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Title:
INTERVENING IN THE CITY: CO-DESIGNING NEIGHBOURHOOD INFRASTRUCTURE WITH RESIDENTS OF A LONDON HOUSING ESTATE

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INTRODUCTION:
Infrastructure is about norms, standards and social organisation. It helps construct categories of gender, family, citizenship (Star 1999). Infrastructure is about power and politics. It determines who has access to standards of living and the political ecology that results from differentiated access (Graham and Marvin 2001; Kaika 2004). Infrastructure is also about resources and sustainability. Centralised supply-driven systems have been critiqued for hard wiring the resource intensity of everyday life at unsustainable levels (Shove 2003). Infrastructure is rarely about co-design, although end users, even residents in their homes, are increasingly being seen as key to achieving system aims and are described as 'co-managers' of national infrastructure systems by van Vliet et al (2005, 2). Demand-side response activities have opened up a field of research about how parts of infrastructure can be designed to bring users more reliably into the frame of resource management. However the residents' role is typically restricted to using the equipment on their side of the meter appropriately. From shower timers, to thermostats, smart meters to time of use tariffs, information and equipment are being designed to bring user interaction in line with networked utilities' distribution priorities (for example Strengers 2013 on smart electricity grids; Jeffrey and Gearey 2006 on water demand management).

Engineering Comes Home takes a different approach to infrastructure. It challenges the starting point of infrastructure design, looking first to the home and it's occupants in order to involve them in the design of systems that supply water, energy and food. Co-design of WEF infrastructure is new area of research, although it builds on the theories and practices of design for sustainability (Lockton, Harrison, and Stanton 2008) and on value-sensitive design (Friedman 1999). In this paper we outline the co-design pilot project that ran in 2016-2017 in a housing estate in south east London. The project used a co-design methodology and resulted in a smart rainwater harvesting tank and hose being installed on an estate downpipe for residents to use. The paper starts with an overview of the design theories and practices that shaped the methodology, then provides the details of the pilot project and ends with a discussion of the evaluation and reflections that were produced throughout the process by the research team and participants.

CO-DESIGN AS RESEARCH METHOD
Engineering Comes Home drew on two strands of design thinking to form the co-design methodology. The first looked to the participatory design tradition developed within the field of information technologies to find ways to engage residents in the design process. The second looked to the tradition of product design within the sustainability design field, in order to look at how interventions can disrupt the status quo of WEF resource use in the home.

Participatory design

Participatory design has been a field of research and practice in Information Technologies since the 1970s (Simonsen and Robertson 2012). In it's early forms it focused on improving workplace IT systems and supporting the users of technologies to create humane and ethical workplace environments. As IT systems have expanded beyond the workplace, participatory design theorists and practitioners have followed, moving into domestic and other settings. This field has led to specialisms such as Value-Sensitive Design which incorporate alternative design principles based on 'human well being, human dignity, justice, welfare, and human rights' (Friedman 1999, 3). It has also led to more open design practices moving first to user-centred design which observed people's practices to improve design, then to user-led design which put users in charge of identifying the design problem, to co-design which embraced both suppliers and users to work together in defining problem spaces and design solutions (McDougall 2012). At its core, participatory design is about improving the systems that serve people and emancipating the users through engaging them in the design process.

Design and Sustainability

If participatory design is focused primarily on human agency and social institutions supported by ICT, design for sustainability is focused primarily on the environmental impact of designed goods and services. It's origins lie in product design and improving product performance to provide consumers with the same service levels while reducing the volume of resources used. Challenges such as the 'rebound effect' led design theorists to consider not only a product's performance, but also its use by people. This has led to fields such as 'design for sustainable behaviour' which encourage more sustainable consumption behaviours through product design (Jelsma and Knot 2002). This approach focuses on an idealised interaction between user and technology rather than fully embedding the design into messiness of everyday life. This has been criticised for prioritising the individual as the locus of agency and change and understanding behaviour through a rational choice paradigm based on normative assumptions which can obscure broader political questions about resource consumption and the relative empowerment and disempowerment that certain technological arrangements can bring (Kuijer 2014; Wever, van Kuijk, and Boks 2008). Recent approaches to sustainability and design tackle some of these issues by drawing on Social Practice Theory to engage with resource using practices (Kuijer 2014), and Actor Network theory to move beyond the individual as the source of agency (Teh 2011). Both Teh and Kuijer studied social practices around resource use and then used design methods to disrupt or innovate and project possible alternative socio-material configurations and co-evolutions.

