The economics of green economy strategies at a city scale: can low carbon, energy efficient development approaches be extended to urban resource efficiency?

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Abstract

Cities are major contributors to global emissions, producers of waste and consumers of resources such as energy, water and food: implementing green development strategies is hence a core challenge of modern city-planning. The attention of research has been focusing on the development of energy efficient, low carbon strategies, yet city decision makers need truly integrated approaches, as the one proposed by Nexus. The purpose of our paper is to investigate whether it is possible to take one step in this direction by extending existing approaches to energy efficiency strategies to include other priority resources, *e.g.* water. To test this hypothesis we have taken a robust and well accepted methodology, the ELCC (Economics of Low Carbon development strategies for Cities) developed by SEI and CCCEP, and we have extended it to the case of water efficiency strategies for cities. We have then applied the adapted ELCC framework to the case study of the domestic

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sector of the city of Bologna (Italy), identifying and prioritizing several efficiency measures. Measures were evaluated through their capital investment, annual values of savings, payback period and reduction in consumption, and then aggregated in different scenarios in order to highlight potential urban investments and showcase a possible approach to the prioritization of water efficiency measures . The results show that, with an upfront investment of € 17 million, a feasible subset of Bologna's households could be equipped with five selected cost-effective measures, generating annual savings of € 10.2 million and reducing the total domestic water consumption of 34% by 2020 compared to the 2012 initial value. With additional € 28.5 million, households could be equipped with more costly appliances reaching an overall water reduction of 37% by 2020. Our findings confirm that it is possible to successfully extend current approaches to urban energy efficiency strategies to include water efficiency, adding an important component to the construction of an integrated Nexus based approach to green development strategies at city level. We encourage further tests to confirm the robustness the methodology.

Keywords

Bottom-up strategies; Italy; sustainability; urban resilience; urban resources; water management.

1. Introduction and Background

Implementing effective and innovative green development strategies is one of the core challenges of modern city-planning (CoR EU 2013; Hoornweg *et al*. 2012; UN Conference on Sustainable Development 2012; UN-Habitat 2011). In this view, cities are the essential ground for climate mitigation and adaptation actions: on the one hand they are one of the main causes of global environmental threats, on the other they are equipped with the citizen engagement, technical know-how and policy resources to effectively act on it (Bulkeley 2010; Bulkeley 2013; Bulkeley *et al*.

2011; Romero-Lankao and Dodman 2011; Schreurs 2008).

Until recently, research efforts and actions have focused on low carbon, low GreenHouse Gas (GHG) emission and energy efficient development strategies. Several initiatives have been launched at global and regional level in order to support cities in their effort to mitigate the effect of climate change, reduce their emissions and become more energy efficient (*e.g.* Covenant of Mayors, ICLEI, Energy Cities Network, Eurocities, C40 Cities Climate Leadership Group). Yet, the impact of cities goes well beyond the mere contribution to energy consumption patterns and GHG emissions: they are rapidly becoming one major cause of concern as consumer of global valuable resources, in particular water and food, as producers of waste and as clients of "ecosystem services" (Bai 2007).

Integrated approach which account for the synergy between the so called water-waste-energy nexus, and adaptive efforts, become thus the key for a successful urban green transition. This, by containing the foreseen impact of climate change, reducing vulnerabilities and fostering resilience (Keskitalo 2010; Klein *et al*. 2005; Tol 2005; Smit and Wandel 2006). In our paper, we attempt to progress towards the development of such an integrated approach by addressing the following research question: can we extend low carbon, energy efficient approaches to include other priority resources beyond carbon?

Many methodological approaches to evaluate the economic implications of low carbon and energy efficiency strategies implementation have been proposed by scholars and practitioners. Their aim is supporting city decision makers in their effort to make the local economy more energy efficient and lowering urban emissions. In general, these strategies are addressing the problem of city level mitigation and adaptation by a broad mix of actions aiming to:

1. enhance the sustainability and resilience of city by an integration of "urban planning, architectural design, ICT and energy management" in order to "improve energy efficiency, reduce environmental pollution, provide innovative economically viable means to absorb urban growth, and enhance living conditions" (UNECE 2013);
2. evaluate the key urban ecosystem services (*e.g.* renewable energies, water provision, waste disposal, access to cleaner air);
3. boost innovation and efficiency usage of resources, to increase the overall system efficiency and improving environmental performance of existing services.

