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Energy resilience in developed and developing countries

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The concept of ‘resilience’

- First introduced as a descriptive ecological term (Holling 1973), has extended to a range of disciplines as an approach to analyse socioecological systems

- Entails the notion of coping with external stresses, emphasising the interconnectedness of various human social systems, physical systems and natural environmental systems

- Energy systems are highly complex systems, often under external stresses in relation to supply, demand and efficiency – Which factors affect energy resilience? How they influence each other and energy resilience as a whole?

Outline of the presentation

To further explore the concept of energy resilience at the local level through three case studies:

- ☐ Nepal
- energy resilience mapping, institutional framework and decentralised governance

- ☐ UK
- multi-level governance and technological innovation systems

- ☐ Mexico
- capabilities and wellbeing in relation to energy services

Energy Resilience mapping – a case study of Kathmandu

- Project: Long-term institutional change in the wake of crisis - Understanding implications for energy-system resilience in Nepal (*Xinfang Wang (PI), Louise Reardon, Long Seng To*)

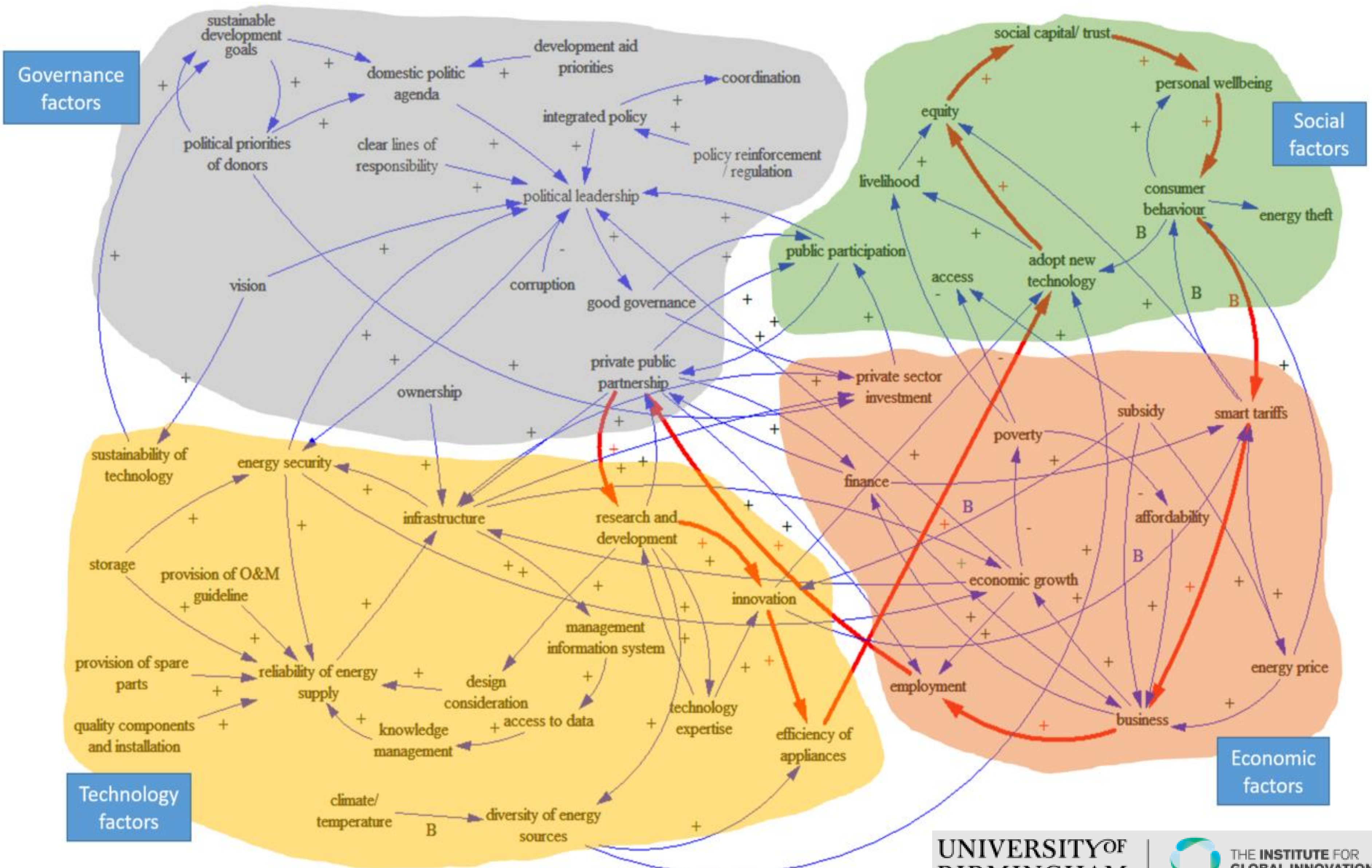
- Funded by Institute for Global Innovation (IGI) Resilient Cities theme, University of Birmingham
- Collaborators: various organisations in Nepal, covering government authorities, local authorities, NGOs, private sector, universities etc.

Data collection and methods

- Participatory approach - workshop with stakeholders on energy resilience and decentralised governance, for **causal loop mapping** of energy resilience in Nepal

- >10 semi-structured interviews with key stakeholders – academic, national government authorities, local authorities in Kathmandu Valley, NGO, private sector etc. (separate from workshop)

