Global (best) together with (or against) local networks and practices? Liquid engineering and the uses programme

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Global (best) together with (or against) local networks and practices? Liquid Engineering and the USES Programme

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Abstract

There is potentially tension between world class research and global standards on the one hand and local contexts of engineering and development practice on the other. One aims at scientific status and entirely new knowledge, suggesting just one standard of quality. The other at building products and processes that might bring socio-economic development, often prizing pragmatism and bricolage. The UK funded programme 'Understanding Sustainable Energy Solutions in Developing Countries' (USES) was set up on the understanding that such tensions, if they exist, can be transcended. It was funded by two organisations, the UK Engineering and Physical Sciences Research Council (EPSRC) and the UK international development agency Department for International Development (DFID).

This paper analyses the USES research programme, looking at the processes of its establishment, partnership building, the research undertaken and its early impact. The paper shows that the USES programme goes beyond 'normal' pure vs applied, research vs policy, low tech vs high tech dualities. Instead it throws up a complex series of issues that require attention if research is to lead to long standing and sustainable economic and social development.

The paper suggests that the concept 'liquid engineering' might be a good way to conceptualise the ways in which the programme, without denying the tensions of dualistic realities, has moved towards a more fluid process to take account of its multiple and complex goals. The programme highlights that progress can be made towards Engineering and

Development being accepted as a legitimate area of engineering theory and practice.

Keywords: liquid engineering, global standards/local context, networks and bricolage

1 Introduction

There is a strong perception, backed up by significant evidence, of major disjuncture between the global peer and publication standards of excellent scientific and engineering research and the local practices of technology to improve social and economic development. The global excellence/local relevance divide has often been treated as a binary chasm between pure and applied, narrowly disciplinary versus fuzzy interdisciplinary (Robbins, et al., 2017a; Robbins et al., 2017b).

Recently, there have been signs that such divides are not universally applicable. In the UK, for example, there have been attempts to integrate the aims of scientific and engineering excellence on the one hand, and utility to resolve problems of international development on the other. Examples include jointly funded programmes between UK research councils (Economic and Social Research Council - ESRC, Medical Research Council - MRC, Natural Environment Research Council - NERC and EPSRC) and the UK government Department for International Development (DFID). One off initiatives have been followed by a large Global Challenges Research Fund with £1.5bn over five years 2016- 2021 with three main aims, that illustrate well the attempt both to focus on research and innovation and to emphasise problems of international development:

- to increase ‘Equitable Access to Sustainable Development’ by ‘creating new knowledge and drive innovation that helps to ensure that everyone across the globe has access to: secure and resilient food systems supported by sustainable marine resources and agriculture; sustainable health and well-being; and, inclusive and equitable quality education; clean air, water and sanitation; and affordable, reliable, sustainable energy’.
- to build ‘sustainable economies and societies’ by encouraging research and innovation that in the longer-term, builds: Sustainable livelihoods supported by strong foundations for inclusive economic growth and innovation; Resilience and action on short-term environmental shocks and long-term environmental change; Sustainable cities and communities; and, Sustainable production and consumption of materials and other resources
- To engage with ‘Human Rights, Good Governance and Social Justice’ by supporting research and innovation that enables us to: Understand and respond effectively to forced displacement and multiple refugee crises; Reduce conflict and promote peace, justice and humanitarian action; and, Reduce poverty and inequality, including gender inequalities.

‘The challenges facing societies and individuals across the globe are often complex, protracted and multi-faceted and cut across the three areas above. The Global Challenges Research Fund is well placed to address these complex issues given the size of the fund, its challenge-led approach and broad remit.’ (UKRI, 2019)

Our research question concerns the extent to which global science and engineering excellence can be integrated with local engineering practices for social and economic development. This paper aims to use the concept 'liquid engineering' (c.f. Bauman, 2000) as a way to conceptualise the ways in which these research programmes, without denying the tensions of dualistic realities, have moved towards a more fluid research process to take account of its multiple and complex goals.

We use the term 'liquid' as a way to describe the increasingly fluid, flexible, 'finding a way through' approach, without getting too much into the detail of how homogeneous liquid is anyway. In other words, we do not consider liquid engineering to be akin to water versus honey as Rattansi (2017) puts it, but as a way to think about flows and mixing of knowledge between pure and applied, science and innovation, narrowly disciplinary versus inter- and transdisciplinary.

In this article we narrow our empirical focus towards engineering research and its relevance to international development. In a previous article (Robbins, et al., 2017a) we analysed engineering and development as narrated in REF impact case studies. Here, we turn to analysis of research which has been jointly funded by the Engineering and Physical Sciences Research Council (EPSRC) and DIFD. Although there are now a range of GCRF programmes initiated by the EPSRC, these have not yet produced research results. Our empirical data is drawn from a previous project called 'Understanding Sustainable Energy Solutions in Developing Countries (USES)'.