Design for sustainability as method can be speculative and allow for new possibilities to open up. It draws in the non-human world as partners and questions embedded power relations. Co-design as method widens the circle of those involved in the task and enables alternative knowledge and value systems to be part of the projection of the alternative arrangements. This combined approach was followed by the Engineering Comes Home team.

THE ENGINEERING COMES HOME CO-DESIGN PROCESS

The project put these design principles into practice in order to test whether the co-design of inner city infrastructure was possible. In this section we discuss the co-design process employed in our project on the Meakin Estate in Southwark[1] .

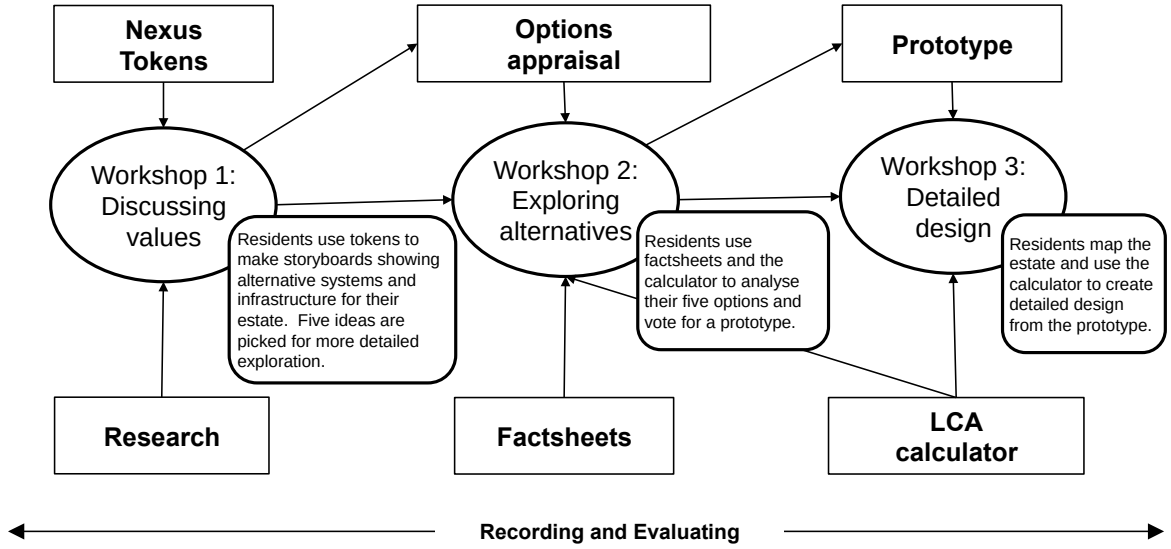

Figure 1: Co-design process for community scale WEF infrastructure

The co-design process was carried out in three half day workshops held in the estate's community hall and involved 19 residents (15% of the total number of households). The process was run by the research team, supported by an external facilitator, videographer[2] and the local Tenants and Residents Association.

Workshop one: Discussing values

Workshop 1 focused on eliciting values relevant to domestic WEF resource management on the estate and on generating ideas for interventions that might fit with these values and with the material configuration of the estate. 13 residents turned up to participate. The first set of activities were designed to elicit values. We started with a 2-4-8 process, whereby groups of two discussed ideas, and then joined into groups of four then eight until we had a list of values reflecting all members' inputs.

[1]The recruitment of the residents as partners in the process is discussed by Johnson et al. (Forthcoming), this paper focuses specifically on the co-design process

[2]Videos of the three workshops are available to watch at http://www.engineering.ucl.ac.uk/engineering-exchange/video-articles/

We then used bespoke co-design tokens and equipment for discussing systems ideas. The tokens were printed with icons representing aspects of WEF systems, a toilet, a flower, a plug for example. Participants were invited to play with these tokens, and construct narratives attached to locations within the estate. Two examples are shown below (*Figure 2* and *Figure 3*).

