidarà aquifer is located at the neck of Guadalest reservoir. This water is extracted with 10 pumps and it flows to the Guadalest reservoir. General conduction system transfers water flowing with gravity from the reservoir through towns such as Polop, La Nucia to supply water to Benidorm. Water that reaches Torres dam where it is equipped with Torres pump station is pumped to Almadorio reservoir through impulsion of Torres.

- *Consortium*
- *Hidraqua*

[19] http://www.embalses.net/pantano-642-guadalest.html
[20] http://www.embalses.net/pantano-618-amadorio.html

- *Agua Alicante is a mixed company created by public administration and Acuamed.*
- *UTE runs the Muchamiel desalination plant under the management of Acuamed*.

As this research chose Benidorm as a case city, the fieldwork focused on understanding the hydrosocial cycle of Marina Baja related to water provision scheme for the town and collecting energy intensity data for water provision. The sections followed provide a summary of data collected and are in the order of the entities visited during the fieldwork. Lastly, hypotheses for consideration and data gap are presented.

3. Muchamiel(Mutxamel) Desalination Plant

This desalination was built with 60.5 million euros investment for the plant construction and additional 44million euros invested for the pipelines. Technical description for the plant notes that it was built to benefit 200,000 habitants with distribution capacity of 50,000 m^3/day and total installed capacity of 10,953kW with 4.56 kW/m^3 energy consumption rates. As of May 2015, only 10.7million euros of the investments for pipelines have been realized and the connection to Rabasa – Fenollar – Amadorio is not yet constructed. Thus, the visit to the plant confirmed that it was preparing water provision to Sant Joan, Alicante and Muchamiel but not to Marina Baja.

The electricity is used to pipe water from 4km away sea with 1 pump at the end of Rio Seco. From 100% of seawater extracted, 45% becomes desalinated water and the rest 55% is discharged as saline water with concentration double that of normal seawater.

Typically water in Alicante would cost 0.11€/m^3 but as previous studies have already proved, desalinated water cost more as it is highly energy intensive. However, the person in charge of Muchamiel desalination plant seem to have no idea how much electricity it will consume or how much it would cost to produce m^3 of water.

Reverse osmosis (RO from here forth) system with energy recovery (American) exchanges energy between water and brine and produces mechanical power to move the water. It does not have any type of energy generation system but has increased its efficiency to 95-97% using the energy recovery system. Reverse Osmosis membrane requires 60 to 70 bar of pressure during the process. Every 4 to 5 years, it is necessary to change membranes when it is run regularly.

Table 16 Proportion of energy consumption per installation at Muchamiel plant

Facilities	%
Sea water capture system	11,65%
Pretreatment	6,80%
High Pressure Water Pumps	70,87%
Treated water pumping	4,85%
Others	5,83%
Total	100,00%

During the summer when water temperature is higher, less pressure is required to treat seawater but the water quality of the first RO filtered water often has quality that does not comply with Boron level. Thus part of the first RO filtered water goes through 2nd RO filtration in order to increase the water quality.

The saline water is pumped to the filtration phase of the plant to be recycled and to be used for cleaning the filters. After the dirty saline is sent to the treatment plant before it is released to the sea.

Table 17 Projection of energy intensity for water production according to amount of water production and water temperature (kWh/m^3)

Production	16°C	19°C	22°C	25°C
16,666m^3	4.812	4.856	4.896	4.953

33,333m^3	4.605	4.650	4.691	4.748
50,000m^3	4.567	4.611	4.653	4.710

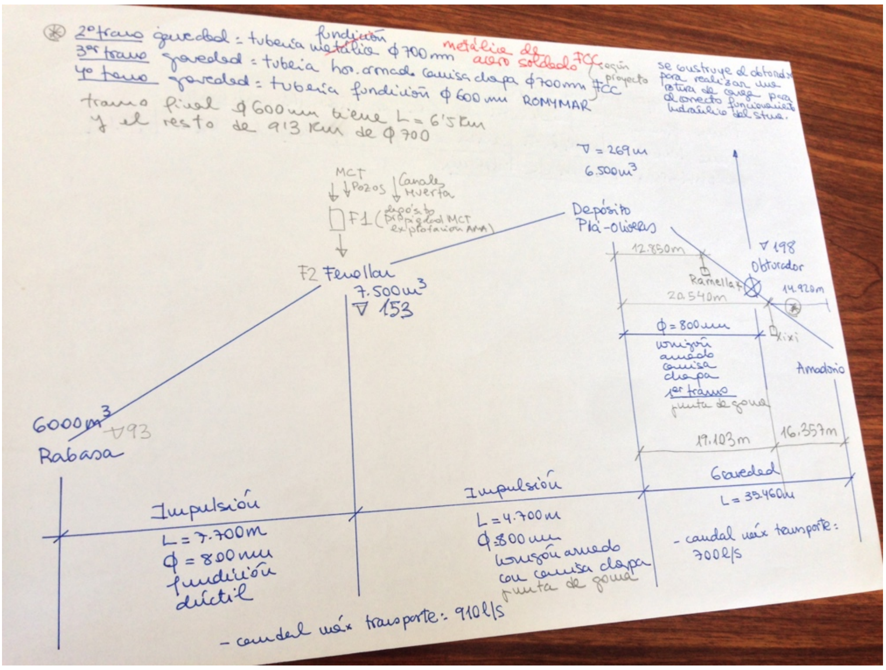
4. Fenollar-Amadoria connection

Fenollar-Amadoria connection is an emergency system established for water transfer to Benidorm during the severe drought period. This connection sends water from Rabasa pump station to Amadorio for the water to be transferred with conduction line from Finestrat to Benidorm. The total length of this conduction is 7,728m, total elevation is 180m from Rabasa to deposit. From deposit to Amamdorio water flows with gravity. The pipeline was built in 1996 during 6 months. As it was built over short time, the pipeline has had some problems in the past such as tumbling, breaks and has suffered water loss. The nickname of this line is *la tubería de la risa*. When Acuamed started managing this pipeline and started to supply water to farmers, they started to confront problems with the pipe. The major reason to this problem was because the engineer had chosen an inappropriate type of pipe which could not resist sulfur in the soil.
The last time water was provided to Benidorm through this connection was in Dec 1999 to Feb 2002. The water pumped and energy consumed during this period is provided at the table below.

Table 18 Water and energy consumption during the water provision period (June 1999 to January 2002)

Phase	Period	Duration (Months)	Electricity consumption (kWh)	Amount allocated (Hm^3)	Amount delivered (Hm^3)	Energy intensity-average (kWh/m^3)	Energy intensity-monthly average (kWh/m^3)
1	Jun. 1999 to Oct. 1999	5	NA	5.5	4.8	NA	NA
2	Nov. 1999 to Mar. 2000	5	NA	3.6	3	NA	NA
3	Apr. 2000 to Nov. 2000	8	NA	8.8	7.5	NA	NA
3 BIS	Dec. 2000 to Mar. 2001	4	804,588	1.5	15	0.536	0.536
4	Apr. 2001 to Jan. 2002	10	8,015,598	11.7	10	0.802	0.685

This transfer system contracts power supply on annual term. Even though it has the capacity to pump maximum 910 l/s when water is sufficient inter basin water transfer is not necessary. Thus usually they will not contract high power supply. However, when the severe drought is not predicted, the fixed power contract can become the locking factor as it will be difficult to increase the water transfer rate. The week we visited the inter basin transfer was pumping 50 l/s with the plan to increase it to 200 l/s but they had to solve the problem with the fixed power contract as they needed more power to pump more water. The water was sent directly to the pipe without passing through reservoir. The pipe went through some brakes during the summer of 2015 as it could not resist the pressure.



5. HiDRAQUA Benidorm

Benidorm receives water from both Amadorio and Guadales reservoir. The demand for water reaches its maximum in August and minimum in February when the water demand decreases to 19,000 - 20,000m^3 per month. There are two scheme of water in Benidorm but the second line is the old one that is not in use these days. The total length of pipeline in Benidorm is 224,704km. Even though potable water plant chlorinate the water, due to long supply line, it is necessary to equip chlorine-controlling system in the middle of supply line to meet the regulation for potable water at the point of use (regulated at the tap). Recently the conductivity of the water has decreased and average water consumption per capita day in Benidorm in the last year marked 125 l/day. In 2014, total 9,636,536m^3 of water was consumed in Benidorm for domestic, commercial, hotel and other use.

Table 19 Water supplied and billed in Benidorm (2014)

Category	Amount (m^3)	Category	Amount (m^3)
Water supplied		Water billed	
Registered potable water use	9,381,072	Domestic water use	4,846,988
Registered water use by Municipals	255,464	Commercial water use	1,541,039
		Lodging water use	2,930,679
Total registered potable water use	9,636,536	Total potable water billed	9,318,706

Hidraqua only supplies cold water to individuals. So in order to check the energy used for hot water system we should study the heating system that is installed in each building. However, recent regulation change has obligated new buildings to install solar heating system to heat water.

For potable water supply through pipes in Benidorm, there are total four pump stations equipped with 9 pumps. In 2014, total 128,800.5kWh of energy was spent in these pump stations.