We begin with a description of the USES programme and why it is innovative, including in its melding of 'best' with 'relevant' and global' with 'local' via 'liquid engineering'. We then use two cases from the USES programme, which allows us to analyse a series of themes important for transcending tensions between local and global standards and practices. Fluidity and hybridity can be analysed concretely from study of the USES programme, for example by attention to the relationships between: global academic focus on publication and new knowledge and local academic pressures towards capacity building and relevance to local socio-economic processes; barriers to translation and commercialisation in less dense innovation ecosystems; the gaps between visions of engineers as designers and the existing practices of users in developing countries; and analysis of energy technologies as socially embedded less in different fuels, more in emergent and potentially new socio-economic regimes.

2 The USES Programme

2.1 Background

In 2013, the UK Engineering and Physical Sciences Research Council (EPSRC) and the UK government development assistance agency (DFID) set up the programme 'Understanding Sustainable Energy Solutions in Developing Countries (USES)'. The UK government Department of Energy and Climate Change (DECC) was also involved. The programme was intended to:

‘increase clean energy access, resilience and wealth creation in developing countries (particularly for the urban and rural poor), through high quality research that improves the understanding and evidence-base of opportunities and challenges associated with clean energy for development. The research is based on five themes: energy systems and decentralised use; solar; bioenergy; urban and transport; and energy efficiency. … The overall goal of the programme is that it will lead to:

- Improved understanding of clean energy options and opportunities for developing countries
- Improved understanding of the social, market and political economy aspects of scaling sustainable energy access for poor people
- Strengthened developing country research capacity on clean energy
- Improved access to practical and policy-relevant knowledge on the challenges and opportunities for sustainable energy solutions in developing countries.’

(LCEDN, 2019)

The Engineering and Development research team at the Open University decided to study this programme as an example of a major initiative to bring together a council that funds world class research and an agency that aims to bring social and economic development to low and middle income countries. Concerns have been raised about UK capabilities in the engineering and development field. Traditionally, the UK has been strong in this field, with its historical colonial and then post-colonial activities through into the 1980s. But funding was cut after that until the new millennium, when it began to increase, with a threefold increase in infrastructure research. However, concerns remain about capabilities and incentives for research in this area (UKCDS/RAE, 2014).

USES has 13 projects. MECON energy efficiency policy implementation (University College London - UCL); STEPS sustainable thermal energy service partnerships (UCL); SAMSET SSA sustainable energy transitions (UCL); Agricen agriculture and clean energy in Africa (UCL); BARRIERS to cookstoves (University of Nottingham); Energy and low income housing (Warwick University); Energy from Rice Straw (Manchester); Energy literacy for decentralised governance (Loughborough University); SONG solar nano grids and community energy (Loughborough University); Green growth diagnostics for Africa (IDS); RE4Food energy efficient food processing (Newcastle University); ESCO Box smart monitoring (De Montfort University); The next generation of low-cost energy appliances to benefit bottom of pyramid (Open University).

The projects were chosen to cover all five themes. Two themes were fuel type based around ‘new fuels’, solar and bioenergy. But the major focus was on engaging with new energy regimes and trajectories to address poverty and low carbon challenges. Given the world class research orientation of the programmes, it was not possible to emphasise clear novel commercial and ‘research into use’ pathways but efforts were made to build trajectories towards use in ways that reduce poverty, enhance resilience and increase access to energy in developing country communities.

Our data consists of a significant set of grey materials from the programme, together with semi-structured interviews with 3 DFID and USES programme managers which are mostly presented in the next section 2.2, and 4 semi-structured interviews with project Principal Investigators (PIs) and Co-Investigators (Co-Is), data mostly presented in sections 3 and 4. We adopted a case study approach to this study, guided by Yin (1994), who maintained that research case studies can be descriptive, exploratory and/or explanatory, and in our case we endeavoured that they be all three.

The interviews were guided by a set of questions that covered, for programme managers, reasons and drivers for setting up the Understanding Sustainable Energy Solutions in Developing Countries (USES) programme, management of the bidding process, and the relationship between best-with-best and policy relevant approaches to development engineering. When we spoke to PI and Co-Is we asked a set of questions that explored the balance between local context and global standards in their project, the evolution of the project and relationships with partners, and future opportunities and challenges. We transcribed the interviews using our conceptual framework that has been emerging from our ongoing work, which emphasises ideas around mixing, flow and hybridity. We wanted to investigate ways in which practices might go beyond a global-local dichotomy of best-with-best vs appropriate and policy relevant to create new hybrid models of development engineering, through this process our concept of 'liquid engineering' became increasingly clarified.