Figure 3: Electricity story

Figure 3: Food growing story

In total participants created six narratives; individual boards on food growing, electricity generation, gardens, food banks, two boards about re-using things and one board with multiple narratives. As participants discussed each story some key themes emerged. Waste came across as the most important issue for the group; reducing the volume of waste, repurposing it into something useful and improving cleanliness of the estate's public areas. For example, Georgina[3] explained

> *"my idea […is to] have a compressor that could make the bulk smaller. […]In summer it's full up and when it's full up it's everything on the floor and everything is blowing everywhere so those things could be avoided with proper bins."*

Flo commented

> *"If we had the recycling bins on here with clothes, glass, waste food or plastics, [and] a notice board for household items here, [then…] we could pass it on to, like a cot […] someone on the estate could possibly want that cot, and we're recycling it. Plus from the money we collect from the glass, the clothes, could go into other factors for our estate, our environment, and for all of us for future generations."*

[3] Pseudonyms are used for all participants

A second key concern was water. Mary commented "*I think water would be the best, to be able to recycle the water and to use into something else, to come into the garden. Personally to me that would really help the estate"*. The issue transcended the local estate level as Georgina argued *'It'd also be an example to other communities as to how much water we save. It's not just for us, if we transmit to other areas, other cities in Europe, other countries"*. Although not everyone agreed. Neil argued against the ideas "*You know water recycling[…], it's already recycled we don't need to recycle on the estate, it's already recycled, centrally [by Thames Water]"*. He did not see any value in the small scale savings offered by an estate scheme.

We had planned for each participant to create one story and have a narrowing strategy whereby a single issue emerged as one which the whole group would like to explore in more detail. However we had more participants than planned which meant groups worked together on stories and were reluctant to narrow down the number of issues. Instead the group identified a set of ideas that they wanted the team to explore further in the next stage of the co-design process. These were:

- water reuse for garden / home
- composting for garden
- reduction of food and material waste
- management of material waste / cleanliness of the estate

Through analysing the transcript of the discussion the team were also able to draw out a matrix of values that were important to the participants and that could be used to shape the design (*Table **1***).

Table 1: Residents' values for the design

Human	**Practical**	**Concerns**	**Aesthetics**
Community Building	Ease of use	Strangers	Pleasant to look at
Buy in from other residents	Achievable	Scale / quantity / uptake	Reduced rubbish
Wider education	Scalable		
Shared stewardship	Impact		
Care for others	Necessary		
Resilient / future			

The team created a shortlist of existing technologie and systems that could fit into the estate and align with the values elicited during workshop 1. The five shortlisted systems brought into workshop 2 were wormeries, food growing, food sharing, rainwater harvesting, and waste compacting. For the workshop we prepared fact sheets for each of these systems and technologies. We also developed a bespoke LCA calculator that participants could use to gauge the fit of the technology to their community and their estate[4].

Workshop 2: feedback on design options

Nine residents came to the second workshop to assess the technologies and explore how they could be implemented within in the estate. We presented the five ideas, providing participants with fact sheets about each one and showing them how to use the LCA calculator to assess different design criteria. The calculator had a scenario for each technology with adjustable input parameters such as volume of food waste, quantity and scale of technologies. These changed the volume of food that could be grown, or

[4] See Borrion et al., (forthcoming) for the horizon scan of existing technologies and the development of LCA calculator

amount of CO^2 savings realised. Residents explored each scenario in pairs adjusting the calculator according to their assessment of what was appropriate for the estate. These context sensitive adjustments included:

- Levels community involvement: For example, Clare, who'd been involved in other community projects on the estate made an assessment that only 50% of households would participate and went on to limit inputs to this proportion of engagement for all scenarios. By contrast Penny decided the technologies could be designed to increase engagement in some cases. For the waste compactor, she opted to put small manual compactors at each of the stairwells on the basis that residents would then regularly see them and be encouraged to use them.
- Aesthetics and layout of the estate: Participants used their knowledge of the estate, and of the ways communal space was used by different members of the community. This was particularly the case in the gardening scenarios. Participants anchored their designs in which parts of the estate gardens they would be happy to see turned into food growing areas.
- Utility of outputs: Although the LCA calculator was designed to show the resulting CO^2 emissions reductions, these savings were not a very meaningful currency for the group. Instead the designs were more often shaped according to whether the outputs could be used. For example, when assessing the options for the wormeries, Mary was interested in how much fertiliser could be produced and whether the TRA would be able to sell or exchange this amongst other local gardening groups.

