# TRANSITIONS PATHWAYS AND RISK ANALYSIS FOR CLIMATE CHANGE MITIGATION AND ADAPTATION STRATEGIES

# D6.2: Report on Social Discourse Analyses and Social Network Analyses

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# TRANSrisk

## Transitions pathways and risk analysis for climate change mitigation and adaptation strategies

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# Preface

Both the models concerning the future climate evolution and its impacts, as well as the models assessing the costs and benefits associated with different mitigation pathways face a high degree of uncertainty. There is an urgent need to not only understand the *costs and benefits* associated with *climate change* but also the *risks, uncertainties and co-effects* related to different *mitigation pathways* as well as *public acceptance* (or lack of) of low-carbon (technology) options. The main aims and objectives of TRANSrisk therefore are to create a novel assessment framework for analysing costs and benefits of transition pathways that will integrate well-established approaches to modelling the costs of resilient, low-carbon pathways with a wider interdisciplinary approach including risk assessments. In addition *TRANSrisk* aims to design a decision support tool that should help policy makers to better understand uncertainties and risks and enable them to include risk assessments into more robust policy design.

# PROJECT PARTNERS

| No | Participant name | Short Name | Country code | Partners' logos |
|---|---|---|---|---|
| 1 | Science Technology Policy Research, University of Sussex | SPRU | UK | |
| 2 | Basque Centre for Climate Change | BC3 | ES | |
| 3 | Cambridge Econometrics | CE | UK | |
| 4 | Energy Research Centre of the Netherlands | ECN | NL | |
| 5 | Swiss Federal Institute of Technology (funded by Swiss Gov't) | ETH Zurich | CH | |
| 6 | Institute for Structural Research | IBS | PL | |
| 7 | Joint Implementation Network | JIN | NL | |
| 8 | National Technical University of Athens | NTUA | GR | |
| 9 | Stockholm Environment Institute | SEI | SE, KE | |
| 10 | University of Graz | UniGraz | AT | |
| 11 | University of Piraeus Research Centre | UPRC | GR | |
| 12 | Pontifical Catholic University of Chile | CLAPESUC | CL | |

# Executive Summary

The aim of Work Package 6 is to investigate the relationship between innovation dynamics and alternative transition pathways in selected TRANSrisk case studies. Building on the work on the stakeholder analysis work of D6.1, this deliverable sets out an approach to better analysing how these stakeholders act to shape and constrain innovation processes and associated transition pathways. Analysis of such agency and power dynamics have appeared rather peripheral component many theoretical frameworks on socio-technological transitions. Using those frameworks as a foundation, this deliverable seeks to give more explicit consideration of agency and power in innovation and transition processes.

The integrated approach drew inspiration from three theoretical perspectives: the multi-level perspective, in which innovation dynamics are represented as 'niche' technologies seeking to break into the mainstream 'regime'; technological innovation systems, in which innovation is determined by the extent to which certain system functions are fulfilled, and; the system mapping approach, which helps to identify the enabling environment for a given technology market chain. A methodological toolkit was developed to provide a structured way in which to apply the integrated approach in practice. The toolkit detailed a range of data collection and analysis methods, including interviews, surveys, focus group discussions, social network analysis and q-methodology. It also set out a logical step-wise process for applying these methods, depending on the particular research questions, needs and context of any given case study.

The toolkit and integrated approach was applied to the case of biogas development in Bali, Indonesia. Although research is still ongoing, so far the integrated analysis has allowed us to better understand the perspective of multiple actors representing different sectors and interests in the biogas and wider energy sector. By combining this with insights into national and provincial policies and strategies shaping the biogas system, we have generated a more holistic perspective on the factors shaping and constraining the biogas transition in Bali. In doing so, we have been able to identify key implementation risks (barriers) and opportunities, as well and potential agents of change both at the 'niche' level and within the incumbent 'regime'.

The application of the toolkit and integrated analysis in Indonesia has generated useful insights and lessons on the benefits and limits of our approach. As we continue to refine the integrated approach, we believe they can be of practical use in analysis of agency and power in other TRANSrisk case studies and beyond. We also envisage this toolkit could be used to look at cases outside the realm of low-carbon transitions where actors seek to influence processes of change.

# List of acronyms

| | |
|---|---|
| ADD | Village allocation budget (Alokasi Dana Desa) |
| ADK | Sub-district allocation budget (Alokasi Dana Kecamatan) |
| APBD | Local Budget Revenues and Expenditures |
| BAPPEDA | Provincial Development Planning Agency |
| BAPPENAS | Ministry of National Development and Planning |
| BIRU | Indonesian Domestic Biogas Programme (Biogas Rumah) |
| CPO | Construction partner organisation |
| DAK | Special allocation budget (Dana Alokasi Khusus) |
| DAU | General allocation budget (Dana Alokasi Umum) |
| FG | Focus group |
| ICCTF | Indonesia Climate Change Trust Fund |
| LPG | Liquified petroleum gas |
| MEMR | Ministry of Environment and Mineral Resources |
| MLP | Multi-level perspective |
| NGO | Non-governmental organisation |
| OECD | Organisation for Economic Cooperation and Development |
| PLN | Indonesia's state-owned electricity company (Perusahaan Listrik Negara) |
| SIMANTRI | Integrated Farming Systems Program (Sistem Pertanian Terintegrasi) |
| SNA | Social network analysis |
| TIS | Technological innovation system |
| WBNP | West Bali National Park |
| YRE | Domestic Biogas Foundation/Institute (Yayasan Rumah Energi) |

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# 1 EC SUMMARY

## 1.1 Changes with respect to the DoA

There have been no major changes to the aims of Task 6.2 as set out in the DoA. Section 3 sets out a methodological discussion of how to understand and conceptualise framings/discourse and power relations within the 'niche' and 'regime', as proposed initially in the DoA. However, there have been some changes to the planned research design. The original design of Task 6.2 set out in the DoA sought to apply the following tools:

- Q-methodology to identify different social discourses surrounding an issue and categorise individuals based on how their views their 'fit' within these discourses.
- Social network analysis (SNA) to measure relationships and flows of resources amongst actors to identify power nodes and structural holes in the energy network.
- Stakeholder Value Network approach to allow the representation of stakeholder preferences and needs across the whole value chain.

Rather than applying all tools irrespective of their relevance, we developed a toolkit that set out a structured step-wise approach to using these methodological tools (Section 3.2) and we tested it in the context of a case study (Section 4). It was decided not to include the Stakeholder Value Network method in the toolkit as qualitative and quantitative methods for stakeholder analysis and system mapping offered (see D2.1 "Tools and Procedures for Engaging Stakeholders") similar approaches and were deemed more appropriate. The toolkit highlights how quantitative methods can be combined with qualitative participatory approaches, as set out in the DoA. We believe this toolkit is essential to give users a practical guide on how to implement the methodology through a step-based approach. It allows users of the toolkit to choose what depth of analysis they wish to undertake with the different methodological tools, depending on their particular aims and resources available to them.

## 1.2 Dissemination and uptake

This deliverable has potential for widespread usage, particularly given the modular/step-wise nature of the methodology which allows bespoke usage according to particular needs and resource availability. As such, we envisage dissemination and uptake of this research in a number of areas.

Firstly, we will disseminate this methodology amongst TRANSrisk partners, with the suggestion that they utilise it (or some part of it) in their case study analysis. Secondly, we will disseminate this methodological work to the broader academic community through conference presentations and journal articles related to the Indonesia and Kenyan case studies. Presentations are already planned for the Energy Research and Social Science conference in Sitges, Spain, on 2-5 April 2017, at the SEI Science Forum in Bangkok, Thailand, on 29-31 May 2017, and at the International Sustainability Transitions conference in Gotherburg, Sweden, on 18-21 June 2017. Thirdly, we will disseminate the lessons from using this methodological approach to policy- and decision-makers in Indonesia and Kenya, as well as regional and international partners. This will most likely take the form of a discussion brief outlining the methodology and an example of its application in at least one case study, followed by presentations on the same to the research community, policy makers and civil society groups.

## 1.3 Short Summary of results

In this report, we present an integrated approach to guide the empirical study of agency, power and institutions in socio-technical transitions. We set out a methodological toolkit to operationalize this approach, which we then apply to the case of biogas development in Indonesia. In doing so, this report builds on the stakeholder analysis approach developed in D6.1, presenting a way in which to explore the influence of stakeholders in shaping and constraining low-carbon transition pathways.

The integrated approach drew inspiration from three theoretical perspectives: the multi-level perspective, technological innovation systems and system mapping. A methodological toolkit was developed to provide a structured way in which to apply the integrated approach in practice. The application of the toolkit and integrated analysis in the case of biogas in Indonesia generated useful insights and lessons about the benefits of our approach, the challenges we encountered also demand improvements. In particular, the approach and toolkit helped us to identify key implementation risks (barriers), and potential agents of change both at the 'niche' level and within the incumbent 'regime'.

We believe that further practical use in other case studies could strengthen the integrated approach and practical toolkit, which we deem relevant for different contexts and technologies. Fieldwork in Kenya has recently started to conduct a similar socio-institutional study of energy transitions associated with upscaling to geothermal power development using this approach. We will encourage other TRANSrisk case studies to take up this integrated approach to keep applying and improving the toolkit.

## 1.4 Evidence of accomplishment

Beyond this report, evidence of accomplishment of T6.2 comes from a number of sources. Firstly, application of the methodology in Indonesia, looking at biogas, has been well-documented in numerous reports. This will culminate in a journal article on the Indonesian study. Secondly, this methodology is currently being applied in Kenya, looking at geothermal energy. There will be ample documentation of this process, and there will be a journal article comparing the use of the methodology and toolkit in the Indonesia and Kenya case studies. Finally, we envisage a discussion brief outlining the methodology and example applications in at least one case study.

# 2 INTRODUCTION

## 2.1 Rationale

Technological transitions are defined as major socio-technical transformations in the way transportation, communication, housing and other societal systems work (Geels 2002). For these technological transformations to occur, it is critical to consider the role of human actors and the way these actors interact, as they greatly influence the generation, diffusion and use of technology. Consequently, the main focus of Task 6.2 was to study the role of agency, power and other socio-institutional factors shaping technological transitions. By placing particular emphasis on the actors, institutions and policies that influence the potential growth of new technology, Task 6.2 aimed to develop a methodology that can help identify (1) potential tensions or barriers in the socio-institutional context constraining transitions to low-carbon energy systems, and (2) enabling socio-institutional mechanisms and opportunities to support technological transitions through innovation.

From the onset, the team working on Task 6.2 recognised that technological systems generally span across geographic as well as sectorial boundaries. Therefore, if a technological transition was analysed for example at the district level, we considered also stabilising and destabilising forces playing out in the national and even regional context. We also acknowledged that the roles of public and private actors may differ and will be dynamic depending on the different stages of technological innovation. Likewise, we expected to see that different actors related to the technology would have different perspectives and framings on what a low-carbon transition pathway should look like and how to achieve it. On this basis, we aimed to develop a methodological approach that captured as far as possible the complex interactions and myriad of actors involved in shaping and constraining design, deployment and diffusion in socio-technical transitions.

Different approaches have been developed to analyse socio-technical transitions. Two widely used approaches are the multi-level perspective (MLP), which looks at the dynamics of how new socio-technical systems emerge, building on the Twente school of evolutionary economics (Geels 2010), and the technological innovation systems (TIS) approach which is focused on the structure and functions that facilitate or hinder innovation (Bergek et al. 2008). While both are highly relevant, these approaches have been criticised for falling short in capturing key socio-institutional processes influencing transitions. The MLP has been criticised for being too descriptive and underplaying the role of agency and power in transitions (Smith et al. 2005a). The TIS, on the other hand, has been criticised for being more inward oriented, paying more attention to the performance of the system for innovation success than to the system’s environment, thus putting it at risk of missing influential political and institutional processes or windows of opportunity provided by the wider context (Markard and Truffer 2008).

## 2.1.1 Research questions

We aim to address these criticisms by proposing a methodology to integrate and build on the MLP and TIS in a way that guides the empirical study of agency, power and institutions in socio-technical transitions, accounting for stabilising and destabilising forces in the broader environment. This report introduces the methodology and provides a test application in the context of Indonesia, one of the TRANSrisk case studies. We anticipate that the implementation of such an integrated approach could help answer the following set of broad questions about low-carbon energy transitions:

(i) What are the actors, networks and institutions relevant to the socio-technical transition? Why are they relevant, and which ones could play an important role in catalysing the transition pathway(s)?