2.2 The fluid and hybrid: liquid engineering

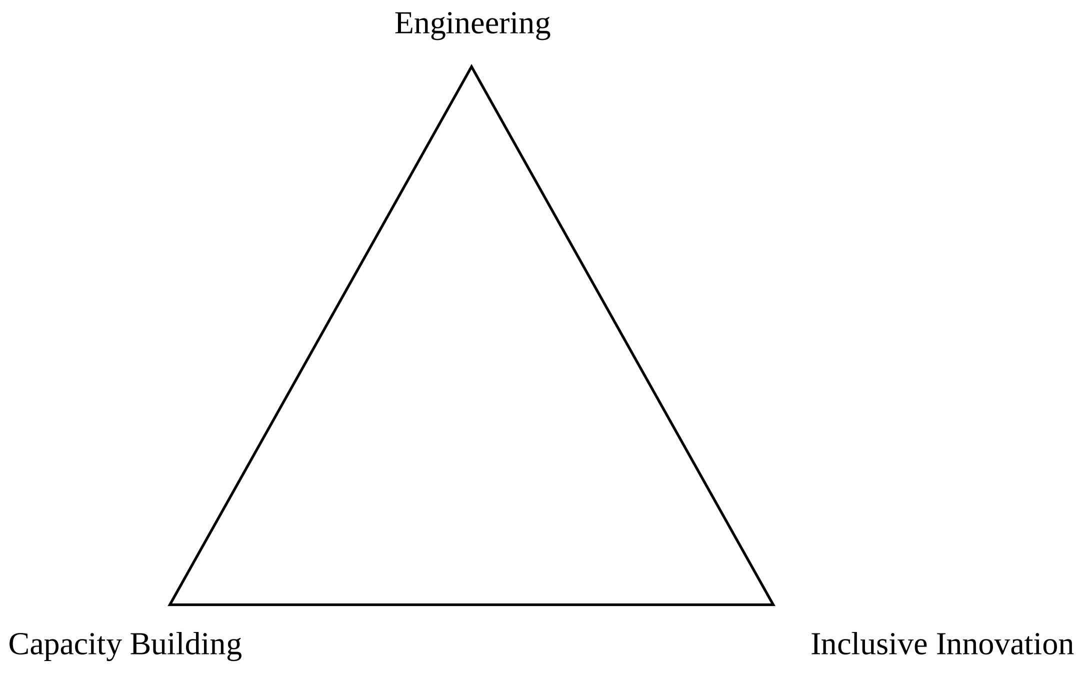
We see USES as an example of a programme that represents 'liquid engineering', which is a set of socio-technical practices. In contrast to a view that would see the global (e.g. best-with-best engineering) and the local (e.g. locally rooted 'appropriate' engineering) as a solid, binary distinction perhaps sparking tensions between the two, globalization processes have increasingly come to be viewed through the lens of a metaphor emphasising their liquidity or flow (Bauman, 2000). Rey and Ritzer's (2010, p 216) definition of globalization is that it 'is a transplanetary *process* involving increasing *liquidity* and the growing multidirectional *flows* of people, objects, places and information as well as *structures* they encounter and create that are *barriers* to, or *expedite*, those flows.' Flows, channelled through networks, synthesise, mix and create new combinations or hybridities (Pieterse, 2009).

Our own research on engineering for development (Robbins, 2007; Robbins et al 2017a and 2017b) has found a set of liquid social practices, which include reflexivity (or making iterative changes in response to conditions), bricolage (mixing of different technological forms, knowledge and practices to create something new), and networks (channels for flows of knowledge and learning), together we call this 'liquid engineering'.

Liquid engineering projects tend to relate to communities as partners, seeing them as having a multiplicity of actors often working towards a common goal, which can evolve over time together with the project team. Their view of development is based on sustainable livelihoods (DFID, 1999), which is a more comprehensive and holistic approach to poverty and its alleviation than those based on a narrower set of indicators, such as the economy or technology transfer. As such, engineering and technology are enmeshed and part of communities, and evolve in a reflexive and iterative process in local contexts, rather than being seen as being transferred in from the outside (Robbins, 2007). Spatially, global and local tend not to be seen as seen as separate phenomena, but are 'glocal' (Robertson, 2012) and mutually enacted in both settings. Knowledge tends to be interdisciplinary and transdisciplinary allowing bricolage (Cleaver, 2012) to produce new, often simplified, technological or practice syntheses adapted to local contexts. Development of ideas and learning is often mutually constructed involving partners and communities. Similar to the way that water flows in streams and then pools, the mode of working draws on networks of NGOs, business, and academics that form communities of practice, which in this case can be defined as groups that share a particular approach to an engineering problem or solution.

How might liquid engineering practices emerge? We see it as unfolding through a tripartite relationship between engineering, capacity building and inclusive innovation, as outlined in the figure below.

Figure 1. Liquid Engineering Innovation Triangle



The triangle above (see Figure 1) shows core components in engineering and development innovation; engineering, capacity building and inclusive innovation. We suggest that the work of integrating global best standards with good social and economic impact involves a three-way dynamic between engineering, capacity building and inclusive innovation. In engineering there is a fluid tension between the focus on world class science and social and economic impact; capacity building (Mormina, 2018), is a key element of network building and avoidance of network breakdown; and inclusive innovation (Chataway, et al., 2014) aims to address the needs of those, such as the poor, who were traditionally left out of mainstream innovation. All are evidenced in how the USES programme was shaped and the projects discussed in the following sections.

2.3 USES programme shaping

USES sprang from this desire to build upon the success and framework of three earlier funded DFID and EPSRC projects. A DFID funded project called Policy Innovation Systems for Clean Energy (PISCES) was concerned with supporting policy development to enable governments to deliver sustainable bioenergy to the poor (PISCES, 2019) and was led by the African Centre for Technology Studies (ACTS) with lead partners University of Edinburgh, Practical Action (Kenya, UK and Sri Lanka), M.S. Swaminathan Research Foundation (MSSRF, India), and the University of Dar es Salaam (Tanzania). A second project, led by Professor AbuBakr Bahaj of Southampton University (Replication of rural decentralization off-grid electricity generation through technology and business innovation), focused on mini-grid energy generation in a Kenyan village (Kitonyani) reaching 40 business and 3,000 inhabitants. The third DIFD-EPSRC funded project (Towards scaling up of electricity access) led by Professor Subhes Bhattacharyya and Debajit Palti of TERI in India, was South Asia based.