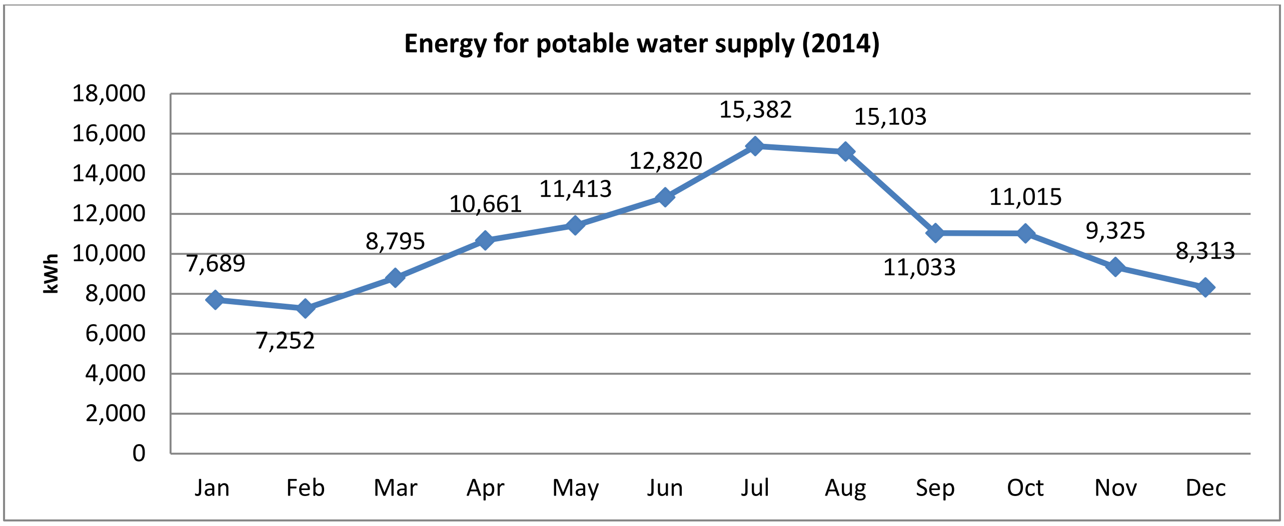


Figure 10 Energy consumption for potable water supply in Benidorm 2014

The technical efficiency of water supply in Benidorm is 95.34%, which is calculated by formula of water billed divided by water purchased from the Consortium.

Benidorm has 471,458 m^3 of unregistered water use (agua no registrada, ANR), which is the amount of water purchased from Consortium subtracted by amount of water billed. This discrepancy occurs due to water use that is not accounted such as fountains in the town without a meter, municipal use of watering gardens, illegal use of water, tricks, errors in the meters etc.

It has been 15 years since the regulation obligates flats to put individual meters but still most buildings do not follow this regulation. The water company tells the buildings with garden and swimming pool to have two separate meters, one for use inside the building and another for garden and swimming pool use. 75-77% of the buildings in Benidorm have their own water tank and motor to pump the water to building as buildings higher than 4-floors need a pump to have enough pressure for the tap water. Some commercial stores are connected to community water supply, as it is usually located at the ground floor of the building. And some of them do not require a pump.

In the pipeline, they try to maintain the lowest pressure possible in order to reduce the possibility of leak of water. The optimal level of this would be 2.5 to 3 bar. This is achieved by placing a pressure regulator (una reductora de presión de agua) at certain point of sectored zones. Because the water need varies seasonally, during the summer there is more erosion in the pipe and during the winter the water may run slower in the pipe but this is a minor issue.

Alicante has a separated system for controlling sewage and residual water from the buildings. The sewage system (el alcantarillado) collects water at the end of the *ramblas* where there is a little storage with a pump. Depending on the level of the storage, it pumps the water to wastewater treatment plants. Storage is equipped with 1 or 2 pumps.

Sewage from Benidorm is treated at the wastewater treatment plant of Villajoyosa and Benidorm. The dividing point for sending sewage to either station is at the playa de Poniente. The residual water from Benidorm can be sent either to WWTP in Benidorm or Villajoyosa. There is a zone where the water can be sent to either one with a bidirectional controlling system. Moreover, sewage can move between these two cities. Wastewater treatment plant in Benidorm has bigger capacity to treat water compared to the one in Villajoyosa.

6. Tertiary treatment system in Benidorm

The tertiary treatment system, Desalination plant of the wastewater treatment plant of Benidorm [Desaladora de la EDAR de Benidorm], is located next to Waste Water Treatment Plant of Benidorm.

The plant started operation from 2006. The water treated from here is 100% used in irrigation. At the end treated water goes to a pond, which belongs to irrigators (la comunidad de regantes) that has a storage capacity of 7,000m^3. This is the boundary where ownership of the water is handed to irrigators (regantes). The treatment runs depending on the demand from irrigators thus when it rains the plant runs less. The water treated per year oscillates between 2 Hm^3 to 4Hm^3 and the plant operates average 16 hours a day. But as mentioned, it runs flexibly from 0 hours, 8hours 16hours or 24 hours a day depending on the water demand.

Previous three years Alicante had sufficient level of precipitation. Thus the water treated from this plant was only considered for the use of irrigation for local farmers. However, since this year the drought is starting other options for water reutilization from this plant is being discussed such as for gardening etc.

When we visited the plant it was running at the operation rate of 85%. Even though it could run 100%, at night sometime there is no water to be treated. The plant started working 9 years ago and on average have treated 24,000m^3/day.

There is seasonal variation for unit energy use. During the summer it requires 0.5kWh/m^3 whereas during the winter season it require higher level of energy 0.7kWh/m^3. And the cost of water reproduced from this plant is around 0.16 – 0.20 €/m^3.

The plant has replaced one pump to an energy recovery system which allowed them to save 15% of total energy required for the plant to run.

Regarding the quality of the water regenerated, desalinated water has a conductivity of 2 µmhos/cm. Generally irrigators are satisfied with the quality of the water but depending on the type of farming some might demand a higher quality of water. The plant has capacity to produce water with better quality but it would obviously be more costly.

On the average about 50% of the treated water from WWTP is sent to the tertiary treatment system to be treated. 35,000-36,000m^3 is treated and 12,000-13,000m^3 is received here. But this also relies on the precipitation rate. For example, in 2012, 20% of the treated water was further treated in the tertiary treatment. But in 2015 we are expecting 65% of treated water to be sent here. Until Feb. this year, irrigators (regantes) were using white water (agua blanca).

There is total 85 point of installation in this plant which allows the plant to function properly. The effluent from this plant is sent to the wastewater treatment plant of Benidorm to be treated again. The data collected below reflects current condition.

Table 20 Energy intensity of the desalination plant of wastewater treatment plant of Benidorm

	Ultrafiltration	Reverse Osmosis	Final Production❄
Water Production (Reuse)	30,000m^3/day	18,000 m^3/day	24,000 m^3/day
Energy Consumption	3,600kWh/day	11,700kWh/day	15,300kWh/day
Unit Energy Consumption	0.12kWh/m^3	0.65 kWh/m^3	0.64kWh/ m^3

❄Water treated from ultrafiltration only is mixed with water treated from Reverse Osmosis.

7. Wastewater treatment plant in Benidorm [EDAR Benidorm]

The total capacity of water treatment plant is 60,000m^3. During the summer wastewater treated reach 51,000m^3 but except for this period, the plant runs 29,000 – 31,000 m^3. The old line runs all year round and the new line runs flexibly depending on the water input.

Due to seasonality in Benidorm, the most important task for this plant is to control caudal of inflow. The new line has “Deposito de homogenizacion” which controls variation in inflow. This installation is essential to cities like Benidorm but it requires more energy as it needs pumping. It also has process that eliminates nutrients. In 2006, the plant installed biogas generation system. Sludge is collected to digester to cogenerate biogas (cogenerador) so electricity is generated and heat would be used to dry sludge. 1.5GW of electricity generated from this process covers 25% of the electricity that is required from this plant. When the sludge is dried, it is used as combustible or else it can be sent to agricultural use. The saving from the cogeneration system would calculate to 140,000€. (1,400,000kW x 0.1€/kW = 140,000€)

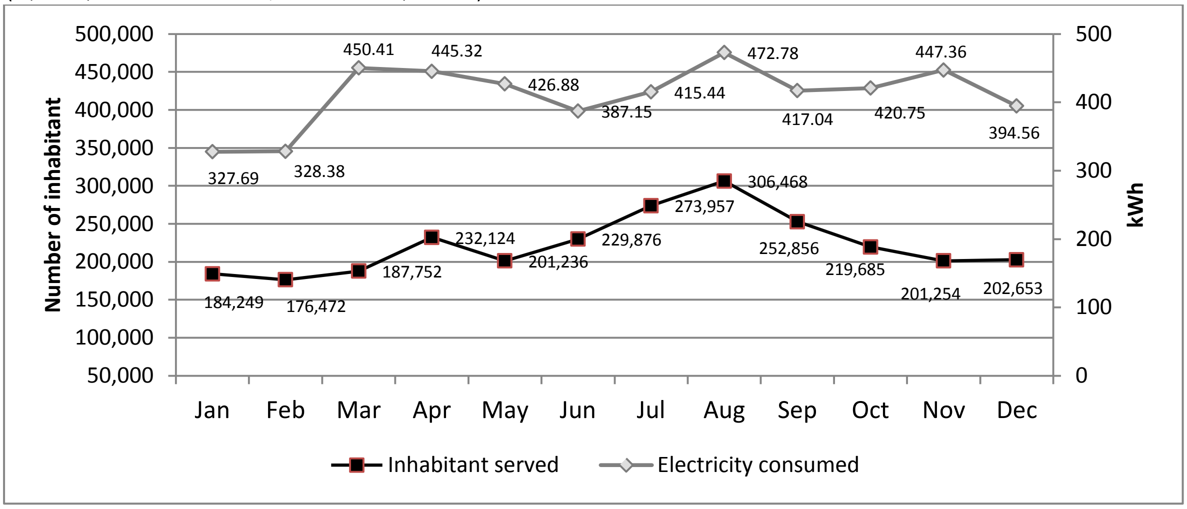


Figure 11 Energy consumption and inhabitants served for Benidorm wastewater treatment plant 2014

8. Wastewater treatment plant in Villajoyosa [EDAR Villajoyosa] – Not visited

The Wastewater treatment plant in Villajoyosa treats water from Villajoyosa, Orxeta and part of Benidorm (Playa de Poniente) designed to serve approximately 142,000 eq-inhabitants. Data from Consortium notes that it is designed to cover 15% of Benidorm's inhabitants.