(ii) What is the current performance of the technological system? How are agency, power and institutions affecting this performance in terms of bottlenecks, capabilities and opportunities?

(iii) What socio-institutional opportunities and enabling mechanisms could support the transition to low-carbon energy systems in the future, taking into account forces playing out in the broader context?

The first question focuses on the structural components that are relevant to the technological system, providing an initial understanding of the current socio-institutional conditions playing a role in the technology development, diffusion and use of a particular technology. It also aims to identify the structural components that could help accelerate any particular transition. The second question aims to understand the functional patterns of the technological system as proposed by the TIS approach, albeit with particular emphasis on socio-institutional factors influencing its performance. This generates an understanding of the technology potential. Based on the results generated with the first two questions, the third research question takes a normative approach to suggest potential mechanisms and opportunities that could facilitate the transition towards ‘desirable’ future pathways.

## 2.1.2 Scope of report and relations to other tasks

Overall, Task 6.2 adopted a ‘micro-level perspective’ in the analysis of agency, power and institutions driving innovation system dynamics, building on the work produced under Task 6.1. This micro-level perspective will underpin Task 6.3, which can benefit from the approach and its application – described in this report – to inform design of an agent-based model and its associated assumptions. Task 6.2 also provides insights to take into consideration in the ‘macro-level assessment’ of innovation policies and recommendations under Task 6.4.

The remainder of this introduction section describes the concepts and approaches underpinning the methodology developed under Task 6.2. Section 3 introduces the methodology, explaining in more detail the integrated approach and toolkit we developed for the empirical analysis of socio-institutional dynamics influencing technological transitions, accounting for drivers in the broader environment. This section also explains how we adapted and applied the methodology in the Indonesia case study. Section 4 provides the case study findings, as an example of insights that can be generated with the proposed methodology. Section 5 discusses the benefits, challenges and lessons from using the integrated approach and toolkit in the case study. Section 6 provides concluding remarks. It is important to highlight that this report focuses mainly on the methodology we developed under Task 6.2, provides an example of how it can be applied and discusses this application. It does not (and does not intend to) fully discuss the results of the case study, which will be included in the case study work in D3.3 and in separate papers currently under development.

## 2.2 Theoretical underpinnings

To study the critical role of human agency, power and other socio-institutional factors influencing technological transitions, we built on and integrated key conceptual components of two approaches that have been widely-used to analyse technological transformations and innovation systems. These are the multi-level perspective approach, and the technological innovation systems approach. To develop a methodology that is practical enough to guide empirical studies, we complemented the strengths of multi-level perspective and technological innovation system approaches with the system map framework (method discussed in Nikas et al, 2017), an approach developed for conceptualising the institutional environment in which technology market chains operate (Albu and Griffith 2006). Hereafter we provide a brief description of the theoretical foundations underpinning each approach, the existing gaps, and the key strengths we used from each approach. Figure 1 illustrates how we integrated these strengths to complement each other.

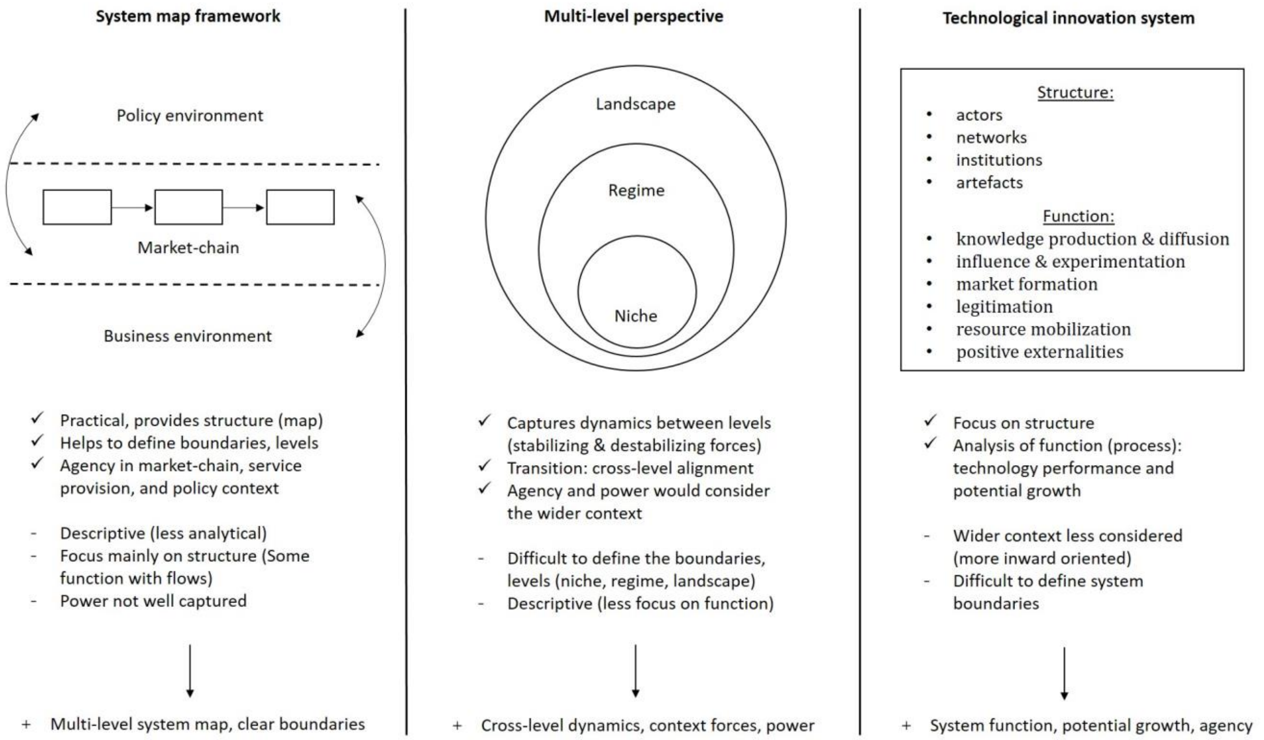



**Figure 1: Strengths and gaps identified in three approaches we built on to develop our methodology**

Notes:

✓ denotes strengths

\- denotes weaknesses

\+ denotes elements or key strengths used to build the integrated approach for analysis of socio-institutional factors influencing technological transitions

*Source: Authors' own*

## 2.2.1 Multi-level perspective on technological transitions

The first aspect we considered important to build on was the recognition that technological change is ultimately dependent on the socio-institutional context. This meant acknowledging that the process of technological change is not only governed by local changes at the 'niche' level, i.e. where the technology is incubated, but also by developments and advancements in the wider socio-institutional context. The multi-level perspective (MLP) approach was developed to appropriately capture these important multi-level dynamics between the 'niches', the 'regimes' and the broader 'socio-technical landscape' (Geels 2002, Geels 2011).

Based on the MLP approach, 'niches' are defined as dynamic configurations in which non-conformism and innovation can brew and develop. Niches may emerge without coordination amongst local or transnational networks of actors (Coenen and Truffer 2012), or they may be actively protected, for instance, by government through policy support mechanisms (Smith and Raven 2012). 'Regimes', on the other hand, are relatively stable configurations that determine the 'normal' or 'dominant' development and use of technologies that fulfil socially valued functions (Geels 2002). Regimes therefore embody strongly held convictions and interests concerning technological practices and the best ways in which these might be improved (Smith et al. 2005a). These convictions and interests are stabilized through mutually reinforcing factors, such as technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge. Regimes have been defined at different levels of aggregation, such as a sector or multiple sectors together, or one regime or multiple regimes together. According to Markard and Truffer (2008), the choice of a particular level of aggregation depends to a large extent on the research question.

Furthermore, regimes are embedded in a 'socio-technical landscape', which is an external structure or wider context of interactions. Geels (2002) suggested that a landscape involves heterogeneous factors, such as oil prices, economic growth, migration, broad political coalitions, cultural and normative values, environmental problems, among others. This level is characteristic of relatively broad and longer-term cultural, demographic and political changes. Landscape changes may put pressure on the regime, which in turn may have cascading effects at the niche level. Likewise, innovations at the niche-level may scale up or out when on-going processes at the levels of regime and landscape create a 'window of opportunity' (Geels 2002). According to Kemp et al. (2001); it is the alignment of developments at these different levels that determines if a socio-technical transition (or regime shift) occurs.

In all instances, the trajectories and cross-level alignments described above are enacted by social agency. This involves interactions between heterogeneous actors embedded in and acting at multiple scales (Geels 2011). However, the MLP has been criticised for being too descriptive and formulaic, underplaying the role of agency and power in transitions (Smith et al. 2005a). Recent attempts to address this gap have sought to further develop the MLP to strengthen the analysis of agency by relating it to power, civil society movements and cultural dimensions (Geels 2011).

The MLP approach combines evolutionary economics perspective on prices, market selection, resources, etc. and constructivist perspectives on meanings attached to technology, world views, beliefs, etc. (Geels 2010). Bridging this material and idealist divide allows for a broader understanding of how and why some types of technological change occur over time, accounting for both 'incremental' and 'radical' regime shifts (Geels 2011). Markard and Truffer (2008, p.599) refer to incremental innovation as "the continuous improvement of the production processes and established product lines in a given system or sector". Radical innovations, on the other hand, lead to a significant transformation of the established production or even to the emergence of an entirely new production system (Perez 1985; Dosi et al. 1998). The MLP approach appreciates the need to analyse power and political dynamics that contribute to both existing lock-in effects and path-dependencies, and hinder the breakthrough of niche innovations and niche-regime formation.

## 2.2.2 Technological innovation systems

A complementary approach to analyse socio-technical transitions is to adopt a functionalist perspective looking at innovation system dynamics (Bergek et al. 2008). The technological innovation systems (TIS) approach studies socio-technical transitions by focusing on the 'structural components' and 'functions' of innovation systems, and identifying possible 'system failures' (Carlsson and Stankiewicz 1991, Klein Woolthuis et al. 2005). The 'structural components' of the system comprise the actors, networks, institutions and physical infrastructure contributing to the overall function of developing, diffusing and utilising new technology (Markard and Truffer 2008, Bergek et al. 2008).

The structural focus in the TIS approach is complemented with a focus on the 'functions', i.e. the processes of what is actually achieved in the system. Bergek et al. (2008) analysed these processes through seven key functions that have a direct and immediate impact on the development, diffusion and use of technology, namely: knowledge development and diffusion, influence on the direction of search, entrepreneurial experimentation, market formation, legitimation, resource mobilisation, and development of positive externalities. These functions were identified through a wide-ranging literature review involving different system approaches to innovation and empirical application. They also integrate insights from political sciences, sociology of technology and organisation theory, which highlight the political nature of the innovation process and the importance of legitimacy.

Taking into consideration different structural components and functions, it is possible to identify if a 'system failure' has occurred. These failures can be when a system fails to develop, due to infrastructural failures (related to actors and artefacts), institutional failures (related to institutions), interaction failures (related to networks) or capabilities failures (related to actors), among others. According to Bergek et al. 2008 (p. 409): "It is in these processes [i.e. the performance of various functions that facilitate innovation] where policy makers may need to intervene, not necessarily the set-up of the structural components (actors, networks, institutions)".

The TIS was criticised for being too theoretical and providing insufficient guidelines for practical implementation, probably due to the conceptual fragmentation and heterogeneity in the innovation system literature (Klein Woolthuis et al. 2005). This led to more recent development of an analytical framework providing a systematic step-by-step approach to capture structural characteristics of innovation systems, as well as key functions listed above (Bergek et al. 2008). Contrary to the MLP, the TIS perspective has been considered more inward oriented, paying more attention to the performance of the system for innovation success than to the system's environment (Markard and Truffer 2008). The critique in this regard is that TIS may miss influential processes or windows of opportunity that could occur through cross-level dynamics. This criticism has led to recent work aimed at better understanding the wider context structures and their interactions with the TIS (Bergek et al. 2015). As in the MLP, this contextual analysis aims to take into consideration various kinds of influences, including technological, sectorial, geographical and political processes.

### 2.2.3 System map framework

Whilst the MLP and TIS approaches described above are under further development and have achieved important advancements in the study of socio-technical transitions, their practical application is challenged by the fuzzy boundaries between the multiple socio-technical levels suggested by the MLP approach and the system, and its structural components suggested by the TIS approach. To overcome this challenge and generate a methodology that can guide not only theoretical but also empirical studies, we combined the strengths of these two approaches with a more practical approach proposed by the system map framework, which helps set up clearer boundaries through a participatory approach.