As a result of PISCES and the joint projects with EPSRC, DFID was led to reflect on whether more could be done on impact, which for them was around whether programmes could enhance resilience of the poor to financial constraints and shocks as well as their access to sustainable energy. The government's agenda of spending more on research and development of clean and renewable energy also played an influencing role for USES and other similar programmes.

For USES, five areas were targeted: bioenergy, solar, decentralised generation, urban and transport, and energy efficiency – a large number of the proposals submitted were in the bioenergy space and this prompted DFID to create a bioenergy programme separate from DFID. In total, 383 proposals were submitted for USES. Of these, representatives from around 60 projects were invited to Nairobi to pitch ideas in a sandpit exercise with the intention of connecting potential project partners.

USES was one of the first significant programmes that involved a collaboration between DFID and EPSRC. While the Engineering and Physical Science Research Council brought a focus on engineering excellence to the partnership, they had less experience in the Global South and promoting impact that was targeted at poverty reduction. The Department for International Development on the other hand had worked with other research councils, such as the Natural Environment Research Council (NERC) and the Medical Research Council (MRC). When assessing potential USES projects, evaluators used criteria that combined excellence in engineering and impact in the Global South. The projects were considered by two to three peer reviewers and were ranked based on merged score arising from those criteria; both criteria had to be met by each project. The selection committee was comprised of academics only, but some of these academics had some industry and NGO experience – they were both academics and practitioners. The initial call generated around 350 expressions of interest, and of these around 60 to 70 proposals were selected to send participants to the sandpit workshop in Nairobi, the final number of funded projects was 13. Those attending the workshop were based in UK and international universities and there was also a strong contingent of entrepreneurs from the South, especially Kenya. The mix was found to be very helpful to developing the partnerships, as most participants had never had strong international, and in the case of the UK participants, African links in the programme area. The programme being based as it was in the UK, like other interventions throughout history, had the potential danger that it could end up being about foreigners parachuting in to do and exploit African research. However, the way it was set up facilitated mutual learning by both UK partners who had not worked in Africa, and by those in Africa who had not previously had UK links. In the vast majority of cases, the projects managed to co-construct research capacity in both regions, as evidenced in the networks that were formed and the outputs produced.

In informing the USES programme and criteria for USES project selection, programme leaders emphasised the balance sought between best-with-best and emerging country impact. This came about through discussions between the funders that took place in meetings where the programme was designed. The main academic funding body, Research Councils United Kingdom (RCUK), emphasised that the projects should be excellent from the standpoint of research. That research had to have the best science and also be interdisciplinary, which included engineering, technology and social science. It also had to be cross-sectoral, involving a diverse range of partners, including academics, businesspeople and/or those from nongovernmental organisations. As such the projects had to meet a diverse set of requirements, including scientific excellence, poverty reduction, which was the key focus of the Department for International Development, transdisciplinary collaboration, and socioeconomic impact, in particular because DFID was the programme's major funder.

This adds more to the notion that the USES programme came about, in part, through a growing awareness among funding agencies and the academic community, and through discussions between them, that engineering (excellence) and development (impact) could be better linked through ideas of inclusiveness and interdisciplinary collaboration, including the social sciences. DFID representatives we interviewed said that they expected the USES projects to have excellent science, led by academics and entrepreneurs. They also sought a mix within the project teams that included a strong social science component, which included an understanding of how technologies were developed and used in communities. The best of the projects performed well in all these aspects.

We also asked them to reflect and elaborate on the potential tension between best of best and impact, and one of the DFID interviewees, emphasising the importance of impact, said:

> *"I think we didn't see the tension in the same way, I think there was an assumption*

> *that there is a tension but actually DFID shouldn't be funding any research that isn't perhaps top quality research anyway, so it almost feels a little insulting sometimes when we talk to others that assume that we're trying not to do that, so yes, so there was tension but it was probably from that misunderstanding, I mean the difference is it has to be best science but actually if it's best science but without an obvious use or obvious impact on development then it's, it's fine but it's not for us to support".*
> (Interview, DFID consultant)

On matching technologies and concepts with 'real world' emerging country context, the interviewee went on to state that there was an implicit view in some projects that the UK partners were to focus on solution-oriented technology, and those on the ground were the experts on the local context, the users and understood implementation challenges and opportunities (cf. Wilson and Johnson, 2007). The interviewee felt that the more successful projects discussed, recognised and used this to bring about a more positive outcome.

There has been a sense within the development engineering community that academic funders have tended to focus on the best engineering with less impact in addressing inclusive innovation concerns, while government and NGOs have emphasised excellent impact in addressing poverty reduction with less strong academic research. The interviews indicate that informants were aware of this, and to a certain extent it shaped the evolution of the programme. As a result of collaborative work and discussions between all the actors involved, the USES programme moved toward an approach that combined elements of both modes of engineering and development through ideas of inclusiveness and interdisciplinary collaboration, including the social sciences, and capacity building towards that end.