Table 21 Number of habitants that the plant covers today

	Number of inhabitant	Proportion of inhabitants
Villajoyosa	30,000	47.02%
Orxeta	800	1.25%
Benidorm (Playa de Poniente)	33,000	51.72%
Total	638,000	100%

The plant has extended aeration system and runs 24 hours all year round. There are total 58 pumps used in this plant. Water treated from this plant amount 9,000-9,500m^3 and is sent to irrigators pump to be reused in Agriculture.

Table 22 Energy intensity of the wastewater treatment plant of Villajoyosa

	Extended Aeration System
Water Production (Reuse)	9,000-9,500m^3
Energy consumption	150,000kWh/month (5,000kWh/day)
Unit energy consumption	0.53-0.56kWh/m^3

9. Consortium of Water for Marina Baja (Consorcio de Aguas de Marina Baja)

Consortium manages surface and groundwater resources in the Marina Baja area in order to secure provision to different stakeholders in the region. In a year, Consortium mobilize 40-50Hm3 of water, and it costs 7 million euros in average which rounds up to 0.18€/m^3. Of these 20Hm^3 goes to Benidorm. Currently because the water is bought from other region, the price has risen to 0.45€/m3. There are total three pump stations where electricity is used in order to move water from one source to another location namely, Algar, Madem and Torres pump stations. There are also groundwater sources where water is pumped from aquifer Benidará, Algar and Polop. During the

summer when there is a peak of demand, pump number 6 operates to meet the water needs. This additional pump adds 100 l/s more to the normal flow of 200l/s.
Add pump information for aquifers
Benidarà aquifer (2013) 0.11€/kW, 0.08€/m3 300l/s, pumps 2 times a year
0.72kWh/m^3
The rate of extraction varies depending on the weather and hydrological conditions. During the drought period 100% of water is extracted, in an average year 50% and during the wet year only 30% is put into function.
Algar acquifer (2013) pumps from 35m depth, 0.11€/kWh, 0.05€/m^3
0.45kWh/m^3
Pumpstation data
They have 4500kW contracted for the pump station at Mandem, Algar and Benidara well. As a public entity they contract electricity supplier every year for a fixed price.
Consortium tries to invest in infrastructure as precaution to the emergency situation. Currently Torres and Algar pump station is running at the efficiency of 85-90% and 70% each. Say the selling price for water is 0.36€/m^3 and in emergency situation like today the water costs 0.46€/m^3, the discrepancy between the two prices reflect the system efficiency.
There are some changes that seem easy to be implemented to benefit the Consortium in terms of efficiency and energy use but realization takes place very slowly because they are a public entity. Or because of a lot of compliance and regulation changes many of them are yet to be implemented.
For example, changing the electricity provision line from high voltage to medium would benefit their system a lot more but the nature of the entity makes the advancement rather impossible. And there is a project proposed to add turbines (to produce electricity) but there was regulation changes so it cannot be guaranteed that this project will be realized.
10. Water purification plant in Benidorm and Galandú (Villajoyosa)
Data for Water purification plants in Benidorm and Galandú were facilitated by Hidraqua. These are the water resources that are treated so that it can be supplied to Benidorm and other towns nearby. The data for water entered, produced, and energy consumption per months are shown below (Table). For water purification plant in Galandú data is from 2015. Last year they went through a facility improvement which would have impact on the energy intensity. Thus data for this year is considered to accurately capture the energy intensity of the plant.

Table 23 Energy intensity of the water purification plant of Benidorm

Facility	Benidorm 2014				Galandú 2015			
Month	Water entered (m^3)	Water treated (m^3)	Energy consumed (kWh)	Energy intensity (kWh/m^3)	Water entered (m^3)	Water treated (m^3)	Energy consumed (kWh)	Energy intensity (kWh/ m^3)
Jan	582,996	581,003	28,885	0.050	179,284	177,936	10,931	0.061
Feb	571,149	570,298	23,765	0.042	144,553	142,640	11,941	0.084
Mar	704,368	702,335	25,177	0.036	163,103	160,542	13,446	0.084
Apr	818,364	816,063	22,597	0.028	177,551	175,353	13,161	0.075
May	874,020	871,186	23,600	0.027	197,571	190,255	12,626	0.066
Jun	942,796	941,189	24,927	0.026	204,558	195,639	13,621	0.070
Jul	1,112,480	1,109,262	25,437	0.023				
Aug	1,197,555	1,193,618	39,401	0.033				
Sep	929,618	924,970	26,210	0.028				
Oct	823,548	821,093	25,043	0.030				

Nov	686,259	682,919	22,399	0.033				
Dec	602,985	599,546	17,478	0.029				
Total	9,846,138	9,813,482	304,919					
Graphic Summary								

The amount of water treated gradually increases from winter months January as it augments to its peak in August reflecting the seasonal variation of the water demand for Benidorm. On the other hand energy consumption stays rather flat except for in August when the plant is charged with the largest volume of water for treatment. The average energy intensity for the facility in Benidorm 2014 is 0.032kWh/m^3 and for the facility in Galandú for 2015 from Jan to Jun is 0.073kWh/m^3.

11. Conclusion

Alicante is a region where periodical drought is foreseen. Despite the fact, some water facilities still work in the oblivion. Especially desalination plant, which has been sitting stand-by during the past 3 years, is now having difficulties to figure out how to provide water of a quality suitable to be potable.

Based on the information gathered during this fieldtrip, some of the hypothesis can be determined in order to facilitate calculation on water and energy consumption for our case city Benidorm. The followings are these hypotheses:

1. Guadalest reservoir – 70% from Bombeo Algar
2. Wastewater treatment plant Vilajoyosa – 51.72% are from Benidorm (Poniente) but whether this already incorporates the water discharged from high number of tourists must be confirmed again.
3. Wastewater treatment plant Benidorm –

Q. Muchamiel desalination plant - Would it be possible to get data on the volume of water produced per month and energy consumption per month for this year's operation? (We need yearly average energy consumption data per m^3 water produced)
Q. Inter basin transfer- How much water was supplied to irrigators (for example in 2014)? What is yearly average kWh/m^3? (or irrigators demand?) From the data that is provided, is it possible to know how much is used for irrigation, and how much is supplied to Benidorm and other cities?
Q. HiDRAQUA Benidorm- Data on electricity consumption of Water pumping station to waste water treatment plant and for sewer?

<Suggestions and ideas after the field trip>

- If studying water and energy nexus could reveal the impact of electricity price that has incremented a lot since 2008, it would be interesting.
- Or another direction of study could be to see three different type of scenario – drought, normal, and abundance of water - for Benidorm to calculate the energy cost of water supply.
- Alicante is located in the semi dry region with periodical drought that takes place every [YEARS].

June 2016

Pregunta	Observaciones
¿Dispone el hotel de servicio de restauración?	Al tratarse de hoteles vacacionales, prácticamente el 100% disponen de servicio de restauración en todos los servicios y bar (una minoría –actualmente no más de 2 o 3 -que trabaja exclusivamente con británicos en temporada baja no ofrece servicio de almuerzo).
¿Quién puede hacer uso del servicio de restauración del hotel?	Son muy pocos los hoteles que ofrecen servicio de restauración a clientes no alojados en el establecimiento, y en todo caso, poco significativo su uso. Otra cosa son los establecimientos que disponen de servicio de eventos (bodas, comuniones…), o que dispongan un restaurante a la carta en sus instalaciones.
Indicar el número de restaurantes de que dispone el hotel	Prácticamente el 100% dispone de un solo restaurante, y de un solo bar / cafetería en uso
Indicar el número de cocinas que tiene el hotel	El 100% dispone de una sola cocina
Indicar el número de lavaplatos que tiene el hotel	El 100% disponen de un lavaplatos y de un lavavasos en servicio comedor, y de un lavavajillas en cafetería. La mayoría de establecimientos grandes (con más de 250 comensales) disponen de máquina lavautensilios, y la mayoría de los pequeños no.
Establecimientos con SPA	11 hoteles de 4 estrellas y 2 de 5 estrellas, todos ellos de gran capacidad (más de 250 comensales)
Establecimientos con piscinas	Prácticamente el 100%, salvo hoteles pequeños de la zona centro y parque Elche – unos 15 establecimientos)
¿Tiene instalado un descalcificador?	Prácticamente el 100%
¿Tiene instalado un clorador?	Prácticamente el 100%
¿Tiene aljibes para agua?	Prácticamente el 100% (es requisito legal)
¿Dónde está localizado el Aljibe?	Prácticamente el 100% en sótano
¿Rebombea agua en el hotel?	Prácticamente el 100%

2) Barcelona

22-6-2015

viernes, 26 de junio de 2015
12:38
AC

There were 33 people attending this time. This includes 2 kids who came with their mom. Both moms were single parents. As summer vacation had started for many schools, they had to bring their children to the session.
There were about 3 cases where people had cutoff from their suppliers.