Causal loop framework of key factors for energy system resilience in Nepal



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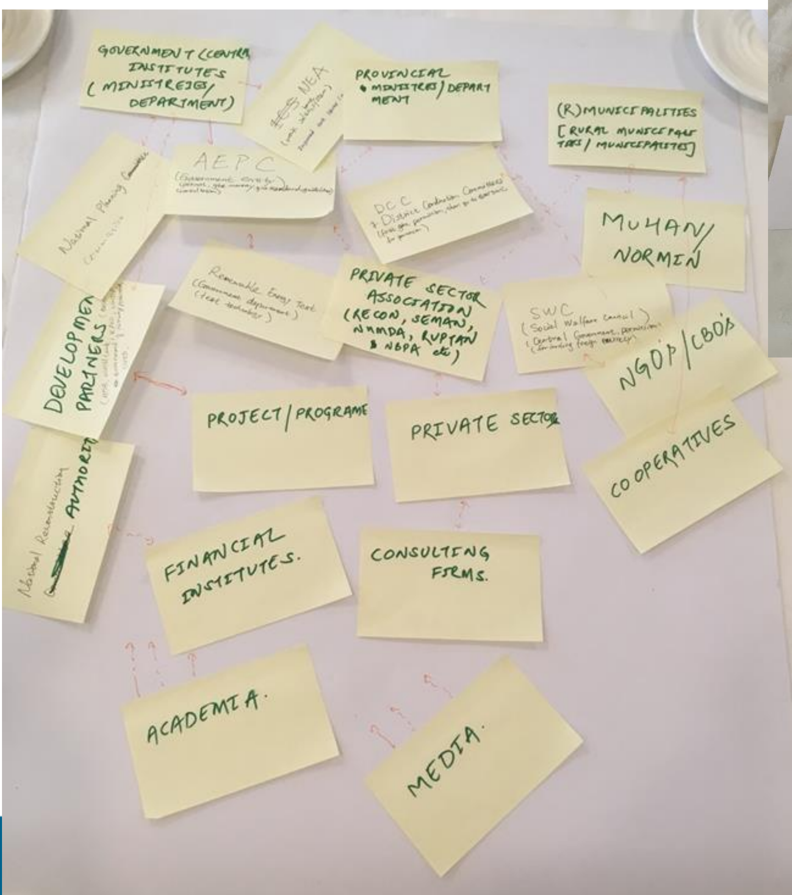
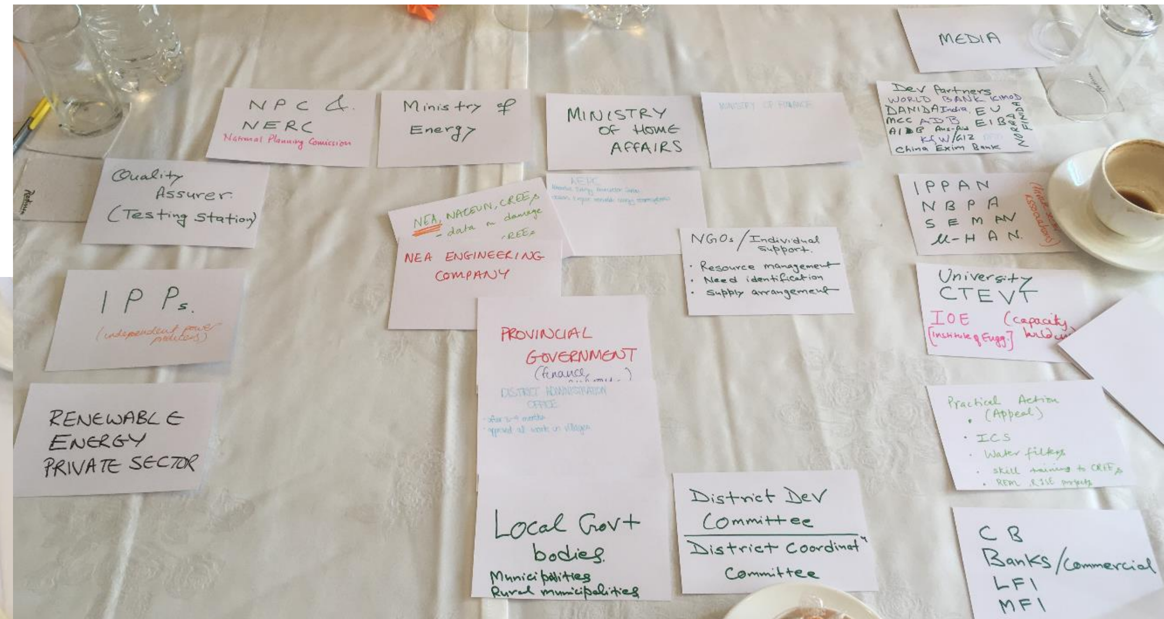
Causal loop framework backed up by stakeholders in interviews in Nepal

- "*If we actually followed the technical parameter, the financial parameter, institutional parameter, social parameter, then, you know, the project becomes in a way sustainable*."

Decentralisation of governance & energy system (Nepal versus UK)

- **Nepal**: actors involved in energy governance





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Decentralisation of governance & energy system (Nepal versus UK)

Nepal:

- Merge of ministers (reduced by half) - better coordination
- Municipalities could play a bigger role in rural areas - not managed by National Electricity Authority
- Gaps of policy process across the national (e.g. NEA, AEPC), provincial and local scales
- Local authorities of Kathmandu lack adequate skills, experience & resources for local energy systems innovation & development
- Local authorities need to collaborate with national government (e.g. Finance Ministry, Ministry of Local Affairs), private sector, NGO & communities

Decentralisation of governance & energy system (Nepal versus UK)

UK:

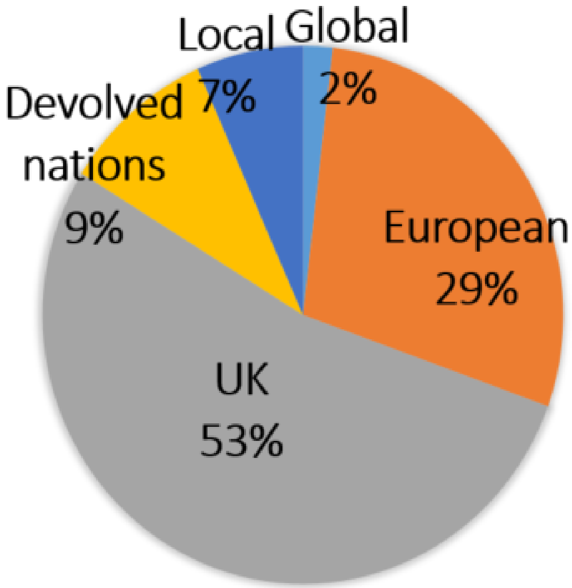
- Research on multi-level governance for deploying energy storage in the energy system transition
- Explore existing policy and institutional framework for deployment of distributed energy storage:
  - Actors from different sectors involved at each scale & the ways they interact
  - Why some local authorities (LAs) are energy leaders with more projects and investment happening than others
  - Gaps of policy process across the UK, devolved levels and local scales

Data and methods

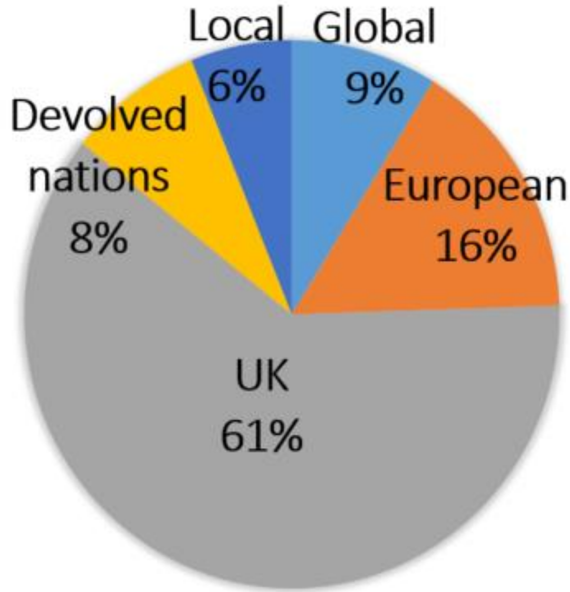
- Updated dataset of 'Local Engagement in UK Energy Systems' by Hawkey et al., University of Edinburgh
- Explored the funding source for 471 energy-related projects and investment across 333 Local Authorities (LAs) in the UK
- Case study of Birmingham as an Energy Leader, mapped its projects, funding source & partners to understand the network based on document analysis (& in progress of interviews for qualitative data) – Social Network Analysis
- Mapped the UK Research and Innovation (UKRI) funding on Energy Storage to different Local Enterprise Partnerships in West Midlands