The system map (sometimes referred to as a 'market map') is a practical participatory tool for conceptualising the enabling environment in which any given technology market chain (or value-chain) operates (Albu and Griffith 2006). Using a simple map, boundaries can be defined around a specific structure and actors positioned in relation to this structure. This map includes the technology 'market chain', the 'policy environment', and the 'business environment'. The 'market chain' refers to the actors involved in making and transacting a particular product or technology as it is developed, transformed and moved from primary producer to final consumer. It includes research labs, producers, input suppliers, processors, traders, sellers and end-consumers. The wider 'policy environment' includes the institutions, rules, interests and practices of governments and policy-makers that affect the entire market chain and drive change. Understanding this environment can help determine the trends that affect the market chain and the opportunities for action, lobbying, and policy reform (Albu and Griffith 2006). Finally, the 'business environment' includes service providers, large competitors and society at large that influence (i.e. support, enable or constrain) or are needed to support the market chain's overall functioning (Albu and Griffith 2006).

# 3 METHODOLOGY

## 3.1 An integrated approach

The integrated approach we introduce here builds on the theoretical underpinnings explained in the previous section. More specifically, we used the structure with clear boundaries suggested under the system map framework to define:

- The technological system, which would comprise the technology supply chain and its business environment (linked conceptually to the technological niche and parts of the regime(s) that supports the niche formation), and
- The wider environment/context, which would comprise the policy environment (linked conceptually to the regime, but particularly the socio-technical landscape of the MLP).

We used elements of the TIS approach to focus on current system dynamics, particularly the role of agency, power and other socio-institutional factors affecting the functioning of the technological system. And finally, we built on the MLP to consider how changes in the broader context can align with changes within the technological system and result in different possible technological transition pathways in the future.

The integrated approach involves three analytical components that inform an integrated analysis of the socio-institutional factors influencing technological transitions. Figure 2 describes these three components: an agency and power analysis (component I), an institutional context and legitimation analysis (component II), and a technology development and market function analysis (component III). All three components use elements of the MLP, TIS and the system map framework, but put particular emphasis on the role of agency, power and institutions in socio-technical transitions. The analytical components and the integrated analysis that make up the integrated approach proposed in this report are explained in more detail below.

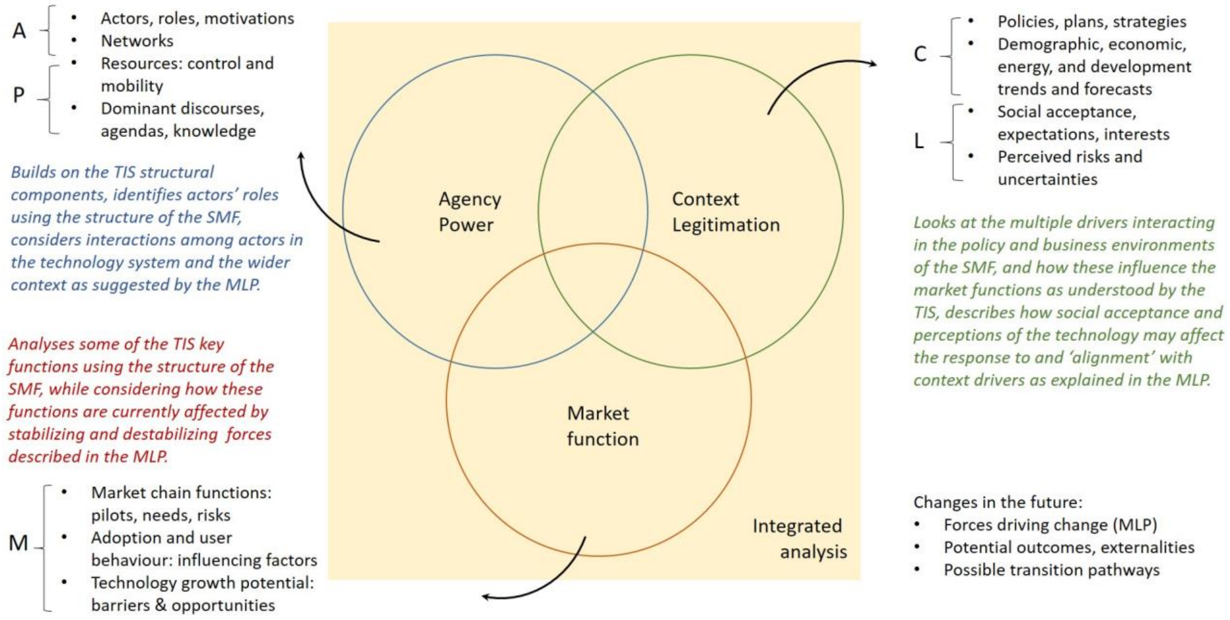



**Figure 2: Integrated approach to study socio-institutional factors influencing technological transitions**

Notes:

The integrated approach includes three analytical components: agency (A) and power (P) analysis, context (C) and legitimation (L) analysis, and technological development and market (M) function analysis. They all use elements of the technological innovation systems (TIS) approach, the multi-level perspective (MLP), and the system map framework.

In addition, the integrated analysis uses the inputs generated by each component to analyse possible stabilising and destabilising forces influencing the dynamics of the innovation system in the future, producing narratives about the development of possible transition pathways.

*Source: Authors' own*

## 3.1.1 Component I: Agency and power

Component I seeks to understand the role of agency in technological transitions, explore how agents (i.e. actors) exercise power in the context of such transitions and identify 'agents of change' that could play a key role in accelerating these transitions. This builds on the idea that regime shifts are enacted through the interactions of many actors and the resources they mobilise, whether these are intended or emergent features of the transformation process (Smith et al. 2005a).

The notion of agency in technological transitions can be separated into two aspects: actors relevant to the technological system and their interactions. Actors typically include private firms or firm sub-units, governmental and non-governmental organisations, universities, research facilities, venture capitalists, associations, and social groups (Markard and Truffer 2008). These actors may play a role in the supply chain of a new technology (i.e. by developing and/or using the technology), or may be actors that are supporting or influencing the supply chain (i.e. by providing relevant services in the business environment or acting at broader level and influencing the socio-technical transition through decision-making processes in the policy environment).

Whilst it is necessary to study individual actors, because they shape and influence the dynamics of the system they are part of, it is also important to look at the interactions among them. The interaction among actors is captured in social networks that show how they collaborate, share and mobilise resources in support of – or resistance to – the new technology. It is important to consider the social networks as a whole, as they can act either as barriers or enablers for socio-technical transitions. These social networks have a function of their own which no single actor or group of actors can control. Avelino and Rotmans (2009, p.544) explain this property using complex adaptive systems theory, referring to social networks as complex because “interactions at the micro-level may have unintended effects at the macro-level and they adapt to the systems’ surroundings”. Also, networks are not always cooperative. Therefore, there is a need to understand the network structure and the position of actors that are resistant to or supportive of the socio-technical transition based on their expectations, interests and willingness to mobilise resources for the growth potential of new technology.

In order to explore more closely how interactions between actors are mediated, we turn to the concept of power and power relations. Definitions of power are manifold, ranging from power as the capacity of actors to move resources to fulfil self-interests to power as the capacity of a society to collectively mobilise resources to realise common goals (see Avelino and Rotmans 2009 for a review of definitions). Broadly speaking, power can be understood as the actual or perceived influence over others, over agendas and over perspectives. In general, actors and the associated power relations can only be understood in relation to other actors in the network and the system as a whole (Smith et al. 2005b).

In our analysis of power, we build on Avelino and Rotmans’ (2009) definition of power as the ability of actors to mobilise resources to achieve a certain goal, which can be collective or purely focused on self-interest. These resources are broadly defined to encompass human, mental (or knowledge), monetary, artefactual and natural resources. It is both the ‘possession’ of resources and the ‘exercise or ability’ to mobilize them that creates the conditions of power. Indeed, Avelino and Rotmans (2009) suggest four conditions for the exercise of power: access to resources, strategies to mobilize them, skills to apply those strategies, and the willingness to do so[1].

Focusing on resources that can be owned, controlled and mobilized by actors presents a very agent-centric view of power (Hayward and Lukes 2008). A more structuralist perspective on power views institutions, such as rules, laws, culture or traditions, which cannot be ‘owned’, as having a significant bearing upon the way in which power is exercised (Hayward and Lukes 2008). This perspective is considered in the next analytic component of the integrated approach.

[1]The ‘empowerment’ of an actor means that this actor gains the necessary resources, strategies, skills and willingness to exercise power.

However, in this component we recognise that some actors may have authoritative power, whereby their demands upon the behaviour of others (i.e. through direct orders, legislation or regulation enforcement) are seen as legitimate because of some established hierarchy. Such authoritative power gives the actors who wield it significant ability to dictate or influence decisions on resource mobility (Smith et al. 2005b). This property is therefore included in the analysis of power.

While power can facilitate agency for socio-technical transitions, it can also keep certain issues off the agenda, circumscribing agency and restricting critical reflection for change (e.g. by preventing an idea from gaining attention. It is important therefore to differentiate between power relations that prevail in the regime – conditioning stable demand, use and supply practices – versus the ability to bring resources into play to make changes in the regime leading to regime shifts. Depending on the position of actors and their power relations in these conditioning structures, they can act to facilitate or to constrain changes (Smith et al. 2005b). Finally, according to Avelino and Rotmans (2009), when different types of power interact, they can either resist or prevent one another ('antagonistic power dynamic'), or mutually enforce and enable each other ('synergistic power dynamic'). These dynamics are also important to consider in the power analysis, as synergies will be required for transformative change to happen.

Finally, exploring agency and power can help us to identify potential 'agents of change' favouring the socio-technical transition. We understand agents of change as actors that can 'catalyse' socio-technical transitions either because they are critical players in the market chain, or key supporting actors in service provision for the appropriate functioning of the market chain, or strategic influential actors that can help shape the decision-making environment in which the technology operates (e.g. through regulation, planning). Smith et al. (2005a, p. 1504) suggested that, "any attempt to side-step incumbent regime members and foster alternative regimes will meet strong resistance by incumbent regime interests". It is therefore important to also identify potential agents of change within the incumbent regime who could play a pivotal role in supporting its shift (see Reinganum 1983).

### 3.1.2 Component II: Institutional context and legitimation

Component II focuses on institutions influencing the socio-technical transition. Achieving a technological regime shift lies not only in the agency of actors and their power relations, but also in the norms and procedures governing the relationships and interdependencies of actors and resources. In broad terms, Ostrom (2005) defines institutions as the prescriptions that humans use to organise all forms of repetitive and structured interactions including those within families, markets, firms, etc. This broad definition of institutions stems from Ostrom's earlier work focused on 'rules', referred to as "prescriptions commonly known and used by a set of participants to order repetitive, interdependent relationships" (Ostrom 1986, p.5). Ostrom emphasized the importance of rules as the means by which people can intervene to drive change, noting also that rules themselves are artefacts that can be changed by humans.

The main focus of this analytical component is the policy and business environments influencing the technology supply chain. Institutional settings in these environments can represent a barrier to socio-technical transitions, promoting lock-in and potential system failure, or alternatively contribute to the creation, diffusion and adoption of technology and the functioning of its market chain (Kemp et al. 2001). Smith et al. (2005b) highlighted two intervention processes as key to understanding the governance of regime transformation. In the first, intervention comes in the form of attempts to shift, re-orient and re-articulate selection of pressures affecting the dominant regime. In the second, rules influencing actors and resources are used at the regime and niche levels to adapt/respond to and 'align' with context opportunities through coordination of available resources and knowledge. Questions of agency, trust, partnership and coalition become very important for the adaptive capacity required to respond to pressures, hence this analysis needs to be complemented with findings of the first analytic component.

In addition to understanding institutional settings, it is important to identify conditions that legitimatise the new technology and hence can support its potential growth. The transition management literature emphasises how codified representations of technological expectations – for example, elaborate or hazy shared visions of a low-carbon city – play a vital role in framing socio-technical problems and legitimatising new technology for actors to get involved (e.g. Brown et al. 2003, Berkhout 2006). The role of different expectations can be analysed through interrogation of different discourses over regime change, and the different framings, ideas, and interests on the new technological growth potential. Smith et al. (2005b) argued that different understandings of the regime and the new technology influence the recognition of selection pressures, and the coordination of responses and adaptive strategies. In part, this is because the interplay of expectations about change – synergistic or contrasting expectations – define the way coalitions of actors (could) form to support transitions and shape the way they respond to selection pressures (i.e. by building collective adaptive capacity).