XX a mother who came with her daughter, had fought 3 days in a row to get her electricity supply back. She had 4 bill arrears which summed up to €550. After complaining, the customer service who attended her made a call to their boss to ask for a solution. He asked what was the bill that had caused the cutoff and if that bill would be paid, they will give back the electricity supply. The employee said €50 bill that was delayed last month. She agreed to pay and got the electricity back.

XX is a rare case where he had domestic problem that caused his cut off. His parter called the electricity company to take the meter away.
He says his major problem is that he cannot use fridge as it is getting hot. And his pet needs fresh water.

XX has been coming to the session for awhile already. He had been trying to get a new electricity and gas contract for his home. His home had contract under his father's name who had passed away already years ago. When he asked for a new contract, Endesa said he needs to prepare "boletín azul" which cost around €100 euros to have contract under his name. And when he went to Gas Natural Fenosa, they asked a interlocutor from APE. This caused a bit of discussion. Edu constantly raised his voice accusing that GNF is playing with the affected who goes there asking for a boss of all the affected people.

There had been a case where a guy with respirador had a electricity cut. It is important to have paperwork submitted to the electricity company so that they cannot cut off their service.

XX complained that social service required so many papers for her to get "informe de vulnerabilidad". The list of things she mentioned incudes empadronamiento, gastos de ultimos 6 meses, certificacion de sueldo, etc.

Everytime I go, I hear more case with piso occupied from the bank and the problem of not having basic utility supplied to the flats. Mostly they start to occupy their building with the hope of acquiring "alquiler social".

A mother with a son have come to the session. She said that she had occupied a flat from the bank 3 weeks ago. She is padronado but does not have electricity at home by legal way - she has it "pinchado". They explained her to go to endesa to ask how much she owe the company as endesa counts the electricity consumption for illegal consumption based on empadronamiento.

XX got a cutoff without a notice. Noone can cut your supply before sending notice at least two times. One of the person in the group says " con la lla mada no funciona tanto" and people in the session shook head in consent. They advice her to go to the office and ask a complaint form.

XX mentions about the problem of fire related to "pinchados" that it is crucial to think it in relation to safety.

XX said "gas natural es volviendo a jugar con tu caso y con servicio social".

XX has light cut off during the past 2 years. He occupies a flat and is padronado there.

This certainly is not the longterm solution to confront a cut off but in case of emergency, it can be used as a way to prolong cut-offs.
They were eager to learn what process they have to follow in order to avoid cuts, solve situations. The ones who come to the session and return to the sessions learn to get rid of their shame to share their stories more openly to other affected people.
Why cant SS ask for less paper. Can't they already have access to much of the database of their cases?
What impresses everytime is that these people come to see the possibility to make things legal. In the end we are so bounded to social norms that we would like to be part of the well-established system, be legal and ethical.
They maybe are less aware of the fact that this is a paractice that is dangerous, that might burn down their home.
Safety is often overlooked when there is a basic need not met and pushes vulnerable closer to the cliff.

OD

There are more and more people coming to the session so it becomes difficult to manage time. XX said that he thinks that people should be given more time. There are various cases so it is god that people listen to the cases of others or try to analyze and come to a conclusion (better for them) together.

A lot of them when they come here for the first time feel angst (angustia/agostar).

They talk about the importance of demonstrating that the problem can be solved here and transmit a relaxed energy to those who come with lots of worries. One of the way proposed is to start with a success story in the beginning.

16-9-2015

jueves, 17 de septiembre de 2015
11:19

I arrived late to the meeting.
They have changed the starting our to 18:00 starting from September so that more people can come after work. I asked XX and she also explained me that now OD takes place before the session to discuss about things that are more related to organizing practical work.

Agbar prefers that people come to their office in order to discuss supports. It is maybe part of their strategy.
We keep seeing the case of cut-offs.
There are cases of threats by letter clearly indicating that in case they connect illegally they will fine them 3000 euros.

There was a case with a lady who lives in hospitalet (?) or Blanes (?) had been living 2 years without water. She is occupying a house. She had a fountain infront of her house. Where she was using water ilegally. They had cut her water already in the house for a while. Then Agbar cut the water fountain closed to her house so now she goes far to fetch water. She can only manage to bring 5 L per day. And this is far too little for her. She has pets at her place, she wants to shower too. The way to find a solution has also been difficult. They have been telling her to go from one place to another. First Agbar told her to go to ayuntamiento and then to Social service. There seems no solution and she seems sick of what is happening. Social service did not even want to hear the explanation that her colleague from PAH wanted to explain further.

Another fact brought up to the session was the iligebility for payment in fraction. Endesa says that they allow fraction payment only when comsumed electricity is more than 90euros. If your bill reach more than 90 euros including the tax.

Yo llevó informe de la vernarabilidad pero le cortaron.
It was a confusion. She had brought her informe around end of last year. This was when the legislation said in order to avoid cuts, you must repeat the process every 6 months. Now with ILP, if you bring it once, they will never be able to cut-off utility. .. Como decia tati ''Nunca jamás¡''

Hay que denunciar
It is important to build twitter movement in case there is a mis treatment from private company… It is really effective than you think. Normally problems get addressed to people with higher ranking- more power- within few hours. So if there is a cut off when there shouldnt be we have to denounce these cases.

Why do they keep asking to pay more
Once paying bills fragmented of a total 1200 euros, come a bill that says it is a fee that we had to charge you. 450euro bill arrived….

Why do they keep calling
She had moved her flat.
She still gets phone call from the bills that she had arreared and couldn t pay from this flat.
The debt collectors keep calling.
She seems stressed. She says she does not know what has solved ILP because she still suffers with her problem. Endesa is in close contact with her but the problem is not yet solved.

After ILP
More works need to be done as private companies pretend that everything is solved after ILP
But it is not true
Preventing cut off only makes debts accumulate for the vulnerable people so APE will continue fighting

Is it a scam or a bad management
Why when people move to another place and ask for contract annulation, they are often refused of this request or ignored?
Is it really a bad case of scam or a bad management?
Why can't they see that new bono social contract and do something to stop debt collecting? When they already know that these are people who need special discount since they are in deep shit, why can't they do everything at once to stop the debt collecting process? At least for the moment…. Until they are financially more stable…
Why is the price of putting a meter, or getting a contract so erratic…
Why going to mercado libre result in more expensive bills

14-10-2015

jueves, 29 de octubre de 2015
11:47

Around 23 people were there. It was a quiet and calm day for APE in a sense that there were not so many people new.
XX is from Nou Baris. She is living in a house which is occupied. She is illegally connected to electrcity, gas and water. She has the gas meter inside her home. But she is afraid that technicians will come and take it away. She openly expresses her fear to the group asking for their advices. They told her that only when they come with the police can the technicians enter your house legally. She probably will never open the door for the guy to come in.

After ILP, *Informe de Vulnerabilidad* have been substituted to a form called *Informe de exclusion residencial*. They explain how ILP have expanded the definition of vulnerability. It is important to ''parailizar el corte''. Now the process has changed so when the notice from utility companies are sent, they automatically add a letter that you can sign and that would allow the company to check your vulnerability with the social service worker.

XX came with water and electricity cut off. XX tells her ''no pasa nada''. This word felt so powerful to soothe to pacify the burst of emotion - sadness, embarrassment- that the affected showed. At the same time, they emphasize the importance to ''constatar'' (verify) everything to the social service… verifying everything to the level that is almost frantic…

XX, is earning very little. 375€ of pension and 96€ (nomina de su mujer). They came because they have difficulties to pay the bill. They came to look for help even though they did not have any cut-off at the moment. They must go and ask for a bono social.

XX has been living in an occupied house for 10 months. Its a house owned by Banker and she is trying to get an alquiler social.

Viladecans ajunatamiento takes care of the occupied households. They give rights to basic utility supply when they are empadronado (registered).

Fon d'atenció solidaria (prepared by generalitat de catalunya) came up as a topic because this fund was noticed with very little time allowed to apply. 17. Aug. The fund was announced. It took a month and half, (until the end of Sep) for this to be realized, start accepting the application, and 15 Oct was the last day to apply. Basically they only opened the place for half a month.

At the company, if you say that you are with APE, THEY COME FLYING… (and all laughs)

Giving 'alta'. The issue with 'boletin' still remains a problem difficult to solve. It is difficult to help. They are looking for a way to solve this problem.