Funding sources for energy projects in LAs

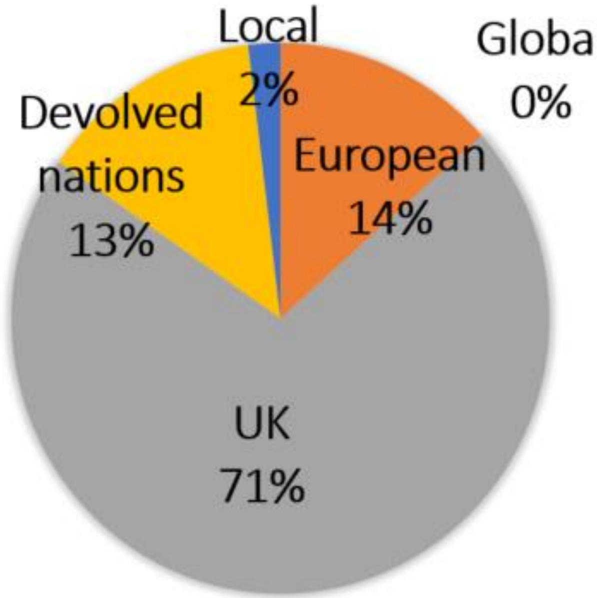
- Percentage is for the number of projects being funded, as the amount of some projects/investment is unavailable



'Energy Leaders': 38 LAs, average 7-8 projects/LA



'Running Hard': 89 LAs, average 1-2 projects/LA & energy strategy



'Starting Blocks': 206 LAs, 1 project or an energy strategy

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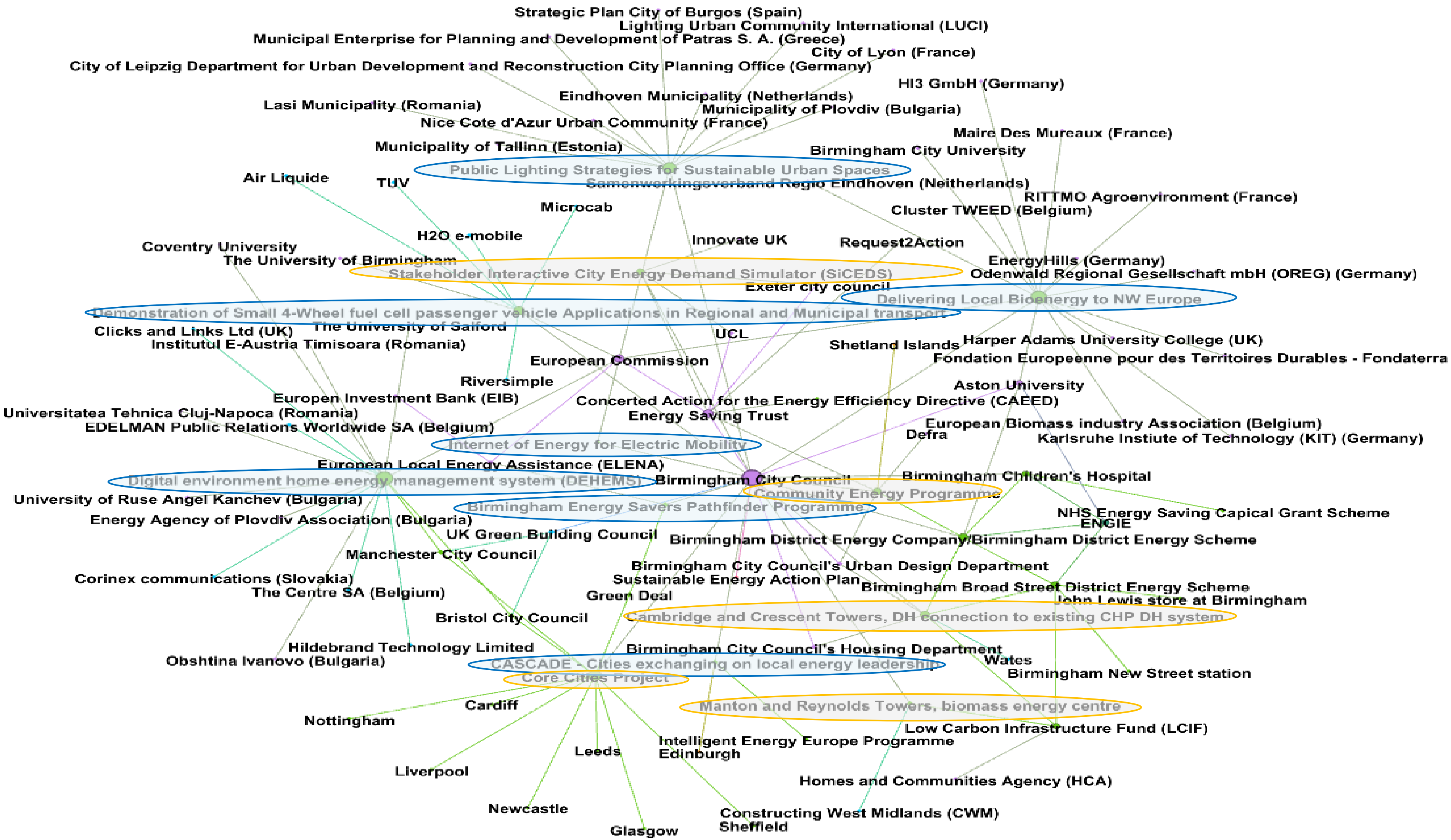
EPSRC Pioneering research and skills