These strategies are indeed important components of the governance of urban environment. Nonetheless, they may lack of an clear multi-level system of coordination among actors that would enable more fruitful engagement of local expertises (Biesbroek *et al*. 2010). A bottom-up approach, focusing on the specific criticalities of the city under investigation, provides sensible evaluations of the cost and benefits of each actions: it may prove to be a crucial tool for effective emissions reduction urban strategies and for building up local resilience to future adverse climate conditions (Puppim de Oliveira 2009; Urwin and Jordan 2008). There is, therefore, the need to build a usable, effective methodology applicable at the city-scale level, apt to increase long term sustainability in terms of a more efficient usage of ecosystem services and resources.

A preliminary attempt towards the identification of such a methodology was developed by the Stockholm Environment Institute of York (SEI-Y) and the Centre for Climate Change Economics and Policy (CCCEP) through the development of a standardised approach towards the Economics of Low Carbon development strategies for Cities, more commonly called the ELCC approach or Mini-Stern Review (Gouldson *et al.* 2012). Different methodological models were developed to provide a guide to local decision-makers towards the instalment of energy efficiency measures.

Measures were ranked accordingly to the benefits generated (efficiency performances and CO_2 abatement potential) and their direct and indirect costs (instalment, missing and running costs). The methodology was successfully tested over several UK urban regions such as: Leeds, the Humber area, Sheffield and Birmingham (for an example, see Gouldson *et al.* 2012).

In this study we focus hence on two aspects:

1. verifying if the ELCC approach to the development of low carbon energy efficiency strategy for cities can be extended to other priority resources that are of main concern for urban planners, in particular water
2. applying the extended approach to develop a water efficiency strategy for a significant real world case study; the City of Bologna. We do so by identifying and prioritizing a series of water efficiency measures apt to reduce efficiently wastes in water consumption, actively create new job opportunities, boost innovation and consequently enhance economic growth (UNW-DPC 2012).

The preliminary results obtained show that it is possible to adapt the ELCC to water efficiency strategies, obtaining meaningful and relevant insights on future water efficiency scenarios. Additional case studies need to be investigated in order to test the methodology further. Research is under way to extend the methodology to other resources and to cover the whole of the Nexus.

2. Methods

The study focuses on the City of Bologna, geographically situated in the North East of the Italian Peninsula and capital of the Emilia-Romagna region (ERR) (Figure 1). With 380,635 residents (December 2012), Bologna is the 9th most populated Italian city (ISTAT 2012a).

Figure 1. The geographical localization of the Council of Bologna in Italy and within the Emilia-Romagna Region.

2.1 Baseline

To develop the Business-As-Usual (BAU) baseline scenario, domestic historical data series of water consumption (2005-2011) were extrapolated from HERA annual water bills provided by the ERR Agency for Water and Waste Services. A linear regression model was built to forecast future domestic water consumption up to 2020. Time progression and yearly population data were tested as explanatory variables of water consumption volumes. Population was included following the rationale that a variation in the number of residents might affect domestic water consumption (Saturnino 1990). Historical population data series (2005-2009) and its estimations (2009-2020) were obtained respectively from the Italian National Institute for Statistics (ISTAT 2012b) and Bologna City Council database (Comune di Bologna 2009) (Appendix A, Table A.1).

The population data for Bologna Council was modified to take into account the fact that Bologna hosts one of the largest Universities in Europe (about 51,000 enrolled university students in 2012; Muraro *et al.* 2012). Population was adjusted adding an estimation of university students that are official residents of other provinces and regions but that reside in Bologna for the majority of the year and thus not accounted in the official statistics (Appendix A, Table A.2). Outside students fluxes were obtained from the University of Bologna statistical database (Muraro *et al*. 2012), and then projected with linear regression up to 2020.

In choosing Bologna as our case study, we were attracted by a number characteristics that make it a good representative of European urban development. Specifically, the mixed morphology of its urban area, with a balance between sprawling suburbs and high density central neighbourhoods;

its hybrid demography, where a large resident population co-exists with a significant number of medium and long-term commuters; the make of up of the domestic sector with a combination of ancient and modern dwellings (Buzar *et al*. 2007).