For the case of occupied housing, the basic utility companies can be sued for giving provision of utility to a person who is occupying the house by the owner. For example, if the bank is owned by BBVA and ENDESA provides electricity to the occupier, which makes the situation complicated to guarantee rights to basic supplies.

After ILP, they are informing the changes to the affected that comes and try to find any illegal cut offs that should be noted.

They are having trouble pushing the administration to apply ILP. So much of the work and campaign is focused on this direction. It seems like an end less fight and they are very well aware of it that the process is going to be more or less endless.

They are very good at calming down the people who are new, getting rid of the fear affacted has, and pushing them to be proactive.

Annex III. Questionnaires and interview guides

1) Benidorm

a) Questionnaires

i) Water related actors

1. Background information

1) The Consorcio de Aguas de la Marina Baja

a. Manages the part of the hydrological cycle involving water supply to the treatment plant as well as wastewater treatment and water reuse.

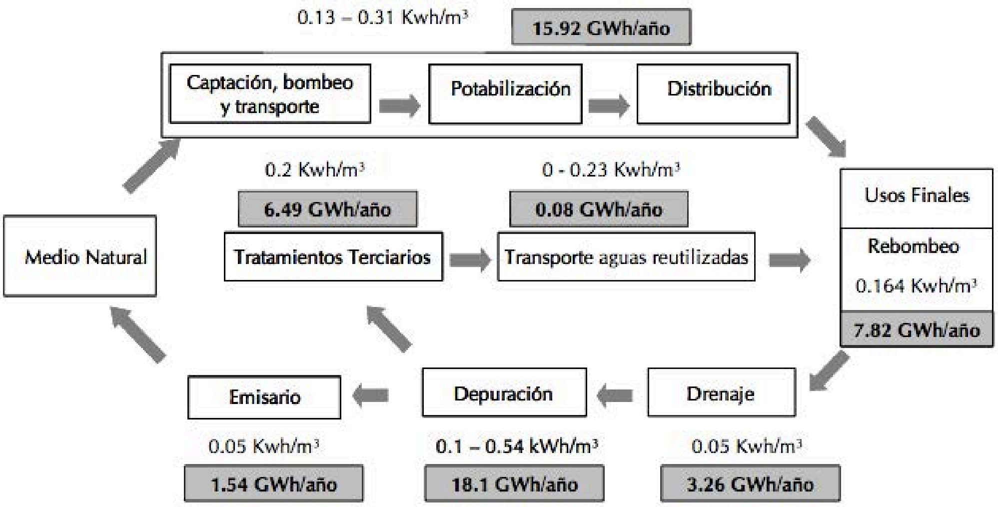
2) HIDRAQUA (the water company

a. HIDRAQUA is in charge of the delivery of water from the treatment plant to the different uses in the city (see chart in paper of the water cycle in the city).

2. Objectives

- To estimate the total energy costs of full water-use cycle, from sources to the end of the cycle (in KWh/m^3 and Gwh/year)
- To include energy consumed as accurately and comprehensively as possible

3. An example of the water-use cycle from the case study on Valencia



4. Data collection

A. Water extraction

a. Guadalest reservoir

i. How much water is withdrawal (monthly data for a year)?
ii. How long does the water travel?
    1. Length and diameters of pipes
    2. Location and elevation of pipes
    3. Designed flow rate (additional capacity of %)
iii. How much electricity is consumed by pumps (monthly data for a year)?
    1. Number of pumps
    2. Location of each pumps
        - At which point and which elevation?
    3. Types of each pumps (hp, watt)
    4. Efficiency of pumps
iv. Where is the electricity supplied from?
    1. Does the electricity used include a renewable source?
v. How much flow goes to which water treatment plant?

b. Amadorio reservoir
   i. How much water is withdrawal (monthly data for a year)?
   ii. How long does the water travel?
       1. Length and diameters of pipes
       2. Location and elevation of pipes
       3. Designed flow rate (additional capacity of %)
   iii. How much electricity is consumed by pumps (monthly data for a year)?
       1. Number of pumps
       2. Location of each pumps
           - At which point and which elevation?
       3. Types of each pumps (hp, watt)
       4. Efficiency of pumps
   iv. Where is the electricity supplied from?
       1. Does the electricity used include a renewable source?
   v. How much flow goes to which water treatment plant?

c. Fenollar-Amadorio connection (drought)
   i. Is it a route of supply that only operates during drought period?
   ii. How often does it operate?

iii. How much water is withdrawal (monthly data for a year)?
iv. How long does the water travel?
   1. Length and diameters of pipes
   2. Location and elevation of pipes
   3. Designed flow rate (additional capacity of %)
v. How much electricity is consumed by pumps (monthly data for a year)?
   1. Number of pumps
   2. Location of each pumps
      - At which point and which elevation?
   3. Types of each pumps (hp, watt)
   4. Efficiency of pumps
vi. Where is the electricity supplied from?
   1. Does the electricity used include a renewable source?
vii. How much flow goes to which water treatment plant (monthly data for a year)?

d. Aitana, Beniardá, Serrella-Aisorta y Algar aquifer
   i. Where are the wells located in Aitana, Beniarda, Serrella-Aisorta and Algar aquifer?
   ii. How many wells are there per aquifer?
   iii. How much water is extracted (monthly data for a year)?
   iv. What is the level of the hydraulic head (monthly data for a year)?
      1. How has it changed over-time?
   v. Which water treatment plant does it gets transported to?
   vi. Is there water that does not get transported to water treatment plant?
      1. If so where is it used?
      2. Repump is required?
   vii. How long does the water travel?
      1. Length and diameters of pipes
      2. Location and elevation of pipes
      3. Designed flow rate (additional capacity of %)
   viii. How much electricity is consumed by pumps (monthly data for a year)?
      1. Number of pumps

2. Location of each pumps
    - At which point and which elevation?
3. Types of each pumps (hp, watt)
4. Efficiency of pumps

ix. Where is the electricity supplied from?
1. Does the electricity used include a renewable source?

e. Muchamiel Desalination plant
i. Type of the plant
ii. How much is energy consumption (Electrical energy) for water treatment (monthly data for a year)?
iii. How much of water is extracted to this plant?
iv. How long was the plant in operation (From what time to what time?)
v. When was the last time it was operated?
vi. How much water goes to Benidorm?
vii. Where is the electricity supplied from?
1. Does the electricity used include a renewable source?

B. Water treatment plant (ETAP)
a. Name and location of the water treatment plant?
b. Type of water treatment system?
i. Which stage requires electricity?
ii. From which device is electricity consumed?
iii. How long is the plant operation time?
c. How much electricity is consumed in the treatment system (monthly data for a year)?
d. How much water is treated from the plant (monthly data for a year)?
e. How much electricity is consumed in the plant other than treatment purpose?
i. In what category and how much is it consumed?
f. Unit energy consumption of the treatment plant (kWh/m^3)
g. How much population benefits from the water provided?
h. Or how much population does the plant aimed to supply water to?

C. Repump (Supplying potable water)

a. How long does the water travel?
   i. Length and diameters of pipes
   ii. Location and elevation of pipes
   iii. Designed flow rate (additional capacity of %)
b. How much electricity is consumed by pumps (monthly data for a year)?
   i. Number of pumps
   ii. Location of each pumps
      1. At which point and which elevation?
   iii. Types of each pumps (hp, watt)
   iv. Efficiency of pumps
c. Where is the electricity supplied from?
   i. Does the electricity used include a renewable source?
d. How much water is lost during the phase of conveying water to the users?

D. End-use (Urban Consumption)
   a. How much water is consumed at each urban sector (monthly data for a year)?
      i. Households
      ii. Hotel sector
      iii. Commercial services
      iv. Public and municipal services
   b. How much energy is required for water heating and cooling per sector (monthly data for a year)?
   c. How much energy is required for pumping water per sector (monthly data for a year)??
      i. Number of pumps
      ii. Location of each pumps
         1. At which point and which elevation/pressure?
      iii. Types of each pumps (hp, watt)
      iv. Efficiency of pumps
   d. How many water reuse and rainwater harvesting system has been applied?
      i. How much energy is required for this system (monthly data for a year)??
         1. Number of pumps?

2. Treatment system?

ii. How many buildings or how much percentage of the buildings has this system in Benidorm?

E. Drainage

a. Total how much water goes through drainage per year (Hm^3/year)?

b. Where are the pumps located, what's their capacity and how are they run?

i. How much electricity is consumed (monthly data for a year)?

F. Wastewater treatment

a. Wastewater treatment plant

i. Type of wastewater treatment plants

1. Which stage requires electricity?
2. From which device is electricity consumed?
3. How long is the plant operation time?

ii. How many pumps are used (monthly data for a year)?

iii. How much electricity is used (monthly data for a year)?

iv. How much population does it serve?

v. How long is the plant operation time?

vi. Is there renewable energy or biogas production?

vii. Where is the water discharged to?

b. Desalination

i. What type of desalination

ii. How much water is treated?

iii. How much is the energy consumption (Electrical energy) for water treatment (monthly data for a year)?

iv. How long is the plant operation time?

v. Where is the water discharged to?

vi. Where is the electricity supplied from?