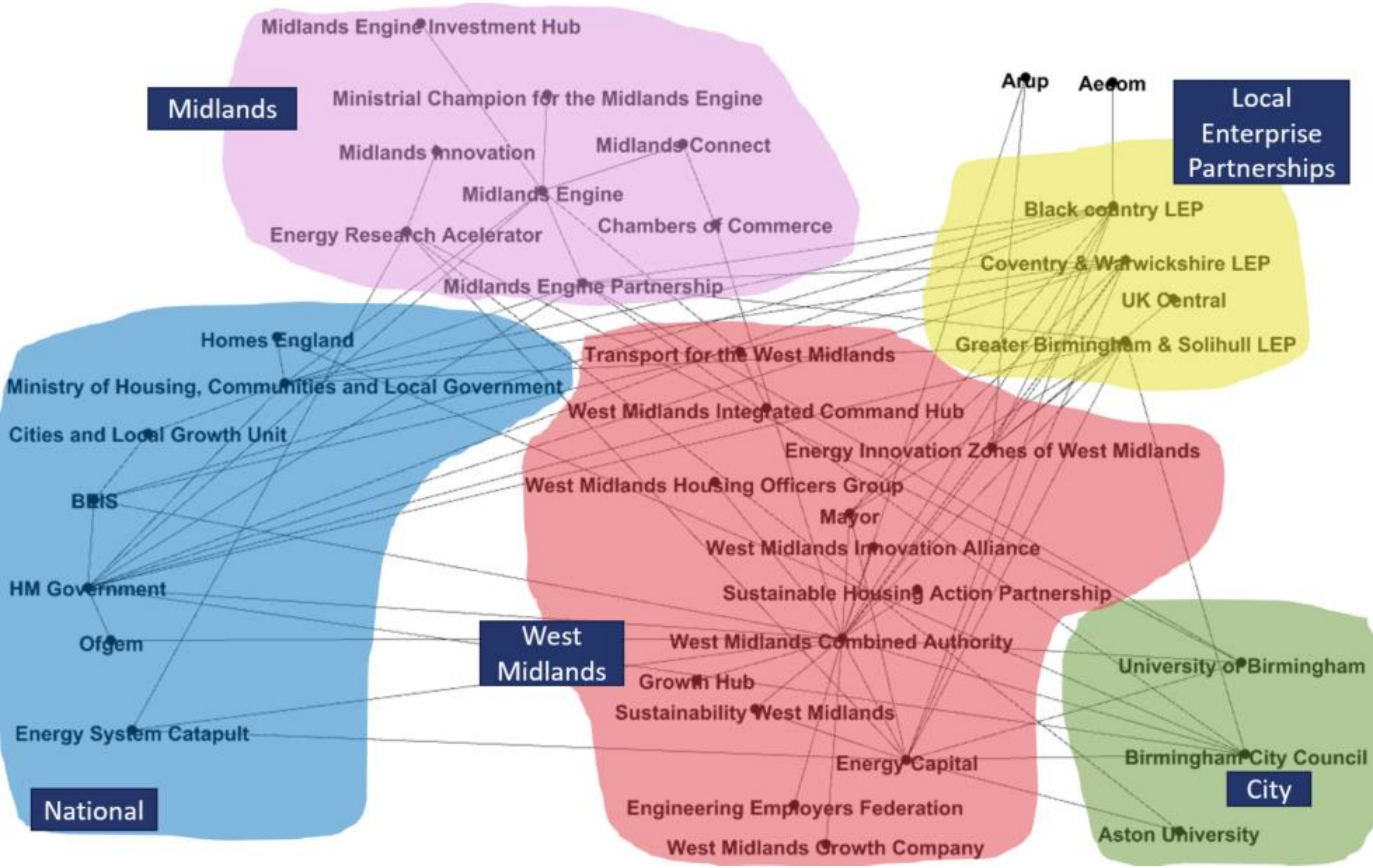
RESTLESS Realising Energy Storage Technologies in Low-carbon Energy Systems

Map funding source and project partners of energy-related projects - Birmingham 2002-12

- European funded projects circled in blue; UK funded ones circled in yellow; green dots are projects/investment, and purple dots are institutions



Map relevant institutions across scales - Birmingham



Map UKRI funding to West Midlands on Energy Storage 2005-19

Key points from the regional case study in the UK (governance aspect)

- Energy storage research projects are dispersed across actors
  - With multiple levels of governance/institutions
  - Lack of intermediaries/boundary organisations that can translate knowledge between research and policy
- There are signs that this has been addressed with e.g. Birmingham City Council Green Commission, Energy Capital etc.; but has been inconsistent
- ‘Local’ decision-makers are constrained in their ability to deploy energy storage; could have impact on development of smart local energy systems

Technology and innovation barriers for energy resilience

- Research project on Energy Storage Innovation with a case study on lithium-ion batteries (LIB)
- The interdependent nature of energy storage may make its innovation challenging
- Technological Innovation Systems
- Indicators framework (input, output and outcome indicators throughout innovation stages); compare UK with other countries
- Analyses innovation performance at different stages with indicators & historical analysis of the LIB innovation journey

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ENERGY SUPERSTORE
THE UK'S ENERGY STORAGE RESEARCH HUB

Lithium-ion battery development

- Pioneering work on implementing lithium as a potential cathode material for batteries was carried out by Prof John Goodenough in Oxford in 1970s

- Birth of the modern LIB: 1983-1987, Asahi Kasei corporation in Japan developed and patented a LIB using low-temperature carbon materials

- Driven by the demand of portable electronic devices (e.g. cell phones), Sony released the first commercial LIB with a soft-carbon anode in 1991

- Continued improvement of energy density and cost reduction

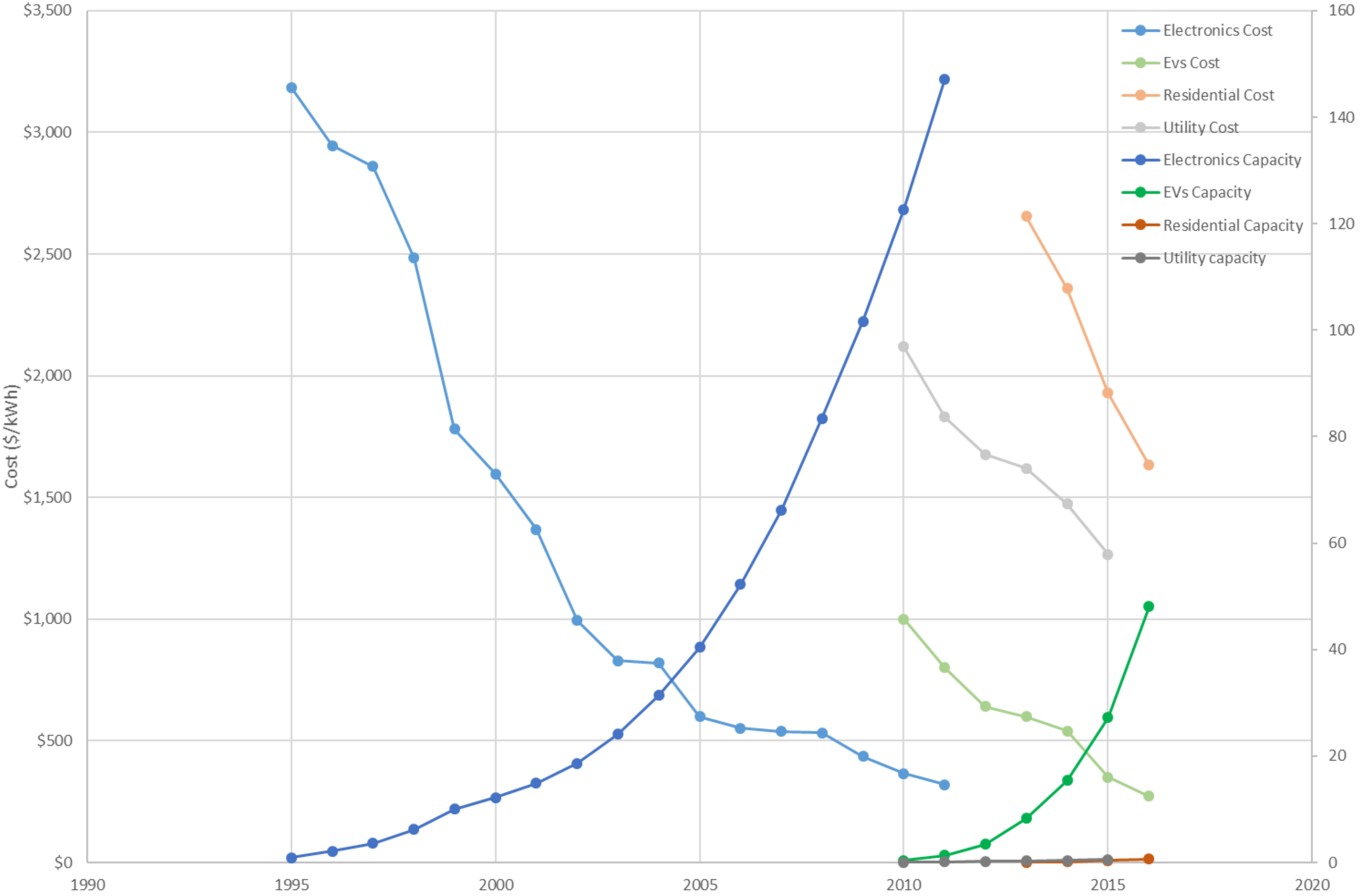
- Driven by later applications, e.g. EV's and stationary energy storage