2.2 Water efficiency measures prioritization

Accordingly to the literature, the average household size in Bologna is 1.9 people (ISTAT 2011), and 70% of Bologna's inhabitants reside in residential unit categorized as 'economic' (Agenzia delle Entrate 2011). According to this definition, economic residential units are houses built in the 1950s-60s, with less than 100 m^2 habitable surface and with a single bathroom and toilet. It was then assumed that the average residential unit would be equipped with the water home devices outlined in Table 1. Per capita domestic water consumption data (2012-2020) were then disaggregated and attributed to each device, using average household water usage percentages obtained from previous studies on the Italian domestic water sector (Bodini, Allesina & Bondavalli 2003; Conte 2008; Fanizzi 2008) (Table 1).

Table 1. Primary water home components of the 'Economic' Residential Unit and their water usage share.

Water home components [a]	**Daily water usage (%)** [b]	**2012 *Per capita* water usage (m^3/person/year)**
Toilet	25.5	14.2
Washing machine	10.0	5.6
Dishwasher	5.5	3.0
Bathroom taps	8.9	5.0
kitchen tap	12.3	6.8
Shower/bath	26.8	14.9
Others	11.0	6.1
	100	**55.6**

[a] Accordingly to the 'Economic' Residential Unit definition, the following water home components were assumed: one low efficiency (l.e.) toilet, one l.e. washing machine, one l.e. dishwasher, two bathroom taps, one kitchen tap, one l.e. shower/bath and one additional outdoor tap.

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[b] Daily water usage values are an average of Bodini, Allesina & Bondavalli (2003); Conte (2008) and Fanizzi (2008).

Domestic water efficiency measures were organized in three main categories (Steg & Vlek 2009; Huber 2004; Topi 2013, pers. comm.):

- Behavioural measures, which involve only a change in the conduct of the people without any change in the technology (*e.g.* close taps while brushing teeth);
- Technological measures, involving a technological improvement on the device to offer an higher efficiency to the users (*e.g.* high water efficiency washing machines);
- Hybrid measures, which act both on the user's behaviour and on one or several technological improvements (*e.g.* dual-flush toilets).

The ensure robustness of the results, the initial database was reduced to eight efficiency measures in agreement with two criteria: stakeholders acceptance, and reliability of the technical and economic information available to perform a full cost-benefit analysis.

Several economic indicators were estimated for each water saving measure using data available in the scientific literature, public reports and private companies' estimations (Table 2). These economical indicators together with 2013-2020 per capita projected water usage per home component, (assuming an instalment of the measure at the 31st December 2012) were used to calculate:

- 2013-2020 projected annual average household water savings for each water efficiency measure (m^3/average size of household/year);
- Net Present Value (NPV) for the deployment of each individual water efficiency measure in the average household. The NPV of an efficiency measure e at year t (t_0=2012) is equal to the difference between the sum of future discounted cash flows deriving from the measure ($W_{et}T_t - RC_t$) and the initial capital investment (C_0);

$$NPV_{et} = \sum_{t=0}^{N} \frac{W_{et}T_t - RC_t}{(1+r)^t} - C_0 \qquad (1)$$

- 2012-2020 estimated discounted annual average value of savings due to the deployment of each individual water efficiency measure in the household. These were determined by multiplying annual household water savings (W_{et}) by the estimated water tariff (T_t) and subtracting related running costs (RC_t). Each value was then discounted with a set rate r. Water tariffs T are obtained averaging the different tariffs available each year. Its historical data series (2005-2013) were obtained from ERR and projected to 2020 with linear regression. The real discount rate r was set at 8%, subtracting the value of 2012 Italian inflation (3% ISTAT 2013) from the 2012 average commercial interest rate (11% Bank of Italy 2013);
- Payback period as the amount of time (in years) required to start earning from the investment.

A sensitivity analysis was also performed to observe how variations on the interest rate could affect the NPV.

Measures were then ranked according to their payback period. The analysis at household level was subsequently expanded to all 144,607 average economic households (ISTAT 2011). In accordance with the commercial availability and accessibility of the selected measures, we regard the adoption of these technologies as suitable for the vast majority of the examined households. To make the case more realistic, we assumed an uptake rate following an S adoption curve and we excluded the intrinsically innovation-resistant agents on the tail of the curve, resulting in the application of a haircut of 16% (Rogers, 1983). These assumptions enabled the identification of three main scenarios (Gouldson *et al*. 2012):

1. the Cost Effective scenario, which includes all measures that would not only repay for themselves

across the lifetime but also generate additional revenue;

2. the Cost Neutral scenario, which includes all options that could be afforded if savings generated by the cost effective measures were reinvested in other efficiency measures;
3. the Realistic Technical Potential scenario including all measures despite of their cost effectiveness, under the realistic assumption on adoption outlined before.