We now turn to a discussion of two case studies, which we selected to examine in detail from the 13 USES projects. They were chosen because they allow analysis of a range of the themes we set out earlier to illustrate the global/local issues, which include the importance of social embeddedness, the fluidity of technology transfer and its trajectory of development.

3 Evolution from a technology transfer to a two-locality project Global and Local - Solar Nano

The first case began as a South-South technology-led and technology transfer project. The idea was to take solar home system technology from Bangladesh, where it is very well established, and transfer or translate it to the Kenyan context. However, in the process of development of the project it transformed into meeting the very different needs of two localities.

3.1 Background

The Solar Nano-grid project is a partnership between Loughborough University, UIU (Bangladesh) and INTASAVE (Kenya). The original idea for the project came from the partners at UIU Bangladesh – the top university in Bangladesh for work on solar energy. They also brought in the solar energy branch of Unison Corp (Bangladesh). According to our project interviewee, Bangladesh is probably the most successful country in terms of rolling out solar home systems with around 3.5 million solar-powered homes in rural Bangladesh, which greatly exceeds the number present in any other country in the Global South.

3.2 The social embeddedness of the project

The initial idea was rather technical. Bangladesh emphasises solar energy home systems, but many of these are very basic and do not provide much more than electric lights. The basic proposal in the sandpit meeting in Nairobi was *'hey, let's develop some small-scale solar and look at how that can provide an answer for irrigation or other use whatever it might be'*. In sandpit discussions the Loughborough partner *said 'look, well this is interesting but what about looking at how the communities interact with this technology, what types of communities you're going to work in, how are you going to consult with them'.* Basically, the project was framed around *'those kind of issues to do with interactions with community members, the internal dynamics of communities, but also the broader policy context using a one-off pilot to research how are you actually going to ensure that this is rolled out, that it's going to have a longer-term future and not just be a pilot'* (Interview, Loughborough USES partner). This sandpit process reflects liquid characteristics of the mixing of researcher and community agent ideas, guided by capacity building and inclusivity, to bring about sustainable interventions that were locally relevant and embedded.

3.3 Transferability is fluid

A primary aim and challenge of the project was to transfer the technology from the Bangladeshi context to the Kenyan context. In this way, a major objective of the project was to 'test' the transferability of the technology. Kenya was an obvious choice as there has been a major roll-out of solar home systems. INTASAVE Kenya played a leading role in these efforts, although their Kenyan office had just recently opened. But the Kenyan socio-economic context was very different. Here, houses were spaced further apart and the population density was lower than in Bangladesh. As a result, a system based on wiring as had been used in Bangladesh was seen as inappropriate to the local context in Kenya. It meant that the team had to adapt the system to create a grid based on portable batteries. The UK branch of INTASAVE had a close link with Oxford University, and INTASAVE UK funded a doctoral student at the Oxford Engineering Department to develop the technology around the battery system. This then expanded the network by creating a new link with the Centre for Engineering that went beyond the original consortium.

Both the student and her supervisor worked closely with the project and INTASAVE to develop the technical side of the system. The project partner from Loughborough describes how the network and project has continued to expand in a fluid process that incorporates and reflexively engages with communities and local need.

> '*we've actually involved a project at the University of Nottingham with, an expert in community consultation from that group and she's used us as one of her projects, so we've kind of brought in her expertise as well. It's been a very kind of open, fluid type of project. That's fundamentally how that's worked. So, in the Kenyan context we've*

got these portable batteries, in both communities. The idea is that the batteries go into the households for basic lighting, but are charged through a central array and at that central array we are providing some business services like incubators for eggs and various other activities depending on what the community want to develop. The particular types of activities that we've funded have come about through a very intense consultation process with the communities.' (Interview, Loughborough USES Partner)

The flowing nature of the development of the partner network alongside local embeddedness of solutions has also been reflected in the evolution of the project aims.

3.4 Fluidity of project trajectory: bringing together project partners into agreement on project aims

The project also allows better understanding of resolving tensions in the processes in order to build capacity that brings better technical solutions for inclusive social need. This involves mutual learning between the project partners and communities.

> *"There's tension between developing a really good new solution and being able to talk to the communities about 'well look, this is a research project and therefore bear with us, learn with us as we go through it'. On the one hand it is a research project but they're having to pay for the service because that is the business model. There have been some really interesting debates around 'is it a research project, is it a service that is a commercial service that's been offered to the community'. That is a lesson we have to learn when moving from a standalone pilot study that might eventually be sold to a commercial concern versus a situation where a commercial concern has been involved in the design of the process right from the start. That is a much better way of going about it but it raises its own problems and issues."* (Interview, Loughborough USES Partner)

Similar to a watercourse that is flowing through a channel and suddenly reaches a barrier, in liquid engineering there are points where tensions will arise and decisions need to be taken, and where there may not be an obvious way forward. This is a moment at which the community and partners normally work together to find a way forward that is optimal for an inclusive local solution. The process of establishing the forward channel of the project trajectory provides an opportunity for learning, and therefore capacity building, for both the project team and the community.