As noted in the previous section, power dynamics have a 'structural' component whereby decision and options are shaped by institutional factors. From this perspective, the institutional setting can significantly influence the construction of guiding dominant visions (e.g. discourses, narratives or storylines) and the deployment of resources to fulfil them (Smith et al. 2005b). As such, some expectations can gain greater legitimacy and credibility than others, supporting or blocking socio-technical transitions. Hence there is a need to integrate legitimation findings with the first analytic component looking at power dynamics.

### 3.1.3 Component III: Technology development and market function

This analytical component focuses on the current functional patterns of the technological system, with particular attention on the technology supply chain and its business environment (as defined under the system map framework). The analysis draws largely on the key 'functions' outlined in Bergek et al. (2008) that influence the development, diffusion and use of new technology (see Section 2.2). By looking at these functions, component III is mainly concerned with the identification of bottlenecks or barriers hindering the technological growth potential, and possible opportunities and enabling mechanisms that could support the technological transition.

Barriers can be understood as blocking factors that affect both the structure and function of the technological system. Barriers therefore point in the direction of work needed to address gaps and overcome existing challenges constraining the transition. Identifying opportunities and enabling mechanisms, on the other hand, provides a basis on which to build to facilitate, if not accelerate, more sustainable (low-carbon) socio-technical transitions. Enabling mechanisms relate to the structure and function embedded within the technological system, while windows of opportunity are created by the wider context (Bergek et al. 2008). Both enabling mechanisms and opportunities point at specific conditions that are promising or effective and could be improved, better used or strengthened to enhance performance and promote further technological growth. Barriers related to societal legitimacy necessarily overlap with the legitimacy aspect of component II.

To narrow down the analysis on the socio-institutional factors influencing market function, more emphasis is given in this component to the first-hand experience of actors engaged in the innovation system. This mainly includes the experiences of those actors within the supply chain (e.g. technology installers, users), and of service providers supporting the market chain function (e.g. NGOs and researchers involved in pilot experimentation). To a lesser extent, experiences of actors involved in regulating or supporting the market chain (e.g. policy makers formulating new regulations) may also be considered. Particular emphasis is placed on the analysis of key processes in relation to entrepreneurial experimentation and market formation, two of the key functions identified by Bergek et al. (2008).

### 3.1.4 Integrated analysis

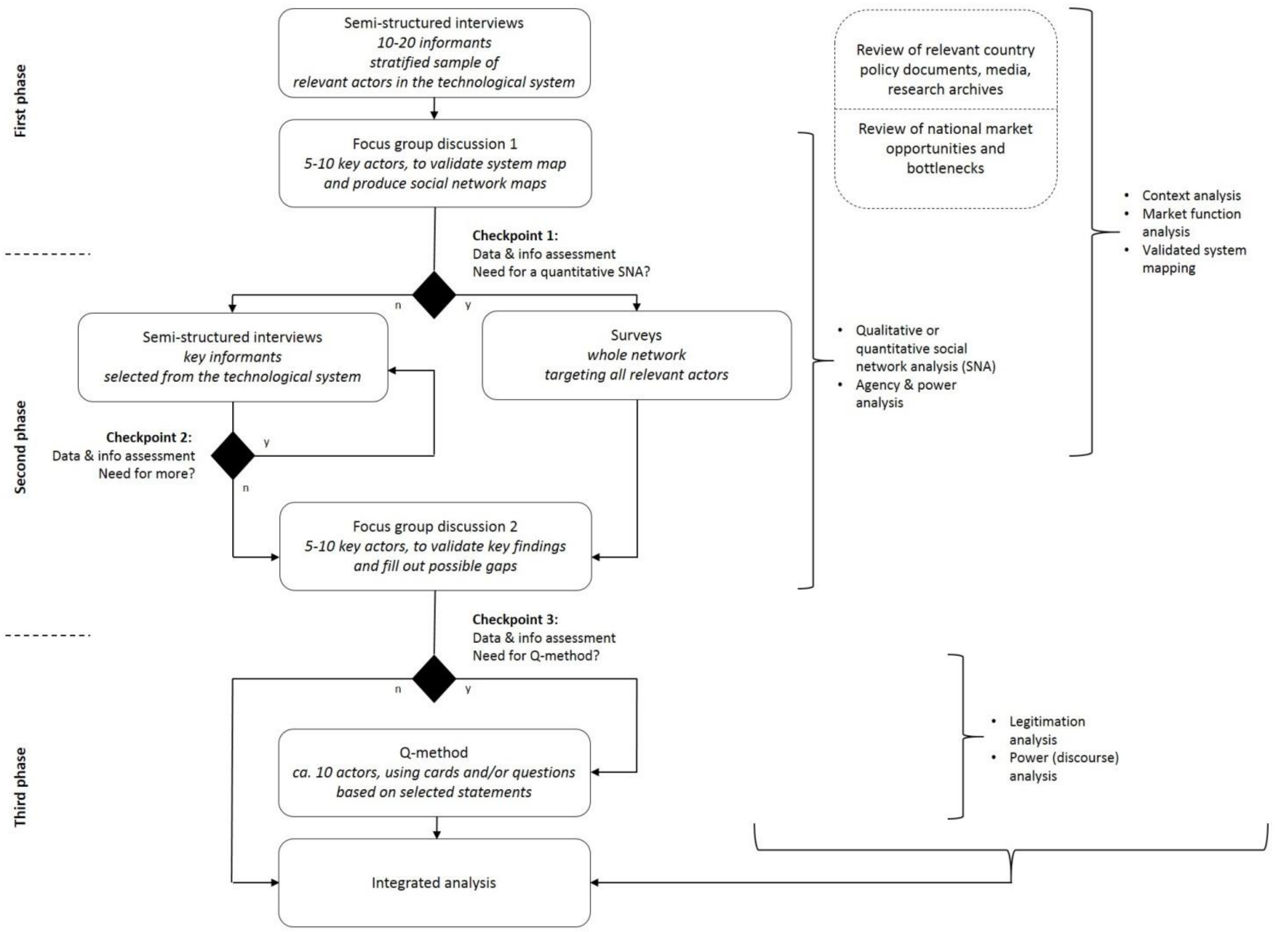
The integrated approach to understanding of how agency, power and other socio-institutional dynamics affect technological transitions put forward in this paper concludes by integrating and further analysing the results generated by the three analytic components presented above. This integrated analysis places particular emphasis on how these dynamics can change over time under the influence of stabilising and destabilizing forces in the broader environment interacting with the technological system. Although in the three analytical components socio-institutional factors affecting the technological system were mainly assessed based on a snapshot analysis of current conditions and functions, these analyses can be used to inform assumptions of future dynamics. These future dynamics can be analysed in light of the interplay between stabilising forces of the regime and destabilising forces of the niche (Markard and Truffer 2008). For example, transformation processes may result from the articulation of selection pressures (i.e. coordinated pressure for change), or from the availability of resources and the ability to coordinate responses (i.e. adaptive capacity) to these pressures (Smith et al. 2005b). Broader contextual drivers of change (i.e. destabilising landscape pressures) could also influence future outcomes by potentially reinforcing or balancing existing barriers and opportunities. This integrated analysis would allow identifying potential (future) ‘alignment’ of developments at different levels, which could facilitate regime shifts (Kemp et al. 2001), or at least distil a set of drivers or pressures that show promising leverage for guiding change in a desirable direction (Smith et al. 2005b).

Based on the analysis of observed trends and current dynamics, and the interplay between multiple forces, different possible transition pathways for the future can be considered. As opposed to predictive scenarios, these future pathways could be conceived as exploratory scenarios based on exploring possibly future pathways, or normative scenarios presenting a picture of 'desirable futures' that could be achieved through certain actions (Hojer et al. 2008). Exploratory scenarios respond to the question '*What can happen*?' Because of their exploratory nature, these scenarios are usually developed as a set of plausible scenarios, illustrating different potential developments or pathways that could be considered in further analysis, as opposed to one single scenario (Höjer et al. 2008). Such an exercise may be a first step to generate recommendations that can support sustainable socio-technical transition pathways. These insights could also be used to study more specific system dynamics and the effects of broader context drivers in predictive scenarios and scenario simulation using different modelling techniques. Exploration of possible transition pathways can also, to limited extent, represent a first step to evaluate potential positive externalities, which are ultimately an emergent outcome resulting from multiple changes in the system.

## 3.2 Toolkit to operationalise the approach

The integrated approach was developed to provide a guide for the empirical study of agency, power and institutions in socio-technical transitions. In the previous sections we explained the theory underpinning the integrated approach and introduced the different components of analysis. In this section we present a toolkit that can help operationalise the integrated approach. This toolkit provides a practical guide to collecting data required for the integrated analysis. More specifically, the toolkit could be considered as procedural guidance for the implementation of methods to collect empirical evidence in a case study.

The toolkit includes four primary data collection methods, and a review of secondary data to inform the integrated analysis (Figure 3). We propose a step-based approach for implementation of the methods to allow for adaptability in the process. This entails making sure the data collection is comprehensive, while at the same time being responsive to the local circumstances and available resources at hand. The step-based approach includes a series of 'checkpoints', which provide an opportunity to: (1) assess the quality, representativeness, relevance, credibility and salience of the data and information collected to that point, using as a reference the research questions posed in the case study, and (2) based on that assessment, make a strategic decision on the next set of methods to use. The final selection of methods that will be implemented in the case study depends on the decisions made at each checkpoint.




## Figure 3: Toolkit guiding implementation of integrated approach

Notes:

The toolkit includes 5 data collection methods implemented following a step-based approach that includes checkpoints. The toolkit implementation is divided into three phases.

*Source: Authors' own*

To facilitate the use of the toolkit during fieldwork, we divided its implementation into three phases (Figure 3). The first phase begins with the implementation of semi-structured interviews in the field (see Section 3.2.1) and the review of secondary data from academic literature and the policy and industry realms. The desk-based review may continue throughout the next phase. Once the first set of semi-structured interviews has been finalised, the next step in Phase 1 is the implementation of a focus group discussion aimed at validating - we are referring to social validation - the interview findings and mapping all the relevant actors in the technological system. A checkpoint is suggested at the end of this first phase.

'Checkpoint 1' includes assessing if the information gathered to that point is sufficient to answer the research questions posed for the case study. Particular attention needs to be given to the data (collected through interviews and the focus group discussions) used to inform the agency and power analysis. At this point, Phase 2 begins with the implementation of either additional semi-structured interviews or surveys constitute the second phase of fieldwork. The decision of which path to choose within Phase 1 depends on the assessment made at Checkpoint 1. If at Checkpoint 1 more detailed information is needed about the interaction among actors, their attributes and the power dynamics influencing them, then the next step would entail implementing surveys targeting all actors considered relevant for the technological system (i.e. as mapped during the first focus group discussion). Implementation of surveys would allow collecting data for a quantitative social network analysis that would provide a more comprehensive and objective understanding of the interaction among actors, resource mobilisation and power dynamics. If semi-structured interviews and the focus group discussions seem to provide sufficient information for the agency and power analysis, but only specific gaps need to be addressed, then the next step would entail implementing additional interviews with key informants.

During Phase 2, 'Checkpoint 2' is used as a mechanism to make sure valuable information or perspectives obtained from the interviews are not missing. The checkpoint would help identify additional informants/perspectives if required. In the case of surveys such a mechanism is not needed because all actors relevant to the technological system would be approached. Also, the questions included in the surveys would be pre-defined according to a specific template. This is not the case with the interviews, where questions follow a general guide but many of them are improvised during the interview, hence the difficulty of knowing in advance all of the information that will be collected through interviews. In this case a checkpoint helps evaluate the type of content and informants that need to be considered in the next set of interviews until enough information has been collected to move forward.

The next step in Phase 2 entails validating and complementing the information collected either through interviews or surveys during a second focus group discussion. This includes presenting some of the findings after preliminary analysis and discussing these findings with a group of key participants. The focus group discussion marks the end of the second implementation phase. After this we propose a third checkpoint.