Table 2. Water efficiency measures classified accordingly to their typology and their associated economic indicators.

Option type	**Efficiency measure**	**Upfront capital cost (€)**	**H.M.R. costs (€) [a]**	**Measure lifetime (yrs) [b]**	**Annual water efficiency (%) [c]**	**Water efficiency data sources**
Behavioural	Close taps when not in use	0	0	-	30	Environment Agency (2013)
Technological	Taps flow restrictors	10	0	20+	17	Alvisi & Scagliarini (2006)
Technological	Water-saving shower heads	10	0	20+	50	Lallana *et al.* (2001); Tonix (2001)
Technological	High efficiency washing machine	330	50 (every three years)	10	52.5	AIAT Sicilia (2010); Legambiente (2012)
Technological	High efficiency dishwasher	650	50 (every three years)	9	45	AIAT Sicilia (2010); Energy Star (2013)
Technological	Mixing faucets	65	0	15	55	Hansgrohe (2010); Ibrubinetterie (2012)
Hybrid	Using/installing shower instead of bath	30	0	20+	66	Environment Agency (2013)
Hybrid	Double flush toilet	90	0	10	64	Koeller (2003); Environment Agency (2007); Rajala & Katko (2004)

[a] Hidden, missing and running costs associated with the measure installation.
[b] Source: NAHB (2007).
[c] The percentage of water savings obtainable if the measure is implemented.

3. Results

The linear regression model used to develop the baseline, i.e. Business As Usual (BAU) scenario, shows that there is significant relationship between the domestic water consumptions and the time series (Bologna: R^2=0.60; F=7.47; d.f.=1,5; p=0.041). Specifically, projected water consumption reduces constantly within the time frame considered.

With respect to the water efficient measures estimation, it emerges that all measures could save a substantial amount of water, ranging from 3.94 m^3/household/year (high efficiency dishwasher) to 19.74 m^3/household/year (closing taps when not in use) (Table 3). In monetary terms these savings translate into a reduction on the annual water bill ranging from 5.24 to 26.32 €/household/year. Amongst all measures, six will allow a full repayment of its relative costs within their life spans, with the most effective being 'closing taps while in use' (immediate payback period) and the least effective being 'double flush toilet' (4.9 years). High efficiency washing machine and dishwasher instead will not allow covering the expenses borne within their lifespan.

Aggregating to a city scale (Table 4), the examined sample of Bologna's households could be equipped with all cost-effective measures (see measures in italic in Table 3[1]) with an upfront investment of € 17 million. This investment would realistically reduce the city water consumption level of 7.7 hm^3/year, generating annual savings of € 10.2 million. At a commercial rate, these investments would be repaid after 1.9 years generating, up to 2020, a total € 41.7 million additional savings, making the investment very attractive.

In the Cost Neutral scenario, the amount of savings created by the implementation of the Cost Effective scenario is reinvested by introducing (in 2012) high efficiency washing machines for all

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[1] Mixing faucets were not included as its effects are covered by the taps flows restrictors.

examined households. Accordingly to this scenario, the city water consumption is reduced by 8.3 hm^3/year, and an average annual savings rate of € 11.1 million is generated by initial investments of € 56.4 million (partially covered by the revenues generated by the Costs Effective Scenario), with a real payback period of 6.4 years due to the adoption curve.

Finally, the implementation of all the measures available in the Realistic Technical Potential scenario would require an initial investment of € 135 million that cannot be repaid over the period under consideration or the lifetime of the measure. On the other hand, it would generate higher average annual water savings (8.6 hm^3/year) , whilst the value of savings would be €11.5 million.

Figure 2 shows the effects of the deployment of the Cost Effective, Cost Neutral and Realistic Technical Potential scenarios on water consumption on the total stock of domestic households (206582, which include the 84% of economic households adopting water efficiency measures, the 16% resistant to them, and the remaining households classified as 'non economic'; ISTAT 2011). It is possible to see that:

- with no intervention, domestic water consumption is forecasted to reduce of 12% by 2020 respect to consumption level in 2012.
- Under the Cost effective scenario the consumption will be reduced by an additional 34%;
- if the Cost Neutral scenario is also implemented, consumption will be additionally reduced by 3%, reaching a total reduction of 37%;
- the overall effect of all latter scenarios with the implementation of the total Realistic Technical Potential scenario reach an comprehensive reduction in consumption of 38% compared to 2012 levels.