3.5 Summary: Context matters and technologies are very community/country specific.

The process of finding an inclusive local solution involves allowing the ideas about the technology to grow and evolve in a new social context, as a technology that works in Bangladesh will not necessary work in Kenya without modifications based on community context:

> *"The original intention was to do wide solutions in all communities, so our Bangladeshi colleague's original proposal was 'let's replicate what we're doing in Bangladesh, in Kenya, see if it works'. What we ended up with though is an interpretation of the nano-grid that is much more about the community than it is about the technology, so we've obviously ended up with solutions that are nothing like his original model [in the Kenyan context], and that was an interesting discussion."*
> (Interview, Loughborough USES Partner)

In elaborating on some of the tensions in bringing together project partners into agreement with project aims a key challenge is to gain a deeper understanding of community dynamics as an ongoing learning process that helps to find appropriate technological solutions which suit the social context. In this context South-South and North-South co-production was crucial. We explore this further in the case of a project that specifically targets improving rural livelihoods.

4 Energy efficient rural food processing – improving rural livelihoods in three localities

4.1 Background

The concept for the RE4FOOD project originated through collaborative work between an academic at Newcastle University and a researcher who had a joint position working with the academic and a group at The University of Kassel in Germany. All were working on different aspects of agricultural engineering, which included food processing and food quality, the food sector and its use of energy, and renewable energy.   They had been working on such ideas prior to the EPSRC-DFID USES call, with the group at the University of Kassel having quite a bit of experience working on projects in Sub-Saharan Africa. Although the sandpit event in Kenya was instrumental in bringing the relevant partners on-board, the academic already had the project mapped out. Partnering with Newcastle University on the project are Njala University (Sierra Leone), JKUAT (Kenya), KNUST (Ghana), Stellenbosch University (South Africa), Practical Action (UK) and Environmental Foundation for Africa (Sierra Leone). The case allows good analysis of excellent (global) engineering meeting important (local) needs.

The project's concept and motivations were driven by the 'scandalous' loss of food throughout the supply chain, food that does not leave the farm, and especially post-harvest loss, which occurs between harvest and the point of human consumption. Essentially the team was driven to find ways to preserve food sustainably. The partners were concerned with the socioeconomic impact of jobs, especially for young people, in rural communities, due to people being pushed towards urban areas in search of employment and enhanced prospects. They felt that a basic food processing technology could easily address post-harvest loss, by up to 60-70%. The use of renewable energy sources provided an incentive to add greater value to food products, and so become a virtuous circle, whereby food was increasingly available, additional value and therefore jobs were being created, and enhanced sustainable livelihoods were being created for people in rural areas.

The project involved significant interdisciplinary expertise, as is normal in such programmes. There was a particularly wide range, which covered food technologists, especially those with expertise in food processing, and mechanical, chemical and manufacturing engineers. The team also included people from policy and business, as well as economists and those who worked in market development, and community facilitators who were often based in nongovernmental organisations (NGOs).

4.2 Social embeddedness

A focus on the importance of local context, as guided by the technical and social aims of the project, drove the choice of partners and countries. The team decided it needed three regions, with crop types that would have the greatest impact in the particular country where the intervention took place. They then looked at the renewable energy and technology that would be used to address the particular context.

They focussed on three countries: Sierra Leone, Ghana and Kenya, and developed links with academics at Njala University in Sierra Leone, the Kwame Nkrumah University of Science and Technology (KNUST) in Ghana, and Jomo Kenyatta University of Agriculture and Technology (JKUAT) in Kenya. They also partnered with Stellenbosch University in South Africa as they had experience of working in Sub-Saharan Africa on utilization of biomass, and as such their involvement on the ground in the local context would strengthen the project. Another group involved in the project was Kassel University in Germany, as it had particular expertise in renewable energy. It was decided that the input of NGOs would be essential, and one of the groups approached to join the project was the Environmental Foundation for Africa, which had strong links with Njala University in Sierra Leone. Another was Practical Action, and the reflexive way it worked between the project and community forms a good example of liquid engineering in action:

> *'Practical Action were already on the ground doing fantastic work in terms of engaging with the community and allowing us to feed input into the project community and feed that back towards the community, so they've been indispensable within this project*' (Interview, Newcastle USES partner).

The project, illustrating well the co-production of knowledge inherent in liquid engineering, designed close consultation with communities and stakeholders as an important part of the process:

> *"Take the example of the hybrid drying unit facility in Ghana, that was a dialogue with all of the farmers there: we met with this group of farmers that had been brought together to discuss what they would like and what they would like this facility to look like; what would really satisfy their needs, not ours, and that's been really valuable. Key feedback from the last visit I made was that they would prefer not to have the units at the markets, but they would want them, on a farm. But it would have to be in some form of cooperative because the farms are very small-scale. That's part of the main difficulty, they couldn't afford to have facilities like this individually, they would*

have to collect together in some way. They would like to do the drying even closer to the fields rather than in these markets" (Interview, Newcastle USES partner).