The 'checkpoint 3' involves assessing if the information gathered to that point is sufficient to answer the research questions related to legitimation, with particular focus on information about discourses and perceptions that could help evaluate the social acceptance, credibility, interests and expectations around the technology. If at this point more detailed information is needed to study these specific perceptions, then the next step would entail setting up exercises with a set of actors to implement the Q-method, a statistical method for analysing conflicting discourses around particular issues (see Section 3.2.4). These exercises would constitute the third and last phase of fieldwork envisaged in the toolkit.

We now provide a brief overview of each method used for primary data collection included in the toolkit. There are of course pros and cons to each method, which should also be considered in advance. Table 1 lists some of these considerations. Capacity, time and budget available to support on the ground activities are also an important condition to decide whether the implementation of the entire toolkit is feasible, or a sub-set needs to be prioritized and adapted to the case study.

**Table 1: Advantages and disadvantages of each primary data collection method in the toolkit**

| Method | Advantage | Disadvantage |
|---|---|---|
| **Semi-structured interview** | • Flexible and tailored to the informant<br>• In-depth discussion on topics of interest<br>• Can use a range of questions to study different angles of the same issue<br>• Can be combined with observation if implemented in the setting of the informant | • Targets only a small sample of key informants, which means that the information gathered is biased (also by the point of view of the researcher/ observer)<br>• Requires more time to transcribe and analyse<br>• Requires experience and good understanding of the background topic and the informant to ask improvised questions |
| **Survey** | • Structured predefined questions, thus needs less experience to improvise in-depth questions<br>• Requires less time to transcribe/ tabulate the responses<br>• Data gathered from the whole network of actors relevant to the technology, which allows for more comprehensive, objective, and quantitative SNA<br>• Ability to systematically compare answers | • Requires more time to complete the implementation of all the surveys<br>• The data generated for the SNA require tabulation and cleaning, which takes additional time<br>• Questions may limit the depth of the information collected, and information may be missing if all questions are not answered appropriately<br>• Response rate is often very low |
| **Focus group discussion** | • It can generate rich information if well facilitated, complementary to the type of information you could gather in a one-to-one setting<br>• Cost-effective use of resources to gather information from a range of actors<br>• Useful setting for participatory group exercises (e.g. qualitative social network mapping) | • Requires preparation and development of specific questions and/or exercises to have a focused discussion<br>• Requires inviting all participants in advance and making sure they can all come<br>• Information gathered represents a biased (subjective) perspective from the set of invited participants |
| **Q-method** | • Allows building a topology of discourses/ perspectives in relation to a specific issue | • Requires several engagements with the participants to collect/ validate statements and then to implement the exercise |

*Source: Authors' own*

### 3.2.1 Semi-structured interviews

Semi-structured interviews include a set of questions based on a structured interview template that can be tailored to different types of actors (Bryman 2012). In addition, many additional questions are phrased *in situ* as a reaction to the information shared by the interviewee. Interviews therefore vary according to the actor's role in the technological system. We suggest structuring the interview questions according to the different components of the integrated analysis (see Section 3.1) to gather information on different socio-institutional aspects affecting the technology development, diffusion and use in the case study. If possible, the interview should be conducted in the working environment of the interviewee. Being in the environment of the informant helps complement the information collected with observations. These observations – particularly in the case of technology adopters – can help generate further information/ questions during the interview process. Interview responses should be transcribed if possible and translated if necessary for the analysis.

Semi-structured interviews are implemented on an individual basis with a sample of actors considered relevant for the technology under study. Actors refer to ‘organisations’ (e.g. a government agency, a company, a non-profit organisation, etc.) or ‘social groups’ (e.g. an association of farmers, a village leadership group, a network of businesses, etc.). Actors are sampled according to their position in the technological system and its wider environment to make sure representatives of all roles are engaged (i.e. actors relevant to the market chain, the business and policy environments). The list of actors to be interviewed is completed during the first and second implementation phases. Ideally the actors interviewed should have at least 3-5 years’ experience working in the organisations (or social groups) that they represent.

### 3.2.2 Focus group discussion

A focus group is an organised discussion with a group of individuals to understand their views and experiences of a particular issue, including where consensus and disagreement lie (Bryman 2012). The focus group discussions we propose in the toolkit engage a selected group of actors playing a key role in the technological system under study. The participants could be selected from the pool of interviewed actors and/or additional participants could be invited. Ideally, the participants engaged in the focus group discussions should fulfil the following criteria: they (1) represent different positions in the technology market chain, the business and policy environments, (2) have knowledge about the technological system, (3) have a good understanding of the market function, and (4) can provide a good overview of the actor landscape.

The first focus group discussion is conducted at the end of the first implementation phase. The specific objectives of this focus group discussion are: to (1) validate the list of actors relevant to the technological system, their role and the resources they control that could be mobilised to support the socio-technical transition, and (2) get an overall picture of actor interactions and power dynamics by mapping networks of existing collaboration and resource exchange among the actors. Two participatory mapping activities are envisaged in this first focus group discussion to achieve these objectives. The first exercise aims to develop a system map that includes positioning the actors and their roles in relation to the technological supply chain, policy and business environments. The second participatory exercise aims to produce social network maps that show resource distribution among actors, and multiple connections among them in terms of collaboration and resource flows.

The discussion and maps generated in the first focus group discussion are combined with the interview responses to better understand the social network in the technological system, identify key actors who could potentially be ‘agents of change’ supporting the transition, and provide insights into how this agency could be enhanced. The maps of resource flow among actors also inform the power analysis.

The second focus group discussion is implemented at the end of the second implementation phase. The objectives of this focus group discussion are: to (1) present the analysis of information collected through the interviews (surveys if applicable) and the first focus group discussion, (2) receive feedback on the findings, and (3) fill out possible gaps with complementary information shared by the participants. To this end, a set of questions are discussed with the participants after the presentation of key findings. It is possible to implement the Q-method (see Section 3.2.5) in tandem with this second focus group discussion (i.e. after the discussion) to use the opportunity of engaging the participants in this last exercise.

### 3.2.3 Surveys

The surveys are implemented on an individual basis to a list of pre-defined organisations and social groups considered part of the network of actors in the technological innovation system. Development of the list is based on responses obtained from interviews in the first phase and the network maps generated in the first focus group discussion. The surveys are structured questionnaires, which can include closed-ended and open-ended questions. The question lists for surveys are generally shorter than for interviews.

In a similar fashion to interviews, surveys are tailored according to actor type using different survey templates. In addition, surveys include specific tables to collect data for a quantitative social network analysis (see Section 3.2.4). These tables list all actors in the network of the technological system. Using this list, informants are asked to specify the type of interaction they have with each one of the actors in the list and the resources they exchange with them. Survey responses should be tabulated (in case of network data and closed-ended questions) and transcribed (in case of open-ended questions) if possible, and translated if needed for the analysis.

### 3.2.4 Social network analysis

Depending on the data collected, qualitative or quantitative social network analyses could be performed. Quantitative social network analysis (SNA), which entails a statistical analysis of network structure (Diestel 2005, Newman 2010), can be implemented if surveys are conducted. Possible network metrics to consider are network centrality (i.e. the density of the whole network), network hierarchy, node centrality (i.e. based on the number of connections of an actor in relation to others), and a cluster analysis to identify possible group formation in the network. The SNA could also relate these statistics to different node attributes (i.e. actor characteristics) collected through the surveys. The surveys would provide a more complete set of data to conduct a quantitative SNA, particularly if all actors included in the network are surveyed. If only semi-structured interviews are implemented, a more qualitative SNA can be implemented, mainly based on the network maps developed in the first focus group discussion. In both instances, quantitative and qualitative SNA network visualisations could be generated informing the agency and power analysis.

The validated system map is an input for the market function analysis. The system mapping follows the structure suggested by the system map framework approach, and includes distinct processes in the market chain, and the actors in relation to these processes. According to Albu and Griffith (2006), the participatory development of system maps can provide a shared understanding of the technology that is valuable for both participants involved in the mapping exercise as well as researchers aiming to analyse the technological system. The system map will help define the components of the technological system, and on that basis, the functions within the system will be analysed (see Nikas et. al. 2017 for details of developing a system map).

### 3.2.5 Q-method

Q-method is a statistical analysis applying a form of factor analysis to q-sorts, which entail a set of statements in relation to the technology (e.g. expectations, interests, pressures, and appropriability of the technology) generated by the participants and collected through the interviews and/or surveys. Analysis of q-sorts allows social discourses to be identified, generating a small number of consistent perspectives, called *factors*. It also provides information about which respondents 'fit' which discourse - a potential measure of how different stakeholders are aligned to a common perspective, and of conflicting discourses around the technology. Generally, Q-method analysis reports the variation explained by the factors, the number of actors associated with each factor (known as 'loading') plus number of actors not associated ('non-loading'), and the scores for each factor.

After refining the set of statements to use as inputs, the Q-method is implemented with a group of key actors – possibly the same sample of actors selected for the second focus group discussion if the Q-method is applied in tandem. To facilitate the Q-method implementation, it is possible to use cards in combination with a set of questions prepared in advance to engage the participants in reacting to the selected statements. The data and analysis obtained through this method mainly inform the legitimation analysis, although information on the discourses and the number and nature of actors sharing a common perspective (i.e. loading on each factor) is also relevant for the power analysis.

## 3.3 Implementation in the case study

To provide an example application of the integrated approach, we applied the toolkit in one of the TRANSrisk case studies. We decided to focus on the Indonesia study, where rapid economic growth, heavy dependence on fossil fuel for energy generation and rapidly rising carbon emissions, make socio-institutional change even more necessary if low carbon pathways are to be pursued. This section provides a short description of the case study, the technology and research questions in focus, and the way we adapted and applied the toolkit. Some of the details in this section and in later sections draw heavily on the Indonesian component of deliverable D3.2, which presented the context of 14 country case studies.

## 3.3.1 Application case: context

Indonesia is a country of more than 17,000 islands[2] which are home to more than 250 million people.[3] Having emerged from a military dictatorship in 1998, the country has made some significant progress since 2000. Its human development index[4] rose from 0.60 in 2000 to 0.68[5] in 2014, positioning the country better than some of its regional peers. GDP has also been growing strongly, averaging 5.26% per annum between 2000 and 2015 and reaching $861 billion in 2015.[6] This sustained economic growth has, inevitably, also driven up greenhouse gas emissions, which rose from 1,372 million tonnes $CO_2e$ (including land use and land-use change) in 2000 to 1,981 million tonnes $CO_2e$ in 2012, making Indonesia the fifth largest emitter country worldwide.[7] Economic growth is expected to continue in the near future due to favourable conditions and a solid anchorage of the economy in global markets (Elias and Noone 2011).

According to the OECD (2016), the Indonesian economy is mainly fuelled by the services sector which accounts for 56.7% of GDP. The manufacturing sector (21.5%), the agricultural sector (14%) and the mining sector (7.9%) follow in decreasing order. However, the agriculture sector still employs around 41% of the work force in Indonesia[8], and the country is the world's fourth largest coffee producer, the world's third largest rice producer and the world's largest palm oil producer.[9]

Moreover, Indonesia has significant fossil fuel resource endowments. According to the International Energy Agency (2015), the country possesses roughly 40 billion barrels of recoverable crude oil (of which 2.7 billion are proven resources) and roughly 3 tcm of proven natural gas. When it comes to coal, estimates range from 120,000 Mt (including inferred and hypothetic resources) to 8,900 Mt of proven reserves (IEA 2015). The export of those fossil fuel endowments generate important revenues for the Indonesian government. The country is the world's largest coal exporter (IEA 2015) and the world's fifth largest liquefied natural gas exporter (International Gas Union 2016). Revenues from oil and gas in 2014, before the fall of oil prices, were worth $30 billion[10], which accounted for about 20% of government revenues, thus underlining the importance of the fossil-fuel based regime that dominates in the country.[11] That said, Indonesia remains a net importer of petroleum products[12] such as liquefied petroleum gas (LPG) due to the lack of refining capacity and the inability to meet rising demand with domestic production.