After participants had explored each scenario we regrouped and discussed the design options each pair had chosen. This allowed the group to share the different priorities and assessments that had informed their adjustments of the LCA calculator parameters. After the groups had explored all five ideas we held a vote to pick a single design option to move forward with. The discussion prior to the vote gave space for participants to raise other context specific values and knowledge they felt should be factored into the group's selection of a design. Governance proved to be a key concern, in particular how much management any design would require, and also how exposed the system would be to tampering from 'uninitiated outsiders'. For example waste compacting was seen as potentially dangerous if people didn't know how to use the compactor properly, likewise food sharing was felt to be open to mismanagement. All participants had a first and second vote and rainwater harvesting won the most votes (*Figure 4*).

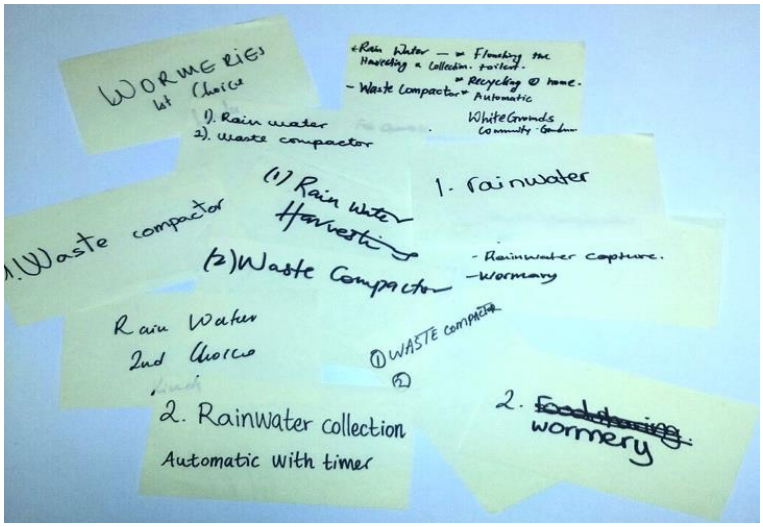

Figure 4: participants vote for a design ideas

The vote gave the research team a design idea to work up into a more detailed design. However workshop 2 had also shown limits to the residents' knowledge of systems that they'd not experienced. Although we worked to address this during the workshop by providing information sheets and

responding to any concerns or questions from residents, the research team wanted to provide some hands on experience of a rainwater tank prior to workshop 3. We were able to get a smart rainwater tank installed on a downpipe on the estate, one just next to the residents' hall where we held our workshops. Installing the tank exposed some of the difficulties of implementing neighbourhood scale WEF infrastructure. At the Meakin there were a number of different departments involved in the installation and use of the water. The tank would have to be located in the garden of the housing management board (Leathermarket JMB), connected to a downpipe managed by a different department and the water was to be used by the TRA for their planters. The groups had different interests and levels of scepticism towards the tank and it's usefulness. Nonetheless we managed to get all parties to agree to the installation. This meant we were able to show the participants what was involved in a rainwater harvesting system.

Workshop 3: detailed design

Workshop 3 aimed to get residents' feedback on the prototype and create a detailed design for rainwater harvesting on the estate. The research team created a bespoke rainwater harvesting module for the LCA calculator which let residents explore design details such as tank size, number and location, rooftop area to be used to catch rain, position of outflows and whether or not to pressurise and pump water. Seven residents joined for the third workshop to experiment with the detailed design. The workshop started with an overview of rainwater harvesting covering technical and operational details as well as its role within the broader picture of London's water governance and infrastructure. We then split participants into groups and went on a walkaround of the estate to mapping the existing drainage infrastructure and potential uses for stored rainwater. *Figure 5* shows one of the maps created by the participants. The residents have marked the downpipes that are free from household wastewater and identified points where water could be used such as car parks. The walkaround was an opportunity for residents to fully engage with the socio-material context of their estate and how a rainwater harvesting system might be integrated into this context. For example we discussed who would use the water. Participants felt the water would be useful for the shared gardens or residents' own gardens and plants, for cleaners to clean common areas, and for residents to wash their cars. We discussed tank positioning. Upper walkways meant there could be a pressurised supply without the need for a pump, but also raised questions about how the pipework would look coming from upper spaces to central courtyard spaces. Participants also discussed questions of access and concerns for safety. All these details and were then used by the participants to come up with detailed design. They worked in pairs using the LCA calculator to gauge different technical modifications. We regrouped and reviewed the designs, discussing additional factors such as maintenance as well as potential ways to implement the designs. As a pilot, the project aimed to test the co-design method, rather than take a design through to implementation. However the estate had an active TRA association with access to funds via competitions from their housing management board and local government and we discussed how the detailed designed could be used to bid for implementation funds. Workshop 3 ended with a reflection on the project overall and an evaluation survey to get feedback from participants.