The sensitivity analysis performed on the discount rate shows that the model is robust to variations in the market conditions.

Table 3. Investment costs, financial returns, water savings and discounted payback periods for eight water efficiency measures. Investments are undertaken in 2012 (t=0). Average annual savings are referred to the 2013-2020 period.

Option type	**Efficiency measure**	**2012 upfront capital cost (€)**	**H.M.R. costs (€)** [a]	**Average annual water savings (m^3/household/ year)**	**Average annual value of savings (€/household/ year)**	**N.P.V. (€)**	**Discounted Payback period (yrs)**
Behavioural	*Close taps when not in use*	*0*	*0*	*19.74 ± 0.1*	*26.32 ± 0.5*	*150*	*Immediate*
Technological	*Water saving shower heads*	*10*	*0*	*13.21 ± 0.2*	*17.59 ± 0.2*	*90*	*0.62*
Hybrid	*Using (installing) shower instead of bath*	*30*	*0*	*17.44 ± 0.2*	*23.22 ± 0.2*	*100*	*1.46*
Technological	*Taps flow restrictors*	*10*	*0*	*5.40 ± 0.1*	*7.19 ± 0.1*	*30*	*1.58*
Technological	Mixing faucets	65	0	17.47 ± 0.2	23.26 ± 0.2	68	3.39
Hybrid	*Double flush toilet*	*90*	*0*	*17.54 ± 0.2*	*23.36 ± 0.2*	*43*	*4.90*
Technological	High efficiency washing machine	325	50 (every three years)	6.69 ± 0.1	8.91 ± 0.1	-345	Not in m.l.t.[b]
Technological	High efficiency dishwasher	650	50 (every three years)	3.94 ± 0.1	5.24 ± 0.1	-610	Not in m.l.t.[b]

[a] Hidden, missing and running costs associated with the measure installation.
[b] Not in the measure life time.

Table 4. Investment cost, financial return, water savings and discounted payback period for three city scenarios. Economic households adopting the measures are estimated to be 121,470. (Source ISTAT 2011; Rogers, 1983). Investments are undertaken in 2012 (t=0). Average annual savings are referred to the 2013-2020 period.

	2012 upfront capital cost (€M)	Average annual water savings (hm^3/year)	Average annual value of savings (€M /year)	Payback period (yrs)	Water savings[a] (%)	Extra savings[b] (€M)
Cost Effective scenario [c]	17	7.7 ± 0.07	10.2 ± 0.14	1.93	58	41.7
Cost Neutral scenario [d]	56.4	8.3 ± 0.08	11.1 ± 0.15	6.4	62	n
Realistic Technical Potential	135.4	8.6 ± 0.08	11.5 ± 0.15	n/a	64	n/a

[a] Percentage of water savings at year 2020 compared to the reference value of 2012.
[b] Actualized additional savings generated by each scenarios after the costs are covered.
[c] The cost-effective level is the simultaneous implementation in the 84% of the 'economic' households of Bologna of five efficiency measures: close taps when not in use, water saving shower heads, tap flows restrictors, use shower instead of bath and double flush toilet (mixing faucets were not included as its effects are covered by the taps flows restrictors).
[d] Savings generated by cost effective measures are reinvested in the adoption of high efficiency washing machines. Upfront capital cost includes costs of high efficiency washing machines actualised to 2012. The pace of adoption of high efficiency washing machines follows proportionally the increase of savings generated by efficiency measures.
[e] Adoption of all the eight measures by the 84% of the 'economic' households of Bologna.

Figure 2. Baseline (Business As Usual) and effects of the Cost Effective, Cost Neutral and Realistic Technical Potential scenarios on water consumption. Water consumption in 2012 is setted as reference point (=100%). Values are computed on the total stock of 206582 Bologna domestic households: (ISTAT 2011).