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[2] http://travel.nationalgeographic.com/travel/countries/indonesia-facts/
[3] http://data.worldbank.org/indicator/SP.POP.TOTL?locations=ID
[4] The Human Development Index is a composite statistical value given by the United Nations, comprising data such as life expectancy, educational access, health and income.
[5] http://hdr.undp.org/en/countries/profiles/IDN
[6] http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=ID
[7] http://cait.wri.org/historical
[8] http://www.fao.org/fileadmin/templates/tci/pdf/CorporatePrivateSector/Indonesia_-_Private_Corporate_Sector_Investment_in_Agriculture__Final_Report.pdf
[9] http://www.indonesia-investments.com/culture/economy/general-economic-outline/agriculture/item378?
[10] Bank of Indonesia. Official Webpage. http://www.bi.go.id/sdds/
[11] Own calculations based on 2016 currency exchange rates based on Bank of Indonesia data http://www.bi.go.id/sdds/
[12] http://www.eia.gov/todayinenergy/detail.php?id=23352

As a strategy to meet domestic demand with domestic production, the government has mandated energy companies to prioritise national economic development, and deliver a certain share of their production to the domestic market under the new government's Domestic Market Obligation (PwC 2016, Tharakan 2015). It is important to note that the domestic energy market in Indonesia is heavily subsidised. Despite the Indonesian Government recently deciding to scrap most of its gasoline and diesel subsidies, IDR 73.1 trillion (roughly $5.4 billion) was paid in electricity subsidies in 2015, and IDR 23.6 trillion (around $1.7 billion) in LPG subsidies (Pradiptyo et al. 2016).

Based on the above, it is evident that addressing Indonesia's carbon-intensive economy and its associated contribution to climate change will demand significant concerted effort. In its Intended Nationally Determined Contributions document, Indonesia sets a 26% emissions reduction target (41% with international help) by 2020 compared to business as usual.[13] Nationally, this has been translated into the National Action Plan for Greenhouse Gas Emission Reduction, which confirms the objectives stated in the Intended Nationally Determined Contributions document and further sets the objective of 29% reduction by 2030 compared to business as usual scenario. In the energy sector, the flagship project of the government is the 2014 National Energy Policy which sets out, amongst other things, a 2025 target for the national energy mix where 30% of energy should be sourced from coal, 25% from gas, 23% from renewables and 22% from oil.[14] For bioenergy, the Indonesian government has set an interim target of a 19% share by 2019[15] and has introduced two targets for 2025, proposing that 30% of diesel consumption should be substituted by biodiesel through blending, and 20% of gasoline demand should be substituted from blending with bioethanol. There are also biodiesel substitution targets of 30% in electricity production and in industrial energy use (GAINS, 2016). In addition, according to the National Action Plan for Greenhouse Gas Emission Reduction, the government has estimated that the agriculture sector can contribute 8 million tonnes of $CO_2e$ to achieve the 26% emissions reduction target by 2020.

It is unclear whether the bioenergy target for Indonesia is feasible given current technological, political and economic conditions. As of 2016, an estimated 8% of biodiesel substituted for diesel in the transport sector, while there was essentially no ethanol used in the transport sector at all (GAINS, 2016). The latter case represents a significant missed opportunity considering that Indonesian ethanol is estimated to reduce greenhouse gas emissions by 67% on average (Khatiwada et al, 2016). Ethanol from sugarcane molasses or cane juice would be the least expensive way to meet the bioethanol target but this would require an enormous expansion in production since use of by-product molasses alone would only substitute 1% of gasoline at current levels (Khatiwada and Silveira, 2017). The biofuel targets are also challenging from the perspective of governance and policy implementation due to Indonesia's complex system of government. Given its vast geography, the country is divided in 34 provinces, which are sub-

[13] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Indonesia/1/INDC_REPUBLIC%20OF%20INDONESIA.pdf
[14] http://www.iea.org/policiesandmeasures/pams/indonesia/name-140164-en.php
[15] http://reneweconomy.com.au/2015/indonesia-sets-19-renewable-energy-target-for-2019

divided into 491 autonomous regions; these autonomous regions are further split into 6,694 sub-district unites comprised of roughly 69,500 villages.[16] Table 2 exemplifies the multiple governmental layers that exist in Indonesia relevant to bioenergy. To date, local people are able to elect their governors directly (Tadjoeddin 2014) and provinces can enact their own regulations and get a share of the revenues from oil and gas exploitation (Aspinall and Fealy 2003).

**Table 2: Government structure in Indonesia relevant to bioenergy**

| Government or traditional structure | Leadership, funding and instruments of authority |
|---|---|
| **National agencies and Ministries**<br>• **Presidential Office of Indonesia**<br>• **National Energy Council**<br>• **Ministry of Finance**<br>• **Ministry of National Development and Planning (BAPPENAS)**<br>• **Ministry of Agriculture**<br>• **Ministry of Energy and Mineral Resources** | A directly elected President is head of the Executive arm of Government, who appoints Ministers to oversee specific policy portfolios.<br><br>Each individual Ministry is headed by an appointed Minister.<br><br>Funding: Ministry of Finance through national budget<br><br>Instruments of authority include: Presidential Decree. Ministerial Regulation. |
| **Provincial agencies**<br>• **Public Works Agency**<br>• **Agriculture Agency**<br>• **Plantation Agency**<br>• **Animal Husbandry Plantation** | A directly elected Governor is head of the provinces. Each individual agency is headed by an appointed Head of Provincial Agency and each division is headed by an appointed Head of Provincial Division<br><br>Funding:<br>- Ministry of National Development and Planning (BAPPENAS) called general allocation budget /Dana Alokasi Umum (DAU) and special allocation budget (DAK)<br>- Development Planning Agency at Sub-National Level (BAPPEDA) called Local Budget Revenues and Expenditures (APBD)<br><br>Instruments of authority include: Governor Decree. Governor Regulation. |
| **Regency or District agencies**<br>• **Public Works Agency**<br>• **Forestry division on Marine, Forestry and Fishery Agency**<br>• **Agricultural Division on Agriculture, Plantation and Animal Husbandry Agency**<br>• **Plantation Division on Agriculture, Plantation and Animal Husbandry Agency** | A directly elected Governor is head of the provinces. Each individual agency is headed by an appointed Head of Local Agency and division is headed by an appointed Head of Local Division<br><br>Funding:<br>- Ministry of National Development and Planning (BAPPENAS) called general allocation budget /Dana Alokasi Umum (DAU) and special allocation budget (DAK)<br>- Development Planning Agency at Sub-National Level (BAPPEDA) called Local Budget Revenues and Expenditures (APBD) |

[16] http://www.pk.undp.org/content/dam/pakistan/docs/Democratic%20Governance/Federalism/International%20Conference%20Sept13/presentations/Day2/3rd%20Ms.%20Budiati%20pdf.pdf

| Government or traditional structure | Leadership, funding and instruments of authority |
|---|---|
| • Animal Husbandry Division on Agriculture, Plantation and Animal Husbandry Agency | Instruments of authority include: Regent Regulation. |
| **Sub- district agency** | A directly elected Head of Sub-district or Camat is head of the Sub-district.<br><br>Funding:<br><br>- Ministry of National Development and Planning (BAPPENAS) called sub-district allocation budget/Alokasi Dana Kecamatan (ADK)<br>- Development Planning Agency at Sub-National Level (BAPPEDA) called Local Budget Revenues and Expenditures (APBD)<br><br>Instruments of authority include: Part of local government regulation in regency and sub-district level. |
| **Village headmen** | A directly elected Head of Village is head of the Village.<br><br>Funding:<br><br>- Ministry of National Development and Planning (BAPPENAS) called village allocation budget / Alokasi Dana Desa (ADD)<br>- Development Planning Agency at Sub-National Level (BAPPEDA) called Local Budget Revenues and Expenditures (APBD)<br>- Badan Usaha Milik Desa (village-owned enterprise)<br><br>Instruments of authority include: Village decree, village regulation. |
| **Banjar headmen** | A directly elected Head of the Sub-village or Kelian Banjar is head of the community / Banjar<br><br>Funding: Village budget<br><br>Instruments of authority include: Awig-awid desa adat (a traditional policy of local customary practices and tradition as villager obligation) |
| **Subak Sawah** | A Head of Subak or Kelian Subak is head of the Subak Sawah<br><br>Funding: Bali Provincial Government budget.<br><br>Instruments of authority include: Awig-awid desa adat. |
| **Subak Abian** | A Head of Subak Abian or Kelian Subak Abian is head of the Subak Abian<br><br>Funding: Independent. Depends on their own production<br><br>Instruments of authority include: Awig-awid desa adat |

*Source: literature review*

This complexity has been furthered by the country's decentralisation policy, which began after the military rule of Indonesia's second President, Suharto, ended in 1998. This governance approach tried to keep the peace between the many ethnic and religious groups in the highly diverse country by transferring some of the governing powers to the provincial level (Aspinall and Fealy 2003, Brauechler 2015). This has allowed for a relatively stable and peaceful transition from an authoritarian regime to a pluralistic democracy, but has come at a price. It has created enormous complexity especially since the division of responsibilities between the national and the regional level are not clear in all cases (Lutrell 2012). Indeed, although the current president Joko Widodo has tried to solidify his governing majority[17], scholars do not see policy making as straight forward in Indonesia, since elites of the old regime seem to have survived (Teichmann 2016) and policies are made often under difficult political circumstances reflecting competing interests (Datta 2011). Moreover, the process of decentralisation has incentivised rent-seeking by local elites (Wever 2012) and decreased accountability amongst leaders (Aspinall and Fealy 2003). As such, Indonesia ranks low on Transparency International's corruption index and is amongst the worst countries to start a business according to the World Bank.[18]

### 3.3.2 Application case: research focus

In the context of Indonesia, we focus on biogas as one of the bioenergy technologies that could contribute towards the achievement of the country's carbon emissions reduction target and, in general, the transition to a low-carbon future. Biogas has been implemented in Indonesia with increasing attention and success since 2009. Furthermore, unlike liquid biofuels that rely on major national efforts, biogas deployment occurs at smaller scales and relies more on bottom-up implementation processes whose achievement seems more amenable to Indonesia's decentralised institutions and governance. We consider that biogas is a promising technology because it uses available agricultural waste as an input, and its use for cooking has the potential to reduce not only the dependence on LPG, but also on firewood. According to the World Bank (2013), about 40% of all Indonesian households used traditional biomass (firewood) as their primary cooking fuel between 2005 and 2010, with a peak of around 49% in 2007. Both firewood and LPG are a large source of greenhouse gas emissions in the country and biogas is considered a simple and relatively affordable technology (when compared to second generation biofuels, PV solar energy and wind) that can be introduced at the household level to reduce carbon emissions. According to the National Action Plan for Greenhouse Gas Emission Reduction, the national government estimated that biogas can contribute reductions of 1.01 million tonnes $CO_2e$ towards achieving the 26% emissions reduction target by 2020. One biogas unit of $6m^3$ capacity has been estimated to reduce 3.2 tonnes $CO_2$/year according to Gold Standard (Vorley et al. 2015) . Based on estimates produced by Yayasan Rumah Energi, an Indonesian biogas development organisation, there is a potential of two million $6m^3$ biogas digesters in Indonesia, which would be equivalent to a reduction of 6.4 million tonnes $CO_2$/year.

[17] https://www.bloomberg.com/news/articles/2016-07-25/jokowi-hits-his-stride-in-indonesia-with-wins-on-policy-police
[18] http://www.doingbusiness.org/rankings

Potential biogas users are mainly located in rural areas of Indonesia because the biogas technology requires livestock manure as feedstock input. The benefits of biogas in terms of fuel substitution are also more evident in rural areas, where in addition to using subsidised LPG, farmers are also still heavily dependent on firewood for cooking.

Within Indonesia, the Province of Bali was a particularly interesting case to study because the adoption of biogas was promoted by four different programmes, each one influenced by several socio-institutional factors. The first programme is an integrated farming programme called SIMANTRI, which was introduced by the provincial government in 2009 to diversify the local rural economy and increase revenue in the agriculture sector. SIMANTRI was promoted by the Bali provincial government as part of a series of activities undertaken under the Governor's Green and Clean programme adopted in 2010. The Clean and Green programme aimed at boosting the green economy in the province, while improving waste management and raising environmental awareness. Zero waste practices in the agriculture sector were therefore promoted as part of this programme. As a result, biogas was promoted as a way to manage livestock manure in the island and introduced under the SIMANTRI programme.