1. Does the electricity used include a renewable source?

G. Tertiary treatment

a. Name and location of the water treatment plant?
b. Type of tertiary treatment system?
    i. Which stage requires electricity?
    ii. From which device is electricity consumed?
c. How much electricity is consumed in the treatment system (monthly data for a year)?
d. How much water is treated from the plant (monthly data for a year)?
e. How much electricity is consumed in the plant other than treatment purpose (monthly data for a year)?
    i. In what category and how much is it consumed?
f. Unit energy consumption of the treatment plant (kWh/m^3)
g. How much population benefits from the water provided?
h. Or how much population does the plant aimed to supply water to?

H. Agriculture use
  a. Conveyance
    i. How long does the water travel?
      1. Length and diameters of pipes
      2. Location and elevation of pipes
      3. Designed flow rate (additional capacity of %)
    ii. How much electricity is consumed by pumps (monthly data for a year)?
      1. Number of pumps
      2. Location of each pumps
        - At which point and which elevation?
      3. Types of each pumps (hp, watt)
      4. Efficiency of pumps
    iii. Where is the electricity supplied from?
      1. Does the electricity used include a renewable source?
    iv. How much water is lost during the phase of conveying water to the users?
  b. How is the water irrigated
    i. What types of irrigation system do farmers use?
    ii. How much electricity do they consume for this irrigation system (monthly data for a year)?

iii. How much land area does the water irrigate?

ii) Hotels

Encuesta sobre nexo agua-energía en Hoteles de Benidorm

Apreciado Sr./Sra.,
En nombre del Instituto Interuniversitario de Geografía de la Universidad de Alicante y del Grupo de Investigación en Agua, Territorio i Sostenibilidad (GRATS) de Universitat Autònoma de Barcelona quisiera agradecerle su participación en el proyecto de investigación sobre "Explorando el nexo agua-energía en ambientes urbanos y turísticos" así como su tiempo y dedicación en responder la encuesta que sigue a continuación. Consideramos esencial remarcar que la encuesta es totalmente ANÓNIMA, para proteger la identidad de los datos que nos facilite. El proyecto es un estudio de carácter académico, descriptivo y no valorativo, y deseamos que también le sirva a su empresa como ejercicio de autodiagnosis acerca de la gestión del consumo/uso del agua y de energía.

La duración estimada para cumplimentar la encuesta es de unos **30 minutos**. Le agradeceremos remita esta encuesta, una vez cumplimentada, a la atención de Hyerim Yoon vía correo electrónico a: **Hyerim.Yoon@uab.cat y al Director del Instituto Interuniversitario de Geografía, Antonio Manuel Rico Amorós a AM.Rico@ua.es**
Una vez más, muchas gracias por su participación.

spectos generales. Tipología - Caracterización del establecimiento.

¿Cuál es la categoría del hotel? (por favor, indicar con una X)
☐ 1 estrella
☐ 2 estrellas
☐ 3 estrellas
☐ 4 estrellas
☐ 5 estrellas
☐ 5 estrellas GL

¿Cuál fue el año de construcción del hotel? ____________

¿Ha vivido el hotel alguna reforma en sus instalaciones en los últimos 10 años?
☐ Sí
☐ No

En caso afirmativo, ¿Cuál/es?
(por favor, especificar las reformas más significativas de los últimos 10 años)
____

En caso afirmativo, para estas reformas ¿Tuvo subvenciones de algún tipo?
☐ Sí
☐ No

En caso de afirmativo, por favor especificar que tipo y de que entidad ____________________

¿Cuál es la superfície total del edificio? ☐ m^2

¿Cuál es la altura aproximada del edificio? ☐ m y ☐ plantas

Indicar el número total de plazas hoteleras (camas) del hotel ☐ plazas (camas)

¿Cuántas personas, aproximadamente, integran/ forman la plantilla total del hotel?
(para plantilla total se entiende contratos fijos más eventuales) ☐ personas

Indicar, aproximadamente, la estancia media en el hotel por cliente ☐ noches/cliente

Indicar, las pernoctaciones totales en 2014 y 2015
☐ en 2014
☐ en 2015

aracterización de las unidades productivas y servicios de que dispone/ofrece el hotel y que están vinculados al consumo/ uso de agua y energía

¿Dónde realiza el hotel su servicio de lavandería?
(Se incluye aquí tanto la colada generada por el funcionamiento del propio hotel,
como la que proviene del servicio de lavandería ofrecido a los clientes por el hotel).
(por favor, indicar con una X)

- [ ] El 100% de la carga de la colada del hotel se realiza en instalaciones propias al mismo
- [ ] Sólo un porcentaje de la carga total de la colada del hotel se realiza en instalaciones propias
  Por favor, en este caso indicar el porcentaje aproximado de la carga total de la colada que se realiza en las instalaciones propias del hotel: ________ %
- [ ] La colada del hotel es una unidad/servicio que tenemos 100% externalizado

En caso de tener lavandería,
¿Cuántos lavadoras y secadoras tiene el hotel? [ ] de lavadoras [ ] de secadoras

Indica, ¿Qué fuente de energía utiliza la/s lavadoras? ____________________

Indica, ¿Qué fuente de energía utiliza la/s secadora/s? ____________________

Tiene el restaurante mas que 250 comensales? [ ] Sí [ ] No

Indicar el número de máquinas que tiene el hotel [ ] Lavaplatos [ ] Lavavasos [ ] Lavavajillas [ ] máquina lavautensilios

El hotel dispone de (por favor, indicar con una X):
• SPA o centro de Wellness (servicios de masaje y tratamiento,
hidromasaje, sauna, baño de vapor, etc). [ ] Sí [ ] No
¿Cual es la capacidad del hidromasaje o jacuzzi (aproximadamente)? [ ] m^3 [ ] m^3
¿Cuál es el volumen de agua que se ha renovado en el hidromasaje o jacuzzi al dia? [ ] L/día [ ] L/día

• Piscina [ ] Sí [ ] No
Cual es la capacidad de la/s piscina/s (aproximadamente) [ ] m^3 [ ] m^3
¿Cuál es el volumen de agua que se ha renovado en la/s piscina/s al dia? [ ] L/día [ ] L/día

¿Cuántos bombas utilizas para recircular agua en el SPA o piscina? [ ] de bomba/s

y de cuántos potencia y rendimiento tiene/n la/s bomba/s de recirculación? [ ]

[ ] %

¿Cúantos cloradores automáticos tiene el hotel? [ ] (unidad) de [ ] W

¿El hotel tiene jardín?
(por favor, indicar con una X)

- [ ] Sí. La superfície del jardín es de menos de 500 m^2
- [ ] Sí. La superfície del jardín es és entre 501 i 2500 m^2
- [ ] Sí. La superfície del jardín és de más de 2500 m^2
- [ ] No

Si tiene jardín, ¿puede indicar aproximadamente cuál es la superficie de césped?

- [ ] La superfície de césped es de menos de 100 m^2
- [ ] La superfície de césped es entre 101 - 500 m^2
- [ ] La superfície de césped esentre 501 - 1000 m^2
- [ ] La superfície de césped es de más de 1001 m^2

onsumo de agua en el hotel

¿De qué tipo de contador de agua dispone el hotel?
(por favor, indicar con una X)

- [ ] El hotel dispone de **un** único contador para todos los usos del hotel
- [ ] El hotel dispone de **varios** contadores diferenciados por sector
  Por favor, en este caso, indicar el número de contadores de que dispone el hotel [ ] contadores
- [ ] No tiene ningún contador

¿Consume el hotel alguna otra fuente de agua además de la proveniente de la red municipal?
(por favor, indicar con una X)

- [ ] No. El 100% del consumo de agua del hotel proviene de la red municipal
- [ ] Sí. Además del agua de red municipal consumimos agua proveniente de otras fuentes

En caso de que la respuesta a la pregunta anterior sea afirmativa por favor indicar qué otras fuentes usa y para qué usos.

Indicar otras fuentes de agua utilizadas	Indicar el uso que se realiza de la fuente especificada

¿Cuál es el porcentaje que ha representado el consumo/ coste del agua sobre el total de gastos/costes operativos del hotel en el último año?

[ ] % es lo que representa el gasto anual de agua sobre el total de gastos operativos anuales

Por favor, indica el consumo total de agua por cada fuente en el hotel en 2015

Fuente de agua	Cantidad	
		m^3
2		m^3
3		m^3

Por favor, indica el consumo total de agua friá y agua caliente sanitaria (ACS) en 2015

Agua fría		m^3
ACS		m^3

¿Qué es el caudal del grifo de la habitación? [ ] L/min

Para agua de red...

¿Qué capacidad tiene el Aljibe ó Depósito? ______

¿Qué nivel de agua mantegan en el aljibe ó depósito? [ ] m

¿Cuántos bombas utilizas para rebombear agua en el edificio? [ ] de bomba/s

y de cuántos potencia y rendimiento tiene/n? [ ]

[ ] %

y si mide el caudal de agua, por favor indicar el caudal aproximado [ ] m^3/h [ ] No lo sé

¿De cúantos acumuladores de ACS dispone el hotel? [ ]

¿Cúantos bombas (aparte de que esta mencionado arriba) utiliza para rebombear ACS en el edificio? [ ] unidad de [ ] W

Para otras fuentes del agua...