An indicator framework to measure energy innovation process (Hu et al., 2018)

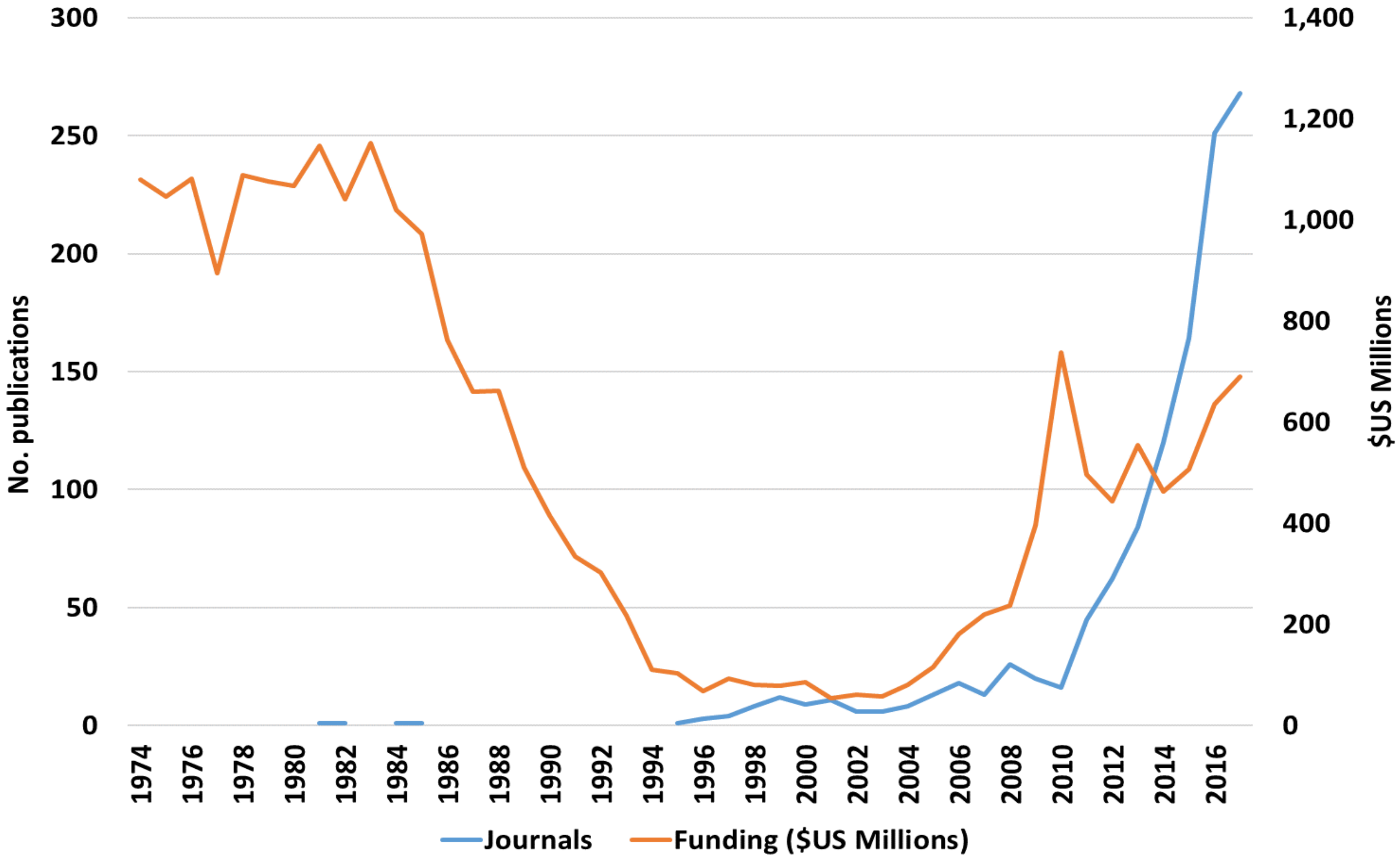
Energy technology innovation chain	Research	Development	Demonstration	Market formation	Diffusion
Input					
R&D expenditure ($)	←→	←→			
Demonstration expenditure ($)			←→		
Asset finance ($)				←→	←→
Subsidies ($)				←→	←→
R&D personnel (counts)	←→	←→	←→		
State labs ($)	←→	←→	←→		
Output					
Scientific publications (counts)	←→	←→	←→		
Patent applications (counts)	←→	←→	←→	←→	
Unit capacity (MW)			←→	←→	←→
Unit cost ($/MW)			←→	←→	←→
LCOE ($/MWh)				←→	←→
Manufacturing capacity (GW)				←→	←→
Installed capacity (GW)				←→	←→
Outcome					
Royalty and license fees ($)				←→	←→
Industrial added value ($)				←→	←→
Technology diffusion via trade (GW, $)				←→	←→
Job creations (counts)				←→	←→
Power generation (TWh)				←→	←→
CO_2 emissions reduction (tonnes)					←→

N.B. The double ended arrows map out the timeframes of indicators across the energy technology innovation chain.