Biogas is not only supported by the Bali provincial government through the SIMANTRI programme, but also by national programmes expanding in Bali. One is the Indonesian Domestic Biogas Programme called 'Biogas Rumah' (BIRU) introduced in 2009 at the national level, with the support from the Netherlands Embassy and the non-governmental organisations (NGOs) HIVOS and SNV. This programme uses a market-based approach including carbon credits to promote the development and adoption of biogas technology. The other programme is funded by the Ministry of Energy and Mineral Resources and implemented in different provinces, including Bali, by the Provincial Public Works Agencies. In Bali, this national programme, which we refer to as the Public Works programme, was introduced in 2015. Finally, the fourth programme, funded by the Ministry of Environment and Forestry and launched in 2013, provided biogas to farmers around the West Bali National Park. Table 3 provides a more detailed description of these four biogas programmes in Bali.

**Table 3: Current biogas programmes operating in Bali (and in Indonesia)**

| | SIMANTRI | PUBLIC WORKS | BIRU | WEST BALI NATIONAL PARK |
|---|---|---|---|---|
| **Year of introduction in Bali** | 2009 | 2015 | 2009 | 2013 |
| **Description** | Integrated farming that includes a biogas system. Communal bio digesters are installed for farmer associations, which also receive cattle whose waste is fed into the biogas digesters. Guarantee period: 3 months. | Individual biogas digesters are installed in farmer households that own livestock and show potential and interest. Guarantee period: 3 months. | Individual biogas digesters are installed in farmer households that own livestock. Guarantee period including maintenance services: 3 years. | Pilot project provided livestock and bio digesters to farmers around the West Bali National Park to discourage firewood collection. |

| | | | | |
|---|---|---|---|---|
| **Implementing Agencies** | The project was initiated by the governor of Bali. The Bali Provincial Agricultural Agency is the lead implementing agency. Others such as Udayana University and YRE (CPOs) joined programme in 2013 to provide backstop. | Public Works is the lead implementing agency. Receives support from the Agricultural and Livestock agencies at the regency level. | SNV Netherlands and HIVOS launched the programme. In 2012 HIVOS created Yayasan Rumah Energi (YRE) to operationalise the programme. YRE is now more independent and follows a market-based approach. | The West Bali National Park authority is the lead implementing agency, with support from the forestry agency operating in Jembrana Regency. |
| **Funding** | Provincial budget, approx. 225 mio IDR per communal installation (incl. biogas). Programme is 100% subsidised and farmers do not pay for the biodigester installation. | Funding comes from the national government (MEMR) Provinces can request for MEMR budget to be allocated for biogas projects. Programme is 100% subsidised | Multiple streams of funding, including HIVOS, credits from the EU carbon market, governments (Indonesian & indirectly: Dutch), and public-private partnerships. Carbon market subsidizes 20% of the biogas installations, adopter farmers also pay part of the costs. | Ministry of Environment and Forestry provides funds that go directly to Jembrana Regency where the national park is located. |
| **Biogas Installations** | 632 biodigesters installed as of Oct 2016. Tentative target: 1000 by 2018.<br>Farmers also produce biourine and bioslurry as part of the integrated farming system. | 57 biodigesters installed in Jembrana Regency. | 16,000+ biodigesters installed as of Nov 2016 in 9 provinces of Indonesia.<br>Target: 100,000 units by 2020 (also the estimated break-even point to make the project commercially viable) | Only a few pilot projects have been implemented around the national park.<br>Farmers are also experimenting with vermiculture in the bioslurry with commercial purpose. |

*Source: interviews, focus group discussions, programme websites*

Another reason for choosing to look at biogas in Bali is that the agricultural sector in Bali is changing, particularly as the province becomes increasingly dependent on tourism for revenue. This shift represents both challenge and an opportunity for biogas. In 2014, almost 3.8 million people visited Bali and tourism was one of the main sources of revenue for the island.[19] Agriculture is the second largest contributor to Balinese GDP, yet is the single largest employer. However, since wages are low in the agricultural sector, young people (in particular) are drawn to the service and tourism sectors and are leaving their land and agricultural practices. Conversely, new agricultural practices that are deemed eco-friendly are also emerging, driven by the demands of the tourism industry.

Land use change, changes in the labour market, different biogas programmes and institutional interests explained above add to the socio-institutional dynamics that may impact the biogas technology and make Bali a particularly interesting case to study. To guide our analysis, we formulated the following research questions:

[19] http://www.thejakartapost.com/news/2015/01/27/tourist-arrivals-bali-reach-376m-2014.html

(iv) What are the actors, networks and institutions relevant to the biogas technological transition in Bali? Why are they relevant, and why are these actors interested in biogas? Which ones could play an important role in enabling the transition pathway(s)?

(v) What is the current performance of the biogas technological system? How are agency, power and institutions affecting this performance by creating either bottlenecks or opportunities?

(vi) What socio-institutional drivers and enabling mechanisms could support the potential growth of biogas in Bali in the future, taking into account forces playing out in the broader context?

### 3.3.3 Application case: methods

The methods implemented in the case study for the integrated analysis involved semi-structured interviews and focus group discussions. To date we have concluded the first implementation phase of the toolkit and started with the second. We intend to finalise the second fieldwork phase with a workshop in Bali during the week of 22-26 May 2017. The third phase may be implemented in 2017, although the application of the Q-method is still up for discussion once we reach checkpoint 3. Given that the Q-method has not been implemented yet, the results generated with the integrated analysis focus more on agency, power and market function, and less on technology legitimation.

The first phase of fieldwork involved a total of 20 semi-structured interviews, which were implemented during October to November 2016 in Bali and Jakarta. Within Bali, most of the interviews with government officials were conducted in Denpasar, capital city of the Province of Bali, and in Negara, capital city of the Jembrana Regency. We focused on the Jembrana Regency, because it is one of the regencies in Bali with the highest number of livestock, and hence potential for biogas. In addition, the four biogas programmes were operating in this regency (including the West Bali National Park programme). The actors we interviewed included: 1 national and 5 local government agencies, 5 representatives of the private sector, 1 international and 1 local non-governmental organisations, 5 farmers that had adopted biogas, and 2 farmers that had not yet adopted biogas (See Table 4). The interviews with farmers were all conducted in the Jembrana Regency.

The interviews included questions to: (1) identify actors considered relevant to the biogas technology development in Bali, (2) validate the biogas system map using the system map framework, (3) gather information on prevailing policies and strategies supporting biogas, (4) collect views on social acceptance, interests and expectations associated with the technology, (5) identify drivers enabling or hindering the biogas market development and the use of biogas in households, and (6) understand the results or transformations observed with the adoption of biogas technology on the ground. Interview guidelines and templates tailored for each type of actor were prepared and included in the toolkit adapted for Indonesia. Interview guidelines were also prepared to guide the interviewers and translators supporting the fieldwork (see Appendix 1). Interview responses were translated and summarised in English for subsequent analysis. Quotes provided in this report are extracts of the response summaries in English.

Table 4: Overview of interviewed stakeholders in the Indonesia case study

| Sector | Code | Position | Organisation, Location | Perspective |
|---|---|---|---|---|
| **Government & Funding** | 01.Gov.N | Management position in Indonesia Climate Change Trust Fund (ICCTF) | National Development Planning Agency (Bappenas), Jakarta | National bioenergy policy and funding |
| **Government & Funding** | 01.Gov.S | Management position in the Agency | Bali Provincial Agriculture Agency, Denpasar | SIMANTRI programme |
| **Government & Funding** | 02.Gov.S | Management position in the production & plantation division | Department of Forestry, Agriculture and Plantation, Jembrana | SIMANTRI programme |
| **Government & Funding** | 03.Gov.S | Management position in the agriculture production division | Department of Forestry, Agriculture and Plantation, Jembrana | SIMANTRI programme |
| **Government & Funding** | 04.Gov.S | Management position in the Agency | Public Work Agency, Jembrana | Public Works programme |
| **Government & Funding** | 05.Gov.S | Senior Staff in the Agency | Forestry Agency, Jembrana | West Bali National Park programme |
| **Government & Funding** | 06.Gov.S | Village Head | Tukad Aya Village | Village head involved in selection of potential farmer candidates. |
| | | | | |
| **Private & NGO** | 01.Pri | Technician | BIRU Construction Partner Organization (CPO), Denpasar | BIRU programme |
| **Private & NGO** | 02.Pri | Project manager | Gasifikasi Prima Energi, Denpasar | BIRU programme |
| **Private & NGO** | 03.Pri | Lawyer | DnD Consultant, Jakarta | Funding for bioenergy (biogas) |
| **Private & NGO** | 04.Pri | Researcher | Udayana University, Jimbaran | Research on biogas technology |
| **Private & NGO** | 05.Pri | Researcher | Udayana University, Jimbaran | Research on biogas technology |
| **Private & NGO** | 01.NGO | Management position | Bali Organic Association (BOA), Denpasar | Support on biogas installation and use |
| **Private & NGO** | 02.NGO^ | Management position | Yayasan Rumah Energi (YRE), Jakarta | BIRU programme |
| **Private & NGO** | 02.NGO^ | Management position | HIVOS, Jakarta | BIRU programme |
| | | | | |
| **Producers (Adopters)** | 01.Prod.A | Farmer | Tukad Aya Village | Biogas adopter, support from Public Works programme |
| **Producers (Adopters)** | 02.Prod.A | Farmer | Tukad Aya Village | Biogas adopter, support from Public Works programme |
| **Producers (Adopters)** | 03.Prod.A | Farmer | Tuwed Village | Biogas adopter, support from SIMANTRI |

| | | | | |
|---|---|---|---|---|
| | | | | programme |
| **Producers (Adopters)** | 04.Prod.A | Farmer | Tukad Aya Village | Biogas adopter, support from Public Works programme |
| **Producers (Adopters)** | 05.Prod.A | Farmer | Blimbing Sari Village | Biogas adopter, support from West Bali National Park programme |
| | | | | |
| **Producers (not adopters)** | 01.Prod.NA | Farmer | Tukad Aya Village | Sent a proposal for biogas installation, still waiting for response |
| **Producers (Adopters)** | 02.Prod.NA | Farmer | Tukad Aya Village | Sent a proposal for biogas installation, still waiting for response |

Note: ^ indicates joint interview.

To complement data obtained with the semi-structured interviews, we conducted a focus group discussion in Bali in November 2016. The specific objectives of this focus group discussion were: (1) to validate the list of actors relevant to the biogas technological system, their role and the resources they control that could be mobilised to support the transition to biogas, and (2) to get an overall picture of actor interactions and their needs by using a participatory exercise to map existing collaboration and resource flows among the different actors. A total of 12 participants were engaged in the focus group discussion, which included not only selected interviewees, but also new participants that were invited based on the criteria indicated in Section 3.2.2. During the workshop we divided participants into two focus groups of 6 actors each: FG1 and FG2. Each focus was comprised of a mix of government, private sector and civil society representatives. Due to the distance to the workshop venue (Udayana University), farmers we had interviewed in Jembrana Regency were not able to participate. This was unfortunate, and is definitely considered a limitation of the focus group discussion network analysis. However, we hope to overcome with further fieldwork in the coming months.

To achieve the first workshop objective, we provided each focus with a list of actors that were perceived to be relevant to biogas in the context of Bali. The list was based on the interviews, and participants discussed and complemented this list by suggesting additional actors. Next, participants discussed the role each actor played in the biogas system by identifying their position and contribution either to the policy environment, the biogas market chain, or the business environment - using the three categories suggested by the system map framework.

Following this, we discussed resources that are important to support the potential growth of biogas in Bali. While we recognised the varied range of resources (according to Avelino and Rotmans 2009), we decided to focus mainly on techno-scientific information and financial resources. This decision was based on time constraints and the following interview insights:

- According to the participants, technical and scientific information was not controlled by many, and the actors that controlled it had more power to make changes/ influence decisions,

- Participants perceived that actions to support the biogas technology development were only possible with monetary support, i.e. actors did not seem to be willing to take action without funding support.

In addition to resources, we also discussed the level of authority associated with each actor as perceived collectively by the participants. For authority we referred to 'legitimate authority' as a property that gives actors the ability to dictate or influence decisions on resource mobility, e.g. authority in making demands upon the behaviour of others through legislation or regulation enforcement (Smith et al. 2005b).

To achieve the second objective of the focus group discussion, we worked in groups to map with the participants the networks of collaboration and resource flow among the actors. This involved drawing bi-directional connections (for collaboration) and directional connections (for information, financial and authority flows) among the actors in the network. The guidelines we used for the mapping exercise in the two focus groups are included in Appendix 2. The networks generated in the workshop were further analysed in terms of centrality, network hierarchy, and node centrality (See Section 3.2.1). We used the R software for statistical computing and graphics (igraph package)[20] for this analysis, albeit recognising that the participatory network maps were rather qualitative in nature, and hence a quantitative analysis was not applicable. The degree centrality analysis and interview responses were combined to inform the different components of the integrated analysis.