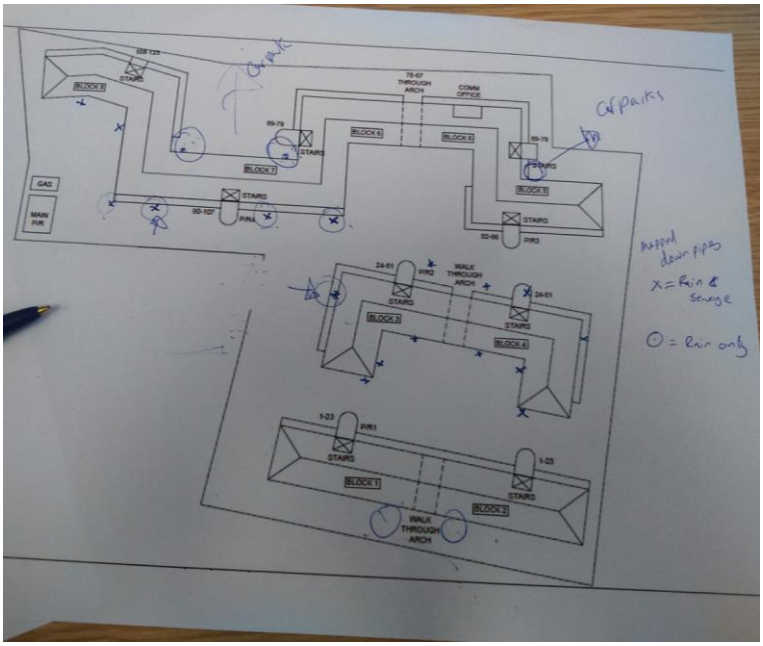

Figure 5: mapping rainwater infrastructure for detailed design

REFLECTIONS AND EVALUATIONS

The objective for the Engineering Comes Home project was to pilot the co-design process. Therefore, as well as inviting evaluation and feedback from the participants, the research team also maintained a continuous process of evaluation and reflection. This meant we adapted our approach in response to the realities of attempting a co-design of infrastructure project. We have also documented the lessons learnt and how future iterations of the co-design process could build these. In this section we outline the evaluations made by participants, and the key reflection points made by the team.

Participant evaluation

Participants were encouraged to provide feedback on the process. This was managed through formal mechanisms such as seeking group consensus on next steps, particularly when this meant a change to our planned activities or schedule. Informal feedback was also captured. For example Justin commented at the end of the first workshop "Nice to see so many people interested. I want to make the estate better and I'm pleased to see that there are other people here interested too". This helped us to get some perspective on the motivations for participation and we were able to formally test with an evaluation questionnaire handed out at the end of the third workshop. This asked how confident people felt in being able to contribute to the activities, whether they felt their ideas had been listened to and gave some free spaces for comments which some people used to discuss their motivations for participating. The nine questionnaires we received were overwhelmingly positive, which may reflect a reluctance to criticise the team. Nonetheless it did show some variation. Seven of the nine strongly agreed with the statement that 'the ideas came mostly from the community', but only four strongly agreed with the statement that 'I've helped influence the outcome of the project'. This may indicate people were hoping for different outcomes or supported other ideas that did not get selected for on-going development. It may also be a result of our open process for participants. People did not come to all workshops and we allowed new participants in at every stage. This meant we had some people participating at later stages who'd not helped establish the value-based criteria or of assess the range of alternative ideas.

The free comments provided space for further insights. Four respondents specifically cited coming together as a community as a benefit of the project. Two stated they had learnt through the project.

These themes; infrastructure literacy, participation and community context were also ones that were picked up by the research team's self reflective evaluation.