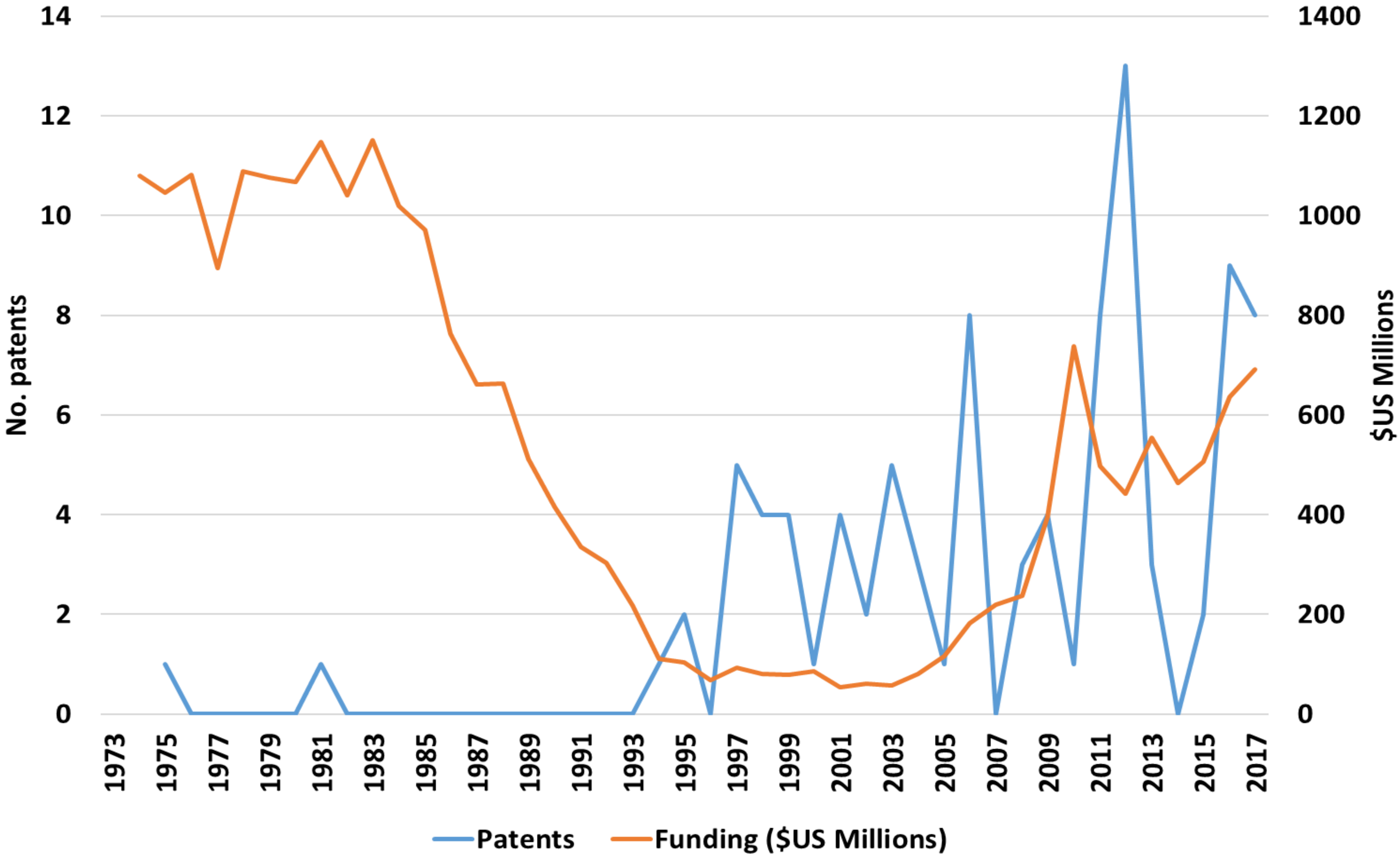
Cost ($/kWh) versus Installed Capacity (GWh) *(Schmidt et al., 2017)*



UK lithium-ion battery journal articles versus total energy funding 2000-2017



Patents filed on lithium-ion batteries in the UK versus total energy funding



Key points (technology and innovation aspect)

- Full value of LIB was not clear at the early stage of R&D
- Cost reduction of LIB is due to a variety of factors, e.g. the increases of installed capacity and R&D investments, economies of scale including supply chain improvements, and spill-over effects
- As an enabler to the low carbon transition, energy storage has positive externalities or spill-overs that the market will not value sufficiently to deploy at an efficient scale on the necessary timescale
- Economic jurisdictional arbitrage will transfer Intellectual Property and value across markets

Social aspects of energy resilience

- Research project on 'Energy Storage Prioritisation in Mexico – case study of Tlamacazapa' (*with Jonathan Radcliffe-PI, Rosie Day and Dan Murrant*)
- Collaborate with INEEL (Mexican National Institute of Electricity and Clean Energy)
- Aim: identify a list of project options with renewable and energy storage technologies that provide the greatest benefits in an area of study case in Mexico
- Understanding the relationships between energy use and wellbeing/capabilities, in terms of current use and how an improved energy situation could improve their wellbeing
- 4 focus groups were carried out in November 2018, arranged by gender and age

Multi-dimensional wellbeing

- Based on Nussbaum’s Central Capabilities
- A multi-dimensional way to understand wellbeing and development (current situation and aspirations)
- The dimensions we discussed included
  - Health
  - Security / safety
  - Earning a living
  - Education / culture / religion
  - Dignity and social respect
  - Relationships with others
  - Environment / other species
  - Recreation

Health and energy – current situation

- Cooking with firewood creates smoke, causes respiratory and eye problems, especially for women and children
- There is a lack of clean pumped water. Water from wells is dirty. Drinking and cooking water has to be bought
- Refrigeration is important for medicines, including diabetes medicine (commonly needed). Most households use ice flasks for personal medicines.
- The health centre has refrigeration but lacks medical appliances that need power

Security and energy – current situation

- No street lighting: individual households are meant to keep a light on to light the way but many do not (due to cost)
- People are afraid of animals in the dark: snakes, scorpions, dogs, also of falling
- Mostly younger women are afraid of being molested by other people in the dark
- People mostly do not go out after dark
- Collecting wood is difficult when it rains – danger of falling

Earning a living – current situation

- Most people make handicrafts by hand, needing hot water, using wood for heating up. Low incomes.
- Lack of machines which could produce more quantity and more consistent quality
- Lack of lighting at home restricts working hours
- Lack of training and employment opportunities for young people
- Do not grow produce due to lack of water for irrigation
- Some would like to start a small food business but need power for appliances

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Education / culture / religion – current situation

- School currently has no electricity connection: no lighting or computer use
- Young people use mobile phones for reading eBooks and for research, but signal is poor
- Restricted lighting at home affects ability to do homework
- Some children work collecting firewood to sell instead of attending school
- Churches have restricted lighting due to the cost
- Festivals need electricity for light, music, cooking