4. Discussion and Conclusions

4.1 Measures of water efficiency

Our results prove there is a robust business case to undertake city-level investments to incisively reduce water inefficiencies. Among the options investigated, behavioural and hybrid measures appear to be particularly cost-effective. This happens mainly because they have low up-front capital cost as they consist in behavioural changes. However, its effective outcomes are difficult to estimate as they are strictly dependent on the users' wills, the complexity of which is hardly taken into consideration by decision-makers (Gilg & Barr 2006). Indirect costs linked to implement successful changes in the users' behaviour could indeed increase substantially the payback period of the related measure (Inman & Jeffrey 2006).

The analysis suggests that high efficient devices (excluding double flush toilets) are not the best investments in term of water savings. These results appear to be somehow different from the finding of Gouldson *et al*. (2012), where several technological measures emerged as both carbon and cost-effective. The low economic performance of high efficiency devices may be due to a combination of factors that does not allow full costs repayment across the measure life-time (*e.g.* short life of modern appliances, high upfront costs and frequent repairing costs). Furthermore, as it emerges from Table 1, dishwasher and washing machine usage account only 15% of the total water usage of the average Italian user. The results may thus be different if the analysis was undertaken for example with respect to the average US user (25% of water destined to dishwasher and washing machine; Mayer *et al.* 1999), the average Danish user (31%) or the average German user (20%) (Aquaterra 2008).

Water saving benefits are not only limited to the individual households, but will positively boost local economy in terms of new job creations, energy security and several other indirect benefits (Wei, Patadia & Kammen 2010). These factors may be ignored by private actors whose forecasts are generally confined to short run monetary losses (Gouldson *et al*. 2012). To bypass these behavioural and economic obstacles, local decision-makers could enter in the scene in order to facilitate the measures' implementation .

4.2 City-level efficiency scenarios

The results can be aggregated into city-level scenarios as shown in the Results section (Table 4). By doing so, we estimate that in the Costs Effective level, more than 7 hm^3/year of water could be saved each year by investing € 17 million. The cost-effective measures not only have a significant impact on the global water uptake, but they are also potentially implementable by local governments distributing water efficiency appliances kits and undertaking educational campaigns. Initiatives in this sense are already undergoing on the ERR such as: the educational campaign 'Acqua risparmio vitale' (Water, vital cutbacks) launched in 2004 that aims to promote behavioural changes towards a water saving attitude (Cimatti, Bortone & Draghetti 2006); and free distribution of water saving devices (HERA 2006). It is worth to mention that we did not consider the additional cost of potential educational campaigns in our forecasts.

The savings that the Cost Effective level would generate could be addressed to the instalment of more intensive and costly appliances *i.e.* the Cost Neutral level. In this scenario, implementing both cost effective and costly measures would generate higher water savings (8.3 hm^3/year) but would require an upfront investment larger than the revenues generated by the costs effective measures (an addition of € 39.4 million), investment which could be part covered by a specific policy intervention (*e.g.* a subsidy). Italian legislation is moving in this direction with the approval in August 2013 of an emendation aimed to enlarge the scope of existing energy green subsidies towards domestic home appliances (Gazzetta Ufficiale 2013).

As seen in the result section, there is a strong business case for investment in the Cost Effective scenario and this opportunity may be very attractive to households or to commercial investors (payback period 1.9 years). On the other hand, the business case for investment in the Cost Neutral scenario is weak (payback period 6.4 years), whilst the Realistic Technical Potential scenario over the time period would not be intrinsically attractive. Whilst the option of public investment may be justified by the clear environmental advantages, special financial delivery mechanisms must be developed to transform these scenarios into opportunities attractive to investors.

From a methodological point of view, it is worthy of note the fact that the households' sample has been built according to a limited number of theoretical assumptions: it serves the purpose of offering an aggregate model of the average household in Bologna. A more qualitative-oriented analysis may identify substantial differences among the city's neighbourhoods and districts; in particular, the size of households, the feasibility of efficiency measures' implementation and the rate of their adoption may significantly vary in accordance with spatial, technical and income-distribution factors (see, *inter alia*, Jacobsson and Johnson, 2000).