This also shows, in terms of livelihoods, the ways in which the technology is embedded in a socioeconomic context, which in this case determines placement of the drying facilities on the farm rather than close to a market. The farmers are also organised as a cooperative which suited the nature of agriculture in the region (small-scale farms), and the issue of affordability in a setting characterised by resource constraints. A key aspect in technological design is also simplification (see also Wilson, 2006). The flexible adaptation of forms of production and distribution also points to Cleaver's (2012) notion of institutional bricolage, which is using existing socio-cultural forms to shape institutions in response to changing conditions.

4.3 Fluidity versus tension between engineering excellence and social and economic impact

The lead academic in the project offered this thoughtful assessment and approach geared toward 'taking out the complexity in the engineering', which again prioritises local context in technology development, whereby simplified products are easier to use and maintain. Of course, while this makes the innovation simpler, it does not mean that it embodies less knowledge:

> "*To a certain extent ['excellent' engineering and social impact] are in conflict with each other or could be in conflict with each other. A lot of our academic life is actually working on making things much more complicated and more expensive rather than deliverable in the environments we meet in developing countries. But quite a lot of my previous work was actually to look at innovation but from a point of view of taking out complexity in the engineering side. I'd previously done research in robotics devices, basically taking out the complexity in the mechanism, actually putting complexity in the software and the control of it rather than the hardware."* (Interview, Newcastle USES partner)

The academic goes on, however, to build the insight that hybridity between practices can make a difference with need for new engineering:

> *"So, you know, there are some examples where we're effectively doing a demonstration facility or what you'd call a prototype, but there's still more innovation that could be done, where we can actually improve and optimise. There's something that can be delivered more immediately and make a difference, not necessarily adding cost but maybe changing the design and maybe adding some different material choices or whatever. That's where you can put the higher-level engineering or science into a solution. That's where the research can actually produce good results."* (Interview, Newcastle USES partner)

The project includes three examples where this tension is effectively addressed, the first is a food drying unit that was established in Ghana.

Hybrid drying facility in Ghana

In Ghana, the local partners built a hybrid drying facility to dry maize. Maize was identified as one the most important staple crops and it had major problems with rot and waste. In one of the areas where maize is grown, it is brought in from farms around and sold, not only in Ghana but to other countries, from where people come to buy the crop. The hybrid drying facility was sited in a particular location to make it easier for farmers to access, dry the maize and therefore increase its life. This would give them greater flexibility in terms of making choices about when to sell it, and therefore enhance its value as an income source and its role in their livelihoods. The facility uses solar thermal energy plus a biomass heater, which is fuelled by husks from the maize. It is also designed so that all biomass waste from the maize can be burned in order to supplement the hot air that is produced by the facility in order to dry the maize. So the technology combines solar with biomass to ensure required temperatures are met at all times, including when it gets cooler at night. The team collects seasonal data from the facility, alongside temperature profiles within the unit. They use highly technical computational fluid dynamics to optimise the technological design of the unit so that it performs well across all four seasons - winter, spring, summer and autumn - when use and temperature fluctuates, which also involves a different mix of solar and biomass energy.

The team is also investigating a further innovation that incorporates the use of phase change materials in the facility, which are those that can absorb or release a great deal of heat when they change from a solid to a liquid. This will allow the unit to maintain temperature, and especially one that is more even at night when solar energy is unavailable. Use of the phase change materials also promise to reduce the amount of biomass needed by the facility. This shows then how a locally embedded technology that is easily accessible to users alongside ongoing innovations to make it more efficient and cost effective to run can help to enhance rural livelihoods. The second case that was part of the Newcastle project also impacts rural livelihoods and food preservation, but in the contrasting industry of fishing and in a different country – Sierra Leone.

Ice making solar absorption refrigeration process in Sierra Leone

Fishing is very important to the Sierra Leone economy. The project team had originally looked at the smoking of fish but this would have involved cutting down of mangrove to smoke the fish. Therefore, using mangrove wood was not a sustainable way forward. The following quotation shows how the thinking on the technology fluidly evolved to link technology and local context.

> *"We've done some work on whether it would be acceptable to people to use smoking with other woods as an acceptable way to dry the fish as it does add a different flavour. We've had kind of conflicting feedback on that and information on the ground there, some taste testing and some saying, "Well not really much difference,". We haven't taken that too much forward. We then moved onto thinking about the fishing side of things: the fish are getting beyond their sell-by date the minute that they land them onto the boats, so we thought that ice making using a solar absorption*

> *refrigeration process would be valuable. And so that's where we've taken the lead.*" (Interview, Newcastle USES partner)

The team has focused on solar absorption refrigeration, working with partners in China. The main challenge has been optimising it in a way that works best for the fishing community. In the view of the project lead *"I think that the innovation is not necessarily the technology, absorption is not brand new or anything. The innovation is actually how the technology would fit in with how they operate in those fishing communities"* (Interview, Newcastle USES partner). This again illustrates a key challenge that liquid engineering addresses, which is around adaptation of technologies to local contexts. It is further explored in the third case from the Newcastle project, which is yet another type of food preservation, evaporative cooling, in a different country – Kenya.