People's aspirations of how energy would enable their wellbeing improvement

- Discussions from the focus groups mostly highlighted their needs for lighting, use of appliances, clean cooking and clean water

- Diagrams are drawn in the next few slides to show how these needs link to their wellbeing, which could be enabled by providing more energy at a lower cost

- Their wellbeing/capabilities are coloured in green in the diagrams

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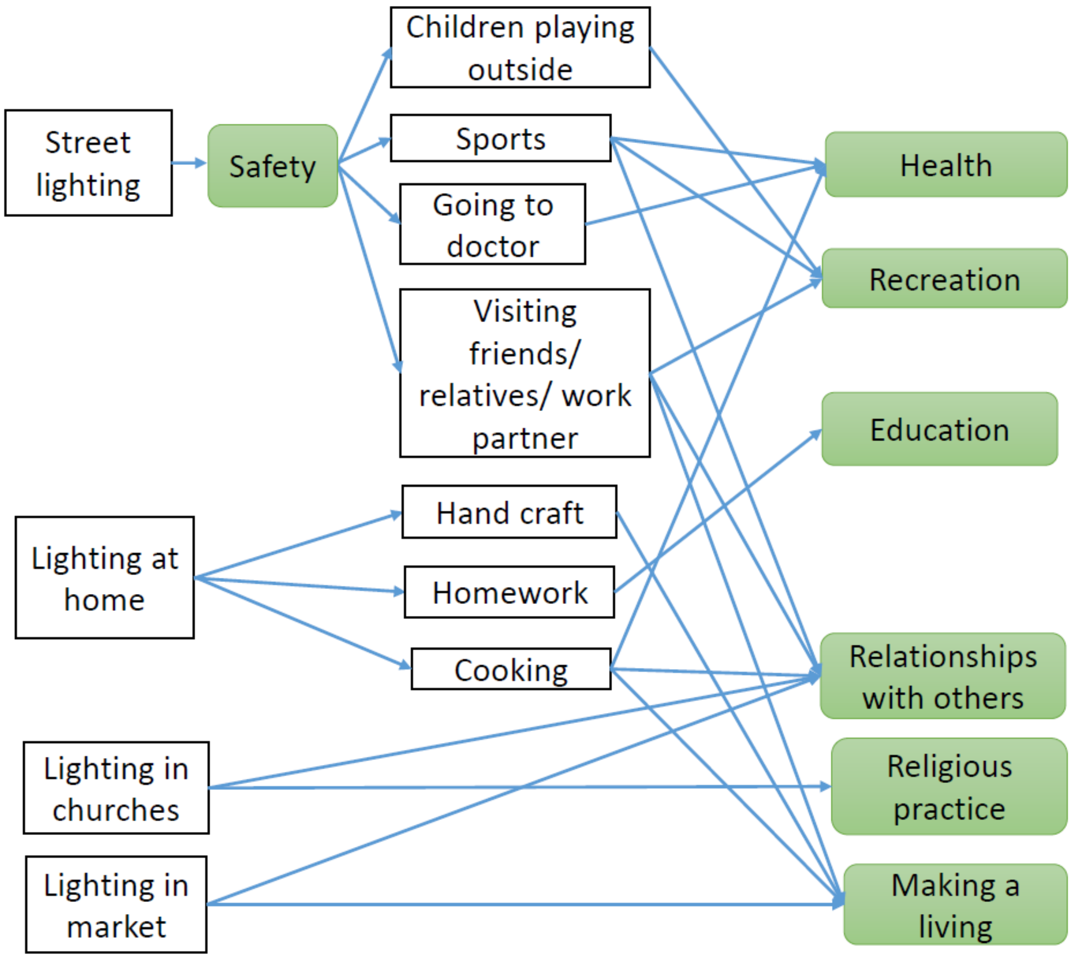
Aspirations for lighting service linking to wellbeing outcomes



- Street lighting would improve people's health, relationships, recreation and income, as they would be able to do activities outside in the evening and spend more time with friends and family
- More affordable lighting at home would help with homework, craft productivity, domestic work
- Cheaper and more lighting would play a significant role in advancing most of the development needs of the village

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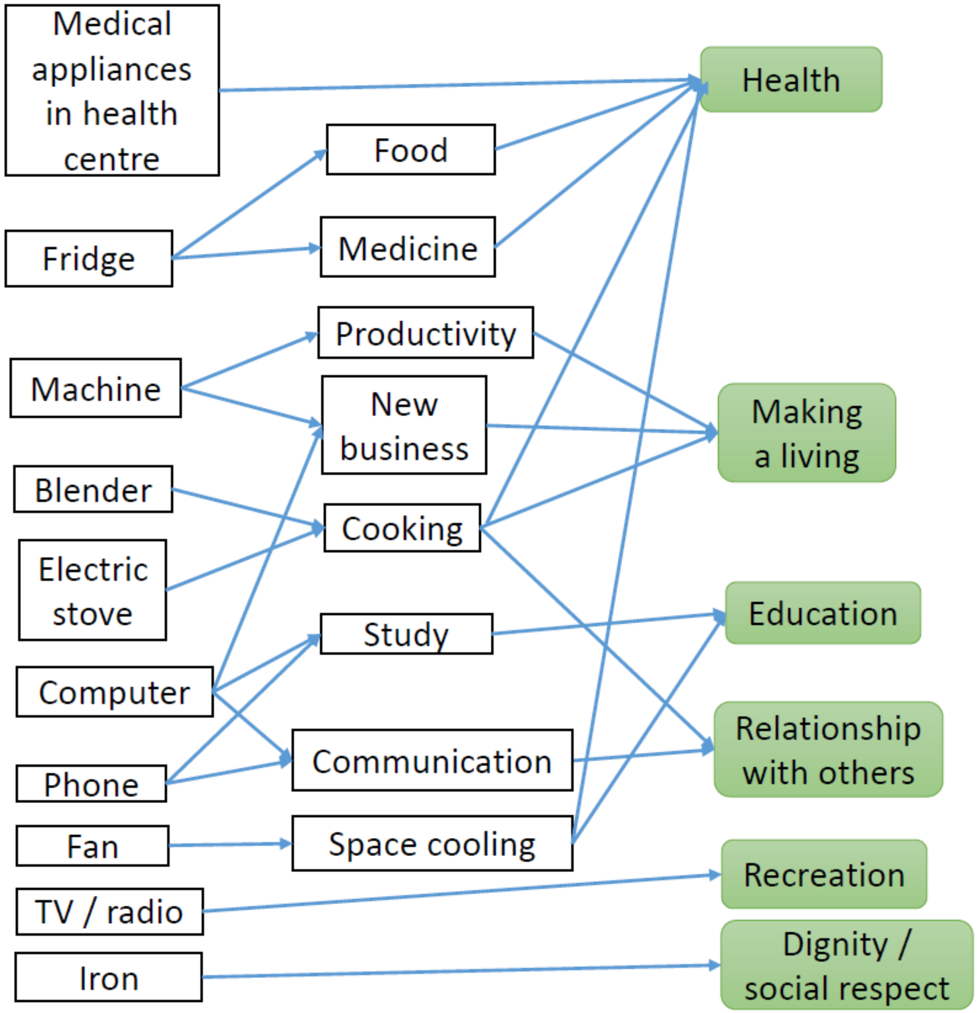
Aspirations for appliances linking to wellbeing outcomes