¿Cuántos bombas utiliza para bombear agua? [ ] de bomba/s

y de cuántos potencia y rendimiento tiene/n? [ ]

[ ] % de rendimiento

y si mide el caudal de agua, por favor indique [ ] m^3/h [ ] No lo sé

onsumo de energía en el hotel

¿De qué tipo de contador de electricidad dispone el hotel?
(por favor, indicar con una X)

- [ ] El hotel dispone de **un** único contador para todos los usos del hotel
- [ ] El hotel dispone de **varios** contadores diferenciados por sectores
  Por favor, en este caso, indicar el número de contadores de que dispone el hotel [ ] contadores
- [ ] No tiene ningún contador

¿Qué fuente de energía consume el hotel?
(por favor, indicar con una X e indicar los usos y consumo total de 2015)

		Indicar el uso que se realiza de la fuente especificada	Consumo total de 2015
	Electricidad		kWh
	Gasóleo		L
	Propano		KG
	Gas natural		m^3
	Butano		L
	Placa solar		kWh
	fotovoltáico		kWh
	Otros		

¿Con que fuente de energía suministra ACS(Agua Caliente Sanitaria)?
(por favor, indicar todos con una X y indica aproximadamente
cuánto consumó el año 2015 para ACS)

		2015	
	Electricidad		kWh
	Gasóleo		L
	Propano		KG
	Gas natural		m^3
	Butano		L
	Placa solar		kWh
	fotovoltáica		kWh
	Otras		

En caso de haber instalado las placas solares,
¿Cuántos colectores tiene y de qué superficie? [ ] de colectores [ ] m^2

Aproximadamente, ¿Cuánto ahorro pueden proporcionar las placas solares instaladas? [ ] Ahorro en kWh [ ] Ahorro en €

¿Cuál es el porcentaje que ha representado la iluminación sobre
el total de consumo/ coste del energía del hotel en el último año? [ ] % (el gasto anual de iluminación sobre el total de consumo de electricidad anuales)

¿Cuál es el porcentaje que ha representado la calefacción y la refrigeración sobre
el total de consumo/ coste del energía del hotel en el último año? [ ] % (el gasto anual de climatización de espacio sobre el total de consumo de electricidad anuales)

iciencia energética del hotel

Este parte de la encuesta incluye información de los hoteles que disponen de**l certificado de eficiencia energética, para valorar el ahorro de energía.**
Si no tiene el certificado, por favor no conteste a esta sección.

¿De qué fecha es el certificado de eficiencia energética de edificio existentes?

Indicar las informaciones sobre sus **instalaciones térmicas**

Generadores de calefacción

Tipo	Potencia nominal [kW]	Rendimiento [%]	Tipo de energía	Modo de obtención
Equipo Rendimiento constante				

Generadores de refrigeración

Tipo	Potencia nominal [kW]	Rendimiento [%]	Tipo de energía	Modo de obtención
Equipo Rendimiento constante				

Instalación de iluminación

Espacio	Potencia instalada [6.94W/m^2]	WEEI [W/m2·100lux]	Iluminación media [lux]	Modo de obtención
Edificio Objeto				

Indica, las informationes sobre el **Análisis Técnico** del su hotel

Indicador	Calefacción	Refrigeración	ACS	Illuminación
Demanda [kWh/m^2]				
Diferencia con situación inicial				
Energía primaria [kWh/m^2]				
Diferencia con situación inicial				
Emisiones de CO_2 [kgCO_2/m2]				
Diferencia con situación inicial				

nal

Muchas gracias de nuevo por su colaboración. Por favor, le rogamos nos facilite sugerencias que pudieran mejorar el ahorro de agua y energía en su establecimiento hotelero..

b) Semi structured Interview guide

i) HOSBEC

(Castellano)

1. ¿Cómo HOSBEC empezó a trabajar en temas de agua y energía? ¿Cuándo empezó y por qué?
    a. ¿Con qué objetivo y motivación empezó?
2. ¿Cómo se las cuestiones del agua y de la energía tratados de la HOSBEC?
3. ¿Podría explicarnos qué tipo de proyectos que has estado haciendo? (Ej. Los proyectos de rehabilitación energética, estudios de optimización de energía)
    a. ¿Cuánto ahorro de energía está prevista a partir de estos proyectos
    b. ¿Qué parte de aquellos se relaciona con el uso del agua
    c. ¿Tiene datos empíricos sobre la cantidad de ahorro podría alcanzar?
4. ¿Usted colabora con otra organización o institución para este tipo de proyectos?
    a. En tus proyectos tienes cualquier forma de colaboración con la empresa de agua o energía?
5. ¿Recibe fondos o apoyo del gobierno?
6. ¿Ve usted la conexión entre el agua y la energía en su trabajo?
7. ¿A qué retos se sintieron más en la gestión en materia de agua y energía para los miembros HOSBEC?

(English)

1. How did HOSBEC start to work on water and energy issues? When did it start and why?
    a. With what objective and motivation did it start?
2. How is water and energy issues treated in the HOSBEC?
3. Could you explain to us what type of projects you have been doing? (Ex. Energy rehabilitation projects, Power optimization studies)
    a. How much energy saving is foreseen from these projects
    b. How much of those is related to water use
    c. Do you have empirical data on how much saving it could achieve
4. Do you work with other organization for this type of projects?
    a. In your projects do you have any form of collaboration with the water company or energy company?
5. Do you get government funds or support?

6. Do you see the connection between water and energy in your work?
7. What challenges are felt most in managing in terms of water and energy for HOSBEC members?

ii) HOTELS

(Castellano)

Información general sobre el hotel

Nombre		**Valoración (estrellas)**	
Año de inicio		Ocupación anual de negocios	
Nº de plantas		Nº de camas	
Altura del edificio			
Consumo anual de electricidad	(kWh)	Facturas de electricidad (promedio anual)	(€/kWh)
Consumo anual de gas		Facturas de gas (promedio anual)	
Consumo anual de agua	(m^3)	Facturas de agua (promedio anual)	(€/m^3)

¿Cuáles han sido los mayores retos a la hora de gestionar el hotel en términos de agua y energía?

En su factura de energía, ¿cuánto estaría asociado con el uso del agua (calefacción y agua de bombeo)?

Datos

1. ¿Podría usted facilitar los datos de consumo de agua y el consumo de energía (datos anuales) en los últimos 10 años?

Consumo de agua

2. Bajo su punto de vista, ha habido algún cambio en el consumo de agua en los últimos años?
3. ¿varía mucho el consumo de agua dependiendo de la temporada?
4. ¿Qué tipo de innovación o políticas tiene usted para ahorrar en el consumo de agua?

   a. ¿Cómo es el precio del agua, ¿cree que es alto, bajo? ¿Se sintió el cambio de la misma?

Consumo de energía para calentamiento del agua

5. ¿Cómo proporciona agua caliente en el hotel, ha habido cambios tecnológicos?
   a. ¿Tiene paneles de calefacción de agua solar o fotovoltaica instalados en su hotel?
   b. ¿En qué año fueron instalados?
   c. ¿Cuánta electricidad se ahorra con este sistema?
6. ¿Tiene un sistema híbrido para que se caliente cuando no haya sol?
   a. ¿Cuál sería la proporción de la operación para los dos sistemas?
7. ¿Cuánta calefacción se utiliza en el hotel?
8. ¿Qué tipo de calefacción usa, calefacción central de gas natural?

Consumo de energía para el bombeo de agua

9. ¿Dónde se encuentra el tanque de agua para sus instalaciones y cuánta capacidad tiene (m^3 o L)?
10. ¿Cómo se bombea a los pisos más altos? ¿Con qué tipo de bombas?
11. ¿Tiene un protocolo particular para el uso del agua en las zonas exteriores como piscina o jardines?

Contrato de energía y selección de la empresa energética

12. ¿Cómo es el contrato energético para el Hotel?
   a. Es por año?
   b. ¿Qué criterio utiliza para elegir compañía energética?
   c. ¿Se sintió mucho el aumento del precio de la energía? ¿En qué año se sintió más?

(English)

General information on the Hotel

Name	Rating (stars)
Year of starting the business	Yearly occupancy rate
# of floors of the hotel	# of beds
Height of the building	
Annual electricity consumption (kWh)	Electricity bills (annual average) (€/kWh)
Annual gas consumption	Gas bills (annual average)
Annual water consumption (m^3)	Water bills (annual average) (€/m^3)

What challenges do you feel the most in managing this hotel in terms of water and energy?

In your energy bill, how much would be associated to water use (heating and pumping water)?

Data

1. Could you provide us data of water consumption and energy consumption (yearly data) for recent 10 years?

Water consumption

2. In your opinion, has there been change in water consumption over the past years?
3. Does water consumption vary much depending on the season?
4. What kind of innovation or policies do you have for saving water use?
    a. How is the water price, do you think it is high, low? Did you feel the change of it?

Energy consumption for heating water

5. How do you provide warm water in the Hotel, has there been technological change?
    a. Does your hotel have the solar water heating panels or photo voltaic installed?
    b. What year did you install them?
    c. How much electricity do you save from this system?
6. Do you have a hybrid system to warm it when there is no sun?
    a. What would be the ratio of the operation for two systems?
7. How much heating is used in the hotel?