Research team evaluation

The team's reflections were captured through observational notes on the workshops and written pieces on the process. Four themes are clear, and reflect those mentioned above by the participants.

Technology literacy

The experience of participants having little prior knowledge of the shortlisted technology options was an important learning outcome. We struggled over the question of how much 'educating' participants could be construed as imposing a particular view on them. An engineer in the team commented "*what's the balance between participants coming up with ideas and being educated with alternative ideas, at a co-design workshop?"* We needed to gauge how far to challenge participants' assumptions about existing or potential systems, aware that we would then shape the outcome of the process. We also found it hard for people to engage deeply in the design of an object or a system as an entirely abstract concept. However by the third workshop we had a working prototype for people to use and become familiar with and the team felt that by the end of the workshop we had managed to raise levels of technical literacy about urban drainage and water management.

Design thinking

Throughout the workshops the participants tended to focus on established design solutions and the practicalities of implementing these within their estate. As one of the design team said '*there was a definite jumping in with pre-formed solutions'* which limited the 'problem space', the process of generating new questions based on personal experiences and values. We felt that overall the process was closer to user-led design than co-design. In other words we had successfully led participants through the 'process of describing and solving problems for themselves' (McDougall 2012) but had not managed to get to the stage where the participants were helping the designers to understand a problem / solution they'd identified through their own experience.

Participation

All 123 households in the estate received a written invitation to the project followed up with a visit to their home for a face to face invitation. Through this recruitment strategy, and our decision to allow newcomers at every stage of the project, we were able to get 15% of the estate's households involved in at least one of our activities. Our approach meant that we had some difficulties with continuity; previously dismissed ideas were revisited by people who'd not been part of the initial screening steps for example. As mentioned above, some at the final workshop did not feel strongly that they'd influenced the outcome of the project. Nonetheless, as the Principal Investigator pointed out '*we managed to have enough participants throughout to test the methods and to get some meaningful data for research. It would have been better to have a more consistent cohort and even more people participating, but it is impressive that people have been willing and interested to engage so far.'* Our approach also meant we were able to engage with people who had a very diverse set of motivations, including those that there were interested in the environmental quality of their neighbourhood and in reducing waste of WEF resources as well as those who were less interested in the environment but supportive of community building activities.

Institutional context

The institutional context also shaped the process. We worked with the estate's governing body (Leathermarket JMB) and the Tenants and Resident's Association. Both were supportive and helped us recruit participants. The management board adopted a hands-off approach, and gave us a free reign in terms of design process. By contrast the TRA had more at stake and therefore took more control of the process, steering it to align with existing initiatives or previous agreements within the community. The PI reflected that '*this has placed some constraints on the 'design thinking', closing down options early in the ideation process'*. The social researcher also reflected that the workshops '*came to feel like a TRA*

meeting' meaning that those used to this governance structure were more vocal in expressing their opinions and proposals for moving forward, while other participants less familiar to the TRA's processes were less vocal. Nonetheless the surveys from participants showed people found it easy to contribute to the discussions. And, as the PI pointed out, working within an institutional context is '*an important part of the design lifecycle, [and involves] understanding local capabilities and constraints. In adapting the process in the future to enable deeper engagement in the co-design process we might think about how we can capture this more productively, to acknowledge local context, knowledge and risks, whilst still keeping design possibilities open.'*

CONCLUSION

Engineering Comes Home demonstrated that residents were willing and able to play a meaningful role in the design of neighbourhood scale infrastructure. We started the co-design workshops with a blank sheet in terms of what form our WEF nexus intervention might take and ended with a rainwater tank and hose providing water for the TRA's flower beds. This specific design solution evolved from the participants' broad concern with wastefulness and the value of pioneering water stewardship.

The co-design process was iterative and responsive to the context. Through it we have found

- A willingness to engage in the co-design process
- That people are motivated by the idea of saving WEF resources beyond rational choice models of motivation
- We could generate a set of shared values to create a design brief
- It was possible to build technical literacy amongst participants

The pilot has allowed us to test the process and learn from this first case-study. Following the principles of co-design, the lessons learnt have been distilled into a set of co-design method statements which are freely available for others to use and build on[5]. This first case-study provides an encouraging example of how residents can be included in the technical work of creating less resource intense, more liveable cities.

[5] The full methodology and tools will be available at https://ech.iilab.org.

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