- The appliances people have/use at home are limited, due to costs and also outages
- Electric machines are highlighted as important for improving their productivity and ensuring the products are of the same size
- For education, electricity is needed for schools for the use of computers and internet
- Greater use of cooking appliances could support small food enterprises

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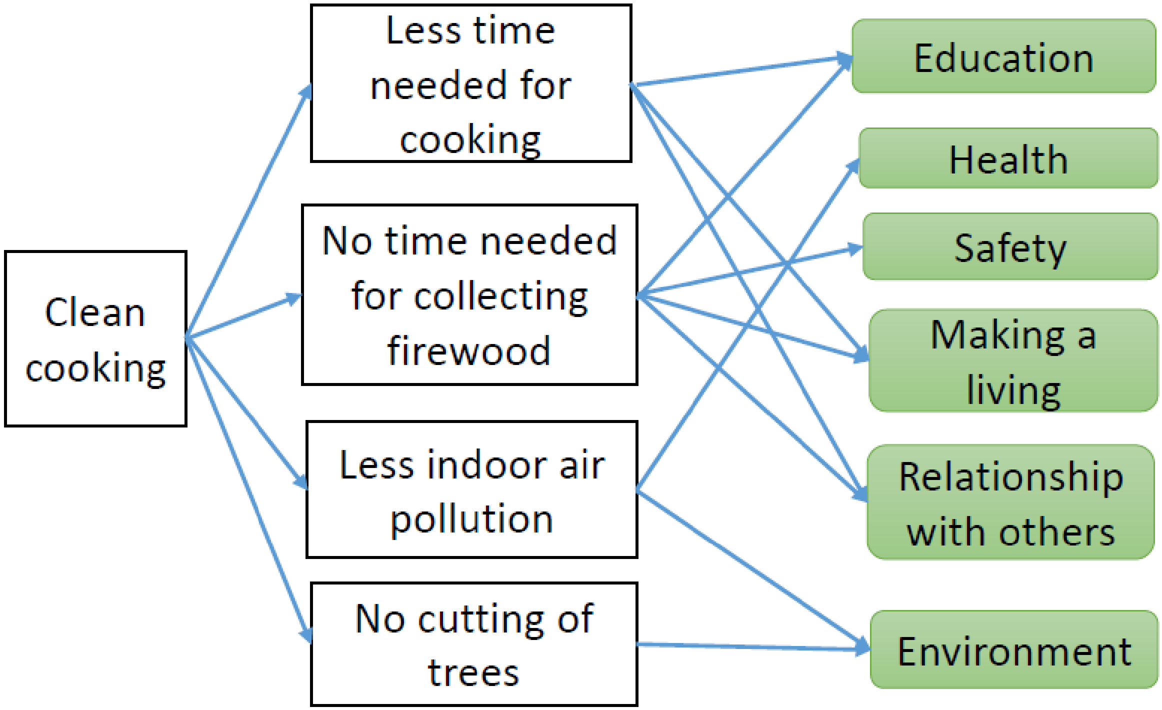
Aspirations for cleaner cooking fuel linking to wellbeing outcomes



- Health would be improved by cooking with cleaner fuel
- Women would have more time for doing other work, socialising and visiting relatives
- Children would also have improved health and for some, possibly better school attendance
- Safety risks of collecting firewood could be removed

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Providing energy and water for wellbeing

We can improve their wellbeing by for example:

- Providing electricity in the home: for lighting, cooking, appliances and machines etc., which would improve **health, safety, education, relationships, dignity** and **recreation**, help people **make a living**, and reduce **environmental** impact

- Providing electricity in the community: for street lighting, lighting in churches and market, appliances in health centre and schools, and creating a workshop/cyber/other local business, which would improve **safety, health, education, recreation, relationships, religious practice**, and help people **make a living**

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Key constraints on energy and water

- Cost
  - Electricity is a relatively large expense for low income households
  - Disconnections are common and a penalty has to be paid before reconnection is possible
  - Firewood is used rather than gas for cooking due to cost, although gas is preferred
  - Lighting is restricted due to cost
  - Appliances are expensive to buy and to run
  - Water bills are often not paid leading to water cutoffs for all
- Reliability and limited supplies
  - Power outages are quite regular and can last up to 24 hours
  - There is limited water supply in both dry and wet seasons

Revisit Tlamacazapa and reconfirm the community's priorities

Discussion at Tlamacazapa (revisit)

How would the community feel about the projects below being piloted, if there was an opportunity for the project to continue?

- Provide street lighting
- Assess how to improve water quality
- Install PV + storage in community buildings: churches, schools, health centres
- ‘Clean’ cooking, with electricity

-Consider integrated solutions of cooking, lighting, refrigeration, water and other needs of local community

-Replicate the case in other regions and countries, emphasizing energy for capabilities and wellbeing

Conclusions from the 3 case studies

- The three case studies in Nepal, UK and Mexico show how the different aspects (e.g. governance, social and technological innovation) influence energy resilience in the different context, which are all important

- Multi-level governance has particular influence on energy resilience in the UK and Nepal

- How energy resilience could improve capabilities and wellbeing is particularly shown in the Mexico case study

- How technological innovation systems affect the research, development, demonstration and deployment of energy technologies, and therefore energy resilience, is shown in the UK Energy Storage/LIB case study

Other on-going projects related to energy resilience

- Improving resilience and reducing emissions from diesel generation in **India** (social and technology aspects) [Joint UK-India Clean Energy Centre; Newton Fund]

- Investigating the transformative adaptation of **Kenya** infrastructure: An assessment of urban and rural connectivity (social and economic aspects) [Institute for Global Innovation]

- Developing Cryogenic Energy Storage at Refrigerated Warehouses as an Interactive Hub to Integrate Renewable Energy in Industrial Food Refrigeration and to Enhance PowerGrid Sustainability (technology aspect) [**EU** Horizon2020]

- Predicting the uptake of air conditioning in **UK** households to 2050 (social, technology and governance aspects) [UK Energy Research Centre funded]

Next steps

- ❑ Develop the energy resilience framework, compare it across developing and developed countries through case studies

- ❑ Further explore how energy resilience link to various capabilities and wellbeings in these countries

Discussion questions

- ❑ How the energy resilience picture differs in Australia considering the governance, society, technological innovation and economic aspects?

- ❑ What other aspects also influence energy resilience?

Thank you!

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