8. What types of heating do you use, central heating from natural gas?

Energy consumption for pumping water

9. Where is the water tank located for your facility and how much capacity is that (m^3 or L)?
10. How do you pump it to higher floors? What types of pumps?
11. Do you have a particular protocol for outdoor water use like for swimming pool and gardening?

Energy contract and selecting Energy Company

12. How is the energy contracted for the Hotel?
    a. Is it per year?
    b. How do you select which energy company to use?
    c. Did you feel a lot the increase in energy price? Which year did you feel it more?

2) Barcelona

a) Semi structured interview guide

i) Stakeholders

- ✓ What is your job here in XX? En que consiste tu trabajo en XX?
- ✓ How long are you working on this position? Cuanto tiempo llevas en este puesto?
- ✓ Did you change your position in this organization? Has cambiado de puesto en esta organización?
- ✓ What is your educational background? Cuál es tu formación?

1. What do you understand by fuel poverty and water poverty? Que es lo que entiendes por pobreza energética e hídrica?
2. Could you explain me about your job related to fuel and water poverty in XX? Puedes explicar la relación entre tu trabajo y la pobreza energética e hídrica en XX?
3. What programs are there in XX regarding fuel and water poverty issues? Qué tipo de programas tiene XX sobre temas de la pobreza energética e hídrica?
4. Could you explain us about the XX fund? How did it start? How is it used? Puedes explicar más profundo sobre el fondo de XX? Cuando comenzó, como es empleado?
5. How can the affected people apply for XX fund? Como las personas afectadas pueden acceder a este fondo?
   - Why do you think it is so easy/difficult to get? Por qué crees es fácil/o difícil de obtener?
   - How many people have been benefited from the process so far? Cuantas personas se han beneficiado de este fondo?
6. What do you think is at the core of fuel and water poverty issue in the Metropolitan Area of Barcelona? Cuál es el factor clave que promueve la pobreza energética e hídrica en el área metropolitana de Barcelona?
7. What is challenging for XX to work on the issue of fuel and water poverty? Cuál sería el principal reto para XX en tratar el tema (de pobreza energética y hídrica)?

- How do you deal with the suppliers that are in private sector?
  ¿Cómo lidia con las suministradoras que se encuentran en el sector privado?

8. What is the general understanding about ley 24/2015 in XX?

9. Do you collaborate with other entities? If yes with whom and how? Formally or informally? Colaboras con otras entidades? De ser así, con quien y cómo? Formalmente o informalmente?
    - Social Service/Utility companies/Ministry/Generalitat/Ajuntamiento/Sindic de Greuges/Social movements (APE or Fuel poverty group)
10. Is there difference in approaching the problem of water poverty and fuel poverty? Existen diferencias en tratar el problema de pobreza hídrica y energética?
11. When did fuel poverty and water poverty was recognized as an issue for the first time? Cuando fue reconocida la pobreza energética e hídrica por primera vez como un tema a tratar?
12. What would be the future direction for XX to work to improve fuel and water poverty? Qué medidas piensa tomar XX para mitigar la pobreza energética e hídrica?
13. Would it be possible to have data on how many people have accessed the XX fund from which municipality per year? Podrías facilitarnos información acerca de cuántas personas han conseguido financiamiento por municipio y por año del XX?

ii) Affected households

(Castellano)

1. Puedes presentarte a nosotros
2. ¿Tiene la vivienda alguna de los problemas como goteras, humedades en paredes, suelos, techos o cimientos, o podredumbre en suelos, marcos de ventanas o puertas?
3. Como has pasado el invierno pasado, dime si podías mantener tu vivienda con una temperatura adecuada
4. Como has pasado el verano pasado, dime si podías mantener tu vivienda con una temperatura adecuada
5. A continuación te voy a preguntar si en los últimos 12 meses el hogar ha tenido que hacer pagos de algunos conceptos y si ha tenido retrasos en alguno de esos pagos debido a dificultades económicas: ¿Tuvo algún retraso en el pago de recibos de agua, gas, calefacción, electricidad, comunidad, etc.?
6. ¿Nos puedes contar tu historia y tu situación cómo te convirtió en uno de los afectados?
7. ¿Cómo has intentado resolver el problema y como fue la experiencia?
8. ¿Tuviste la oportunidad de ayudar a alguien con una situación similar?
9. ¿Qué consejo le daría a las personas afectadas?

10. ¿Podrías compartir con nosotros algunas facturas o comunicaciones con las suministradoras?

b) Questionnaire with APE

Encuesta para estudio estadístico sobre pobreza energética y agua

Esta encuesta forma parte de un estudio sobre pobreza energética y agua en Barcelona por el Grup d'Investigació en Aigua, Territori i Sostenibilitat(GRATS), Universidat Autònoma de Barcelona. Sus respuestas serán confidenciales y serán utilizadas únicamente para fines de investigación. Agradecemos mucho su participación en esta encuesta. Para cualquier duda o aclaración no dude en preguntar o contactar a la investigadora Hyerim Yoon (Hyerim.Yoon@uab.cat).

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1. Sexo
   - a. Mujer ☐
   - b. Hombre ☐
2. Municipio ______________________ Barrio ___________________________
3. Numeró total de personas en la vivienda ___________________
   - Nº de menores ___________________
   - Nº de jubilados ____________________
   - Nº de discapacitados ____________________
4. ¿Pertenece a su familia a cualquiera de estas categorías?
   - a. Familia monoparental ☐
   - b. Familia numerosa ☐
   - c. Pensionista mínimo ☐
5. Situación laboral (de usted)
   - a. Paro con subsidio de desempleo ☐
   - b. Paro sin subsidio ☐
   - c. Trabajo temporal ☐
   - d. Trabajo fijo ☐
   - e. Otros ____
   - Situación laboral de los otros miembros de la familia

     ¿Alguien trabaja en su familia?

a. Sí ☐ ¿Cuántos? ____________________

b. No. ☐

6. Tipo de vivienda
    a. Vivienda colectiva ☐
    b. Vivienda unifamiliar ☐
    c. Otros____
7. Año de construcción (de la casa o el edificio)

    ____
8. Status de la vivienda
    a. Alquiler social ☐
    b. Alquiler ☐
    c. Propiedad ☐
    d. Okupación ☐
    e. Otros____

- ¿Tiene usted hipoteca?
    a. Sí ☐
    b. No☐
- (En caso de respuesta afirmativo) ¿Cuantos tiene usted que pagar cada mes?
    a. Menos de €300☐
    b. €301 - €500 ☐
    c. €501 - €700 ☐
    d. €701 - €900 ☐
    e. €901 - €1.100 ☐
    f. Más de €1.101☐
    g. Ahora no pago. Pero antes pagaba ☐ (por favor, indica cuanto pagaba)

- ¿Tiene usted apoyo desde Plataforma de Afectados por la Hipoteca (PAH)?
    a. Sí ☐

b. No☐

9. ¿Cómo calienta su casa?

a. Calefacción
- Gas natural ☐
- Electricidad ☐

b. Butano ☐

c. Estufa eléctrica ☐

d. Otros ____________________________

10. ¿Cómo cocina usted?

a. Gas natural ☐

b. Butano ☐

c. Electricidad ☐

d. Otros ____________________________

11. Tipo de factura afectada o que había afectada

a. Agua ☐

b. Electricidad ☐

c. Gas ☐

12. Gasto de facturas mensuales (media o actual)

- Agua____
- Electricidad____
- Gas ____

13. ¿Qué dificultades tiene o tenía usted en casa?

a. Falta de luz ☐

b. Falta de agua (para el lavado, la cocina y el consumo general) ☐

c. Mal aislamiento ☐

d. Frío ☐

e. Calor ☐

f. Humedad ☐

g. No puedo pagar ☐

h. Otros____

14. (Ingreso mensual del hogar) ¿Cuánto gana su familia por mes?

   a. No quiero contestar ☐
   b. Ningún ingreso ☐
   c. Menos de € 450 ☐
   d. € 451- € 600 ☐
   e. € 601 - € 750 ☐
   f. € 751 - € 900 ☐
   g. € 901 - € 1.050 ☐
   h. Más de € 1.051 ☐

15. Lugar de origen ¿De dónde es usted?____

16. Edad

☐ < 14	☐ 40 – 49
☐ 15 – 19	☐ 50 – 59
☐ 20 – 24	☐ 60 – 69
☐ 25 – 34	☐ 70 – 79
☐ 35 – 39	☐ 80 <

17. Educación

   a. Sin estudios ☐
   b. Básica ☐
   c. Secundaria ☐
   d. Superior ☐

18. Otros Comentarios

Guardaremos esta hoja a parte de las otras partes de la encuesta para asegurar la privacidad de sus datos

¿Estaría usted interesado/a en ayudar a esta investigación participando en una entrevista?

a. Sí ☐

b. Lo siento pero no ☐

(En caso de respuesta afirmativo) Por favor deja su detalle contacto al investigador/a para ponernos en contacto.

- Número de teléfono____

y/o

- Correo electrónico ____

Annex IV. Other reports

https://ddd.uab.cat/record/190159

http://observatoridesc.org/sites/default/files/estudi-salut-odesc-alta.pdf

Universitat Autònoma
de Barcelona

Department of Geography
Doctorate Program 2018