A food dryer using evaporative cooling in Kenya

In the third case, the team worked to improve an evaporative cooling device fuelled by charcoal in order to provide a more effective way to address the local context of production and consumption of dried vegetables and fruits in particular. The team lead stated that "*we're not obsessed with drying, but it's very important in terms of preserving food, and it's not just vegetables but fruit. It's part of the community; having dried fruits is a normal thing and a normal way to preserve food. But it's not usually done in the most effective way, and in a hygienic way. You see food spread over roads, and cars driving over it*" (Interview, Newcastle USES partner). In response to that challenge the team sought to optimise an evaporative cooling device. This involved working with the Jomo Kenyatta University of Agriculture and Technology to improve an existing small-scale dryer, which used a different type of technology, and dried different types of crops to others in the project. The lead reflected "y*ou know, this type of evaporative cooling is not rocket science, it's not fantastically new, but the types of materials to obtain this water evaporative process for cooling can certainly be improved. There's still quite a lot of design, engineering work that could improve that"* (Interview, Newcastle USES partner). The lead also emphasised that the University partners in Kenya and in the other project counties had a great deal of local expertise and networks in communities. In line with a capacity building approach, the working practice of the team was to build on rather than supplant this expertise and these networks. The overall experience from the project lead's point of view was that this was a positive experience, which was enhanced by good communication between the partners.

The project's sensitive approach was aided by its multiple layers of networks, consisting of local and external expertise, a wide range of disciplines, and multiple sectors. Productive interdisciplinary tensions contributed to fluid combinations of knowledge that helped identify how the technology and local context could interact. The lead describes a conversation between communities, social scientists and engineers as to the interrelationships between gender and engineering solutions.

> *"[W]hat came out of the workshop when we were in Kenya was gender issues. Particularly associated with land ownership, and who controls money. Even though*

> *the women would grow the produce, it would be the men would then take control and then sell it and then control the flow of the money. And so those types of things came out quite a lot in the discussions and with the other colleagues, kind of drawing those things out, that we would have normally--as a kind of an engineer, a thermal person I wouldn't necessarily, we wouldn't really think about those things. But then that has a kind of knock-on effect potentially on what solutions you then provide and who to, and who has control and the governance side of things."* (Interview, Newcastle USES partner.)

Liquid engineering often uses diverse perspectives to highlight the most important knowledge at each point in time, and then applies it to find a way forward. This fluidity can continue after the formal end of projects, the knowledge of what has previously worked in a certain context being used to inform future approaches. In this case the lead thought the project was a positive experience, but wished that it had been able to generate more local businesses and had more of an impact on local employment opportunities, and the lead looked to develop this further in subsequent projects.

5 CONCLUSIONS

In this paper we asked whether there was a tension between a global best-with-best standards and a local appropriate and economic impact approach to development engineering. We considered the EPSRC USES programme development, and two of its projects as case studies of what we call 'liquid engineering', which is a fluid, flexible and hybrid approach to engineering in developing countries that is driven by embeddedness in local contexts.

5.1 Engineering, capacity building and inclusive innovation

The unfolding of liquid engineering melds a global and local approach to development engineering. It reflects on ways to address dynamics around northern science and engineering skills and southern community context in order to surpass potential tensions associated with northern dominated research. The work of integrating global best standards with good social and economic impact involves a three-way relationship between engineering, capacity building and inclusive innovation, which we presented in Figure 1. The data illustrate the ways in which development engineering has a fluid, and productive, tension between the focus on world class science and impact that addresses poverty reduction. This involves two additional aspects. First is capacity building, which is a key element of network building and avoidance of network breakdown. Second is inclusive innovation, which is important in the development of new ideas that address the needs of all stakeholders, not just the wealthy or powerful. We interviewed team members from two other projects, which supported these findings, in particular the importance of networks and capacity building. In one case the network development was strong but the technological output was less clear. The other was a case of network breakdown, which highlighted the fragility of networks in the sense that partners left, and the links with teams in Africa were weak; it highlighted the importance of shared trust and shared values between partners to enable networks to function more effectively. Outputs were still produced by some key individuals but there was the sense that more could have been produced, and capacity building enhanced, had the networks been stronger. What might a successful network-oriented ‘inclusive innovation’ programme look like? We provide one example in the next section.

5.2 Best bets and research into use

The importance of the three-way relationship between engineering, capacity building and inclusive innovation is further illustrated by the outcomes of an innovative DFID programme called Research into Use. It showed how the support of promising technological innovations ‘best bets’ by small businesses in Kenya could have an impact in the agricultural sector by creating jobs, providing new skills training and improving agricultural productivity. The programme evidenced ways technology development and pro-poor aid funding could be much improved by more direct practical involvement on the part of UK engineering and science alongside aid bodies like DFID (Clark, et al., 2013).

5.3 Network building vs doing the research. The tensions between capacity building and ‘doing it’

Additional tensions inherent in programmes like USES are that they involve conducting research and promoting development at the same time. The latter includes aspects of network and capacity building. While at some level this might be seen as a tension, increasingly funders expect research to have a meaningful social impact component. For many researchers combining both expectations is both a challenge and an opportunity. It is a challenge in the sense that activities are engaged in that are not traditional engineering, but it is also an opportunity in that it can have an important positive influence on the development of long term and sustainable socio-technical solutions. The advent of liquid engineering approaches constitute a promising way to resolve tensions that surround the global and the local in engineering, which could potentially be further embedded in future engineering policy and programmes in order to help address global challenges and sustainability goals.

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