4.3 Wider considerations

By using the ELCC approach, an accepted and widely replicated methodology for the development of low carbon, energy efficiency strategies in cities, we make it possible to develop integrated plans where energy, water and, possibly, food and waste efficiencies are managed together. Often water efficiency measures also produce energy efficiency standards (*e.g.* electric water efficient appliances; Hackett & Gray 2009), and the reuse of domestic and industrial waste-water is one of the key-challenges of modern urban development (*e.g.* installing waste-water separation toilets; Larsen *et al*. 2001). Considering these interactions and second-order effects will avoid over/underestimating the impacts of these integrated plans, permitting a city-scale evaluation of the complete nexus water-waste-energy as promoted by Hoff (2011). The investigation of such interactions is paramount to development of realistic integrated strategies for the transition of cities to a green paradigm. Our study provides a first step in that direction, but is far from being exhaustive as further case studies need to be investigated in order to reinforce the methodology.

The next important aspect to consider is the procurement of funding to finance the adoption of measures, considering that the benefits derived from the measures performance should be in part redistributed to the households, which bear the brunt of the implementation, and that the Cost Neutral and Realistic Technical Potential scenario would not be attractive to either households or investors. To show that the scenarios we propose are not only realistic, but also deployable, we have currently developing a cash flow model, based on a revolving fund approach which allows to finance the transition in full whilst minimising the initial investment and at the same time redistributing part of the revenues to households and investors. The presentation of the model is outside the scope of the present paper and is currently object of research.

Finally, the development of new online platforms and methodologies for the distribution and investment of funds (*e.g.* crowdfunding or microcredit groups) opens new avenues for the investigation of alternative mechanisms both of investment in water efficient strategies and of redistribution of revenues among the collectivity, which becomes at the same time strategy planner, investor and implementer. The role of the policy makers at local level becomes both to support and monitor the correct deployment, and to lower barriers and obstacles for the local communities. Such mechanisms are currently being investigated.

4.4 Conclusions

The purpose of this study was to verify if the ELCC approach could be transposed and extended to included other priorities resources, in particular water . Our results show that:

1. ELCC, as a methodology designed for low carbon and energy efficient city strategies, is extremely adaptable and can be successfully extended to integrate water efficiency. This thanks to available technical and economic data that allow a precise estimations of several water efficiency measures costs and benefits
2. there is the possibility for policy makers to implement a selected basket of measures to improve the domestic sector water efficiency in order to achieve the advocated transition to a green and efficient urban model. This could be done by a single up-front investment (Cost Effective scenario), or by increasing the sphere of action reinvesting the savings generated in more costly appliances (Cost Neutral scenario).

It is therefore possible to conclude that this trial study successfully set the basis to expand low carbon, energy efficiency development strategies to other priority resources (*e.g.* water, food and waste) and other urban sectors, (*e.g.* industrial and commercial sectors) by presenting an integrated approach to environmentally sustainable and resilient urban development. Further research is currently under way to extend the approach to food waste efficiency in order to achieve a full coverage of the integrated water-waste-energy Nexus.

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Appendices

Appendix A

Table A.1. Different estimation of Bologna's population data (2005-2020) integrated with university students fluxes. Outside students fluxes data source: University of Bologna statistical database (Muraro et al. 2012).

Year	Population of Bologna (official statistic)	University students from outside Bologna Province [a] [b]	Population of Bologna (new estimation)
2005	373,743	27,574	401,317
2006	373,026	28,175	401,201
2007	372,256	23,938	396,194
2008	374,944	23,583	398,527
2009	377,195	20,985	398,180
2010	378,221	21,630	399,851
2011	379,214	21,890	401,104
2012	380,136	19,166	399,302
2013	381,012	17,984	398,996
2014	381,833	16,802	398,635
2015	382,616	15,620	398,236
2016	383,360	14,438	397,798
2017	384,090	13,256	397,346
2018	384,788	12,074	396,862
2019	385,473	10,892	396,365
2020	386,132	9,710	395,842

[a] Official residents of other provinces and regions but that reside in Bologna for the majority of the year.

[b] 2013-2020 values were forecasted with linear regression (R^2=0.79; F=18.78; d.f.=1,5; p=0.007).

Table A.2. Historical population data series (2005-2009) and its future estimations (2009-2020) for the Council of Bologna. Data sources: the Italian National Institute for Statistics (ISTAT 2012b) and Bologna City Council database (2009).

Year	**Population of Bologna council**
2005	373,743
2006	373,026
2007	372,256
2008	374,944
2009	377,195
2010	378,221
2011	379,214
2012	380,136
2013	381,012
2014	381,833
2015	382,616
2016	383,360
2017	384,090
2018	384,788
2019	385,473
2020	386132