[20]https://rstudio-pubs-static.s3.amazonaws.com/74248_3bd99f966ed94a91b36d39d8f21e3dc3.html

# 4 RESULTS

## 4.1 Case study findings

The interview responses were combined with the network maps to generate a better understanding of the agency, power and institutional factors influencing the transition to biogas in Bali. In this section we provide a summary of the key findings focusing mainly on: (1) the motivations driving the biogas technology, (2) the agency and power dynamics affecting biogas development and adoption, and (3) the socio-institutional bottlenecks and opportunities influencing the biogas market function.

### 4.1.1 Motivations driving the biogas technology

Agency in support of a technological transition is driven by motivations. Understanding these motivations helped elucidate the expectations attached to the technology, i.e. the changes expected to be seen with this technology, as well as the different belief systems underpinning these expectations. This provided us information that we can use for the legitimation analysis that will follow in May 2017. Given the range of actors involved in supporting biogas in Bali, and in Indonesia in general, the motivations varied widely. We tried to capture this diversity to identify synergies that could be produced by aligning actors that have similar motivations. Tensions could also emerge in the future if motivations are very disparate or even contradictory.

The interview responses showed that the four biogas programmes currently implemented in Bali were driven by very different motivations. The SIMANTRI programme was mainly driven by economic development expectations. The programme was concerned with the creation of additional income and livelihood for local farmers in Bali. To this end, the programme supported the production of livestock for domestic consumption and export. Far from considering biogas as an alternative energy source to enhance the SIMANTRI programme, the technology was mainly introduced to deal with the excess waste generated by the increasing livestock, and thus be in line with the Governor's Bali Green and Clean programme,

> *"… the integrated farming system was a way to support the development of the livestock sector with more Balinese cows and provide farmers with an additional livelihood, job and income. From this perspective, the biogas component was included in the package only as a way to manage the waste (manure)… It [biogas] was not necessarily thought as a business, or a bioenergy alternative. Biogas was not perceived as a business, because they [the local government] realize it cannot fight LPG. But it was considered as an option to deal with the waste and generate better fertilizer"* [05.Pri, Professor at Udayana University, 29 November 2017].

The BIRU programme was mainly driven by environmental and human development concerns. The core of the programme was to enhance energy security and reduce carbon emissions, and hence the production of biogas was closely connected to the carbon credit market through a centralised system managed by the international non-governmental organisation HIVOS and Yayasan Rumah Energi (YRE). Further, the BIRU programme focused specifically on domestic biogas in order to address the lack of access to economical and convenient energy sources by many farmer households in Indonesia. Although the principal motivations are driven by environmental and human development concerns, the implementation of this programmes relies on a market-based approach, which demands economic efficiency and financial investment from the adopters. While initially BIRU was mainly supporting biogas generation at the domestic level, YRE has recently expanded their work to support also businesses or industrial companies.

The West Bali National Park (WBNP) programme was also driven by environmental concerns, although from a slightly different perspective. While the BIRU programme aimed at using biodigesters to reduce the greenhouse gas emissions produced by livestock manure otherwise released into the atmosphere, the WBNP programme aimed at reducing deforestation and forest degradation by replacing the use of firewood with biogas. The latter would also result in carbon emission reductions. To achieve its purpose, the WBNP programme mainly targeted households of farmers living in the buffer area of the West Bali National Park who were entering the national park to collect firewood for cooking.

The Public Works (PW) programme was mainly driven by the national policy mandate to increase renewable energy deployment by 2025. In this case, the main funding and policy driver was the Ministry of Environment and Mineral Resources (MEMR). The national government seemed to be particularly interested in biogas because they recognised the potential and availability of feedstock, as pointed out by the Indonesia Climate Change Trust Fund (ICCTF) in the National Development Planning Agency (Bappenas),

> "*Biogas is a promising bioenergy for Indonesia because we can produce it with our own resources... If we do not use these resources, we will miss an opportunity*" [01.Gov.N, ICCTF, 26 October 2017].

In general, within the policy environment we identified economic, political, and environmental motivations supporting the transition to biogas in Bali. The economic motivations related to revenue generation through available feedstock that otherwise would be wasted and potential savings that could be achieved by replacing LPG and synthetic fertiliser with biogas and bio-slurry (a by-product of biogas). Additional revenues were identified through the carbon credit market. The BIRU programme, which has been active in this market, estimated that 100,000 biogas units would cover 100% of their operational costs. In terms of environmental motivations driving biogas, policy actors mentioned waste management, reduction of firewood use and carbon emissions reduction to mitigate climate change.

The main political motivation at the national level was the mandate to support renewable energy to achieve the 2025 national bioenergy target. At the provincial level, the main political motivation was the Governor's Bali Green and Clean programme. One concern we observed with the political nature of this provincial programme is that it could very well be disbanded after the Governor's second term ends and a new Governor brings a fresh focus. This is less likely in the case of the national political motivation, although national government support for bioenergy has been recently curtailed by a budget cut that put bioenergy low in the national agenda. Moreover, recent changes in leadership in the MEMR had resulted in a loss of key champions supporting bioenergy development, leaving enterprises interested in renewable energy stranded waiting for renewed political commitment and motivation:

> *"…recently things have changed, there has been a change in the ministries. The Renewable Energy Minister is not there anymore. So now we are a bit in the limbo with a lot of uncertainty. The Ministry of Energy used to have leadership that championed bioenergy, but now the policies and projects supporting renewable energy are frozen. There is no clear direction, are we going to go renewable, are we going to go coal?..."* [02.Pri, Gasifikasi Prima Energi, 25 October 2016]

The low priority given to biogas in the national agenda was also reflected in the lack of a national target for biogas which could support the national 2025 bioenergy target. At the time of the study, national political attention was far from allocating resources to boost alternative energy sources, instead priority was given to socio-economic development, even if that entailed increasing reliance on conventional fuels. This motivation was clearly stated in one of the interviews we conducted to the national government in Jakarta:

> "*The priority for the country is not to reduce greenhouse gas emissions, our priority is development. We have recently created policies to increase domestic coal-based energy consumption for development purposes. That does not mean that we are increasing the production of coal, but instead we are retaining what we used to export, and consuming it within the country. The emissions that we are generating with our coal remain the same. The difference is that before we used to export these emissions, now they are used in our power plants and are accounted for domestically*". [01.Gov.N, ICCTF, 26 October 2016].

Among the actors involved in the biogas market chain, the motivations were mainly driven by economics. Some of these motivations linked to savings generated by using biogas for cooking, while others related to additional income that could be produced by adopting biogas (e.g. by selling the bioslurry). Unsurprisingly, many private sector representatives highlighted that profitability was an important driver for any technological generation in Indonesia/Bali. It is important to say is that many farmers seemed to show interest in having a biogas installation at the household level. In the Tukad Aya village, where we conducted some interviews with technology adopters, 70 applications were submitted to the Public Works programme. Motivations driving the use of biogas for cooking included:

- The availability of feedstock,
- Perceptions of risk of explosion associated to LPG and kerosene use,

- Access to an alternative source of cooking fuel for farmers that are poor and cannot afford LPG (even if subsidized),
- The savings generated by consuming less LPG,
- Additional income by using waste to produce and sell bio-slurry, and
- Developing new businesses if biogas becomes more widely adopted and its electricity generation potential is better exploited.

In addition to economics, other motivations driving the market chain actors were more social and environmental in nature. For example, interviewees noted that, among other reasons, biogas was adopted by farmers to address complaints by neighbours about the smell of animal dung. Biogas adopters also indicated that they were curious about the technology when they saw it implemented by other farmers. Another motivation mentioned repeatedly was the possibility for women to save time when biogas is adopted. Instead of using time to collect firewood, women in households with biogas installations had reportedly saved two hours a day. This enabled them to spend more time with their children, attend village meetings and get involved in craft activities (Guntur 2015). Biogas operators, particularly those working closely with YRE under the BIRU programme, also mentioned the biogas contribution to climate change mitigation as a motivation driving their actions.

Finally, within the business environment motivations varied, but were mainly related to environmental concerns, human health safety and economics. Researchers at Udayana University mentioned, for example, that their main motivation to support biogas in Bali was human health safety and environmental safety:

> "*our interest is to make sure we are not wasting biogas and aggravating the climate change problem. And make sure it is not harming people. This is why we are working on purification and storage technology to make the biogas technology safe, and make biogas available when people can make use of it when they need it. Our concern is safety and climate change*" [05.Pri, Udayana University, 29 November 2017].

Waste reduction and re-use was also mentioned several times throughout the interviews with actors in the business environment. In terms of economics, biogas technology was recognised as relatively cheaper than other technologies (e.g. solar energy) and more feasible to implement based on locally available materials. The idea of energy security was emphasised by researchers who saw biogas as a complementary source of energy and not necessarily as an alternative that will replace conventional energy. This implies limits to the extent which biogas can actually displace conventional energy fuels.

### 4.1.2 Agency and power dynamics affecting biogas

In this section, we look at how actor agency and power dynamics have affected the development of Indonesia's biogas sector. To analyse agency, we begin by looking at the actors and how they collaborate with each other. To analyse power dynamics – particularly how power exercised by actors – we look at the distribution of power resources within the network of actors in the biogas sector and how those resources are utilised.

#### 4.1.2.1 Agency and collaboration

We started the agency analysis by identifying the actors who were relevant to the biogas technological system in Bali, and understanding the roles these actors played from the perspective of the focus group participants we engaged in the network mapping. Most of the actors listed by the first and second focus groups (FG1 and FG2 respectively) were the same because the focus groups used the actors identified through the interviews as a common basis. Combining the list of actors generated in the focus groups, we obtained a total of 41 actors relevant to biogas technology in Bali (see full list in Appendix 3). FG1 listed 18 actors in the policy, 5 in the market chain, and 14 in the business environments (total 37 actors). The FG2 listed 17 actors in the policy, 6 in the market chain, and 15 the business environments (total 38).

In the collaboration networks mapped by the focus groups, the actors with highest centrality were the *farmers* (Figure 4). This is interesting considering no farmers were able to attend (due to travel constraints, as noted in section 3.3.3); this is a limitation we plan to address engaging more farmers in upcoming fieldwork planned for May 2017. The centrality of farmers in the collaboration networks is most likely explained by the fact that farmers were the main target beneficiaries of all four biogas programmes currently operating in Bali. Indeed, farmers were the main operators and consumers of biogas technology, which was deployed both at the household level and, in the case of the SIMANTRI programme, at the community level through farmer associations. As a result, farmers were connected to the main technology providers and government agencies financing the installations, as well as to NGOs and businesses in the private sector that were interested in supporting biogas uptake. Farmers were also connected to credit schemes, such as KIVA or Bank BPD, sometimes through their village leaders or with support provided by the BIRU programme (Figure 4a).

Other actors that showed high centrality (>5 connections) according to the collaboration networks were *Bappenas* (FG1), *Academics* (FG1), *Bali Provincial Agriculture Agency* (FG2), and *YRE* (FG2). The perceived role of the National Development Planning Agency (Bappenas) was to approve the funding that came from the MEMR to the Bali Provincial Public Works Agency for the implementation of the Public Works biogas programme. The role of academics was to conduct research on ways to improve and deploy biogas technology, ensure environmental and human safety, and provide advice and technical backstop to government-led programmes. For example, in 2013 researchers at the Faculty of Material Engineering in Udayana University joined the SIMANTRI programme to improve the functioning of biogas installations and address problems such as stove corrosion, biogas leakage, storage and distribution, and eventually pilot biogas-based electricity generation.

The other two central actors were perceived as the implementation heads of the SIMANTRI and BIRU programmes respectively. The role of the Bali Provincial Agriculture Agency was to act as the main implementation leader of the SIMANTRI programme with support from other provincial government agencies. Similarly, YRE was perceived as the key implementation partner leading the BIRU programme. When YRE was created in 2009, its main role was to focus exclusively on the introduction of biogas technology in Indonesia. Over time, YRE has expanded to encompass other businesses, albeit maintaining household-level biogas at its core. Under the BIRU programme, YRE worked in collaboration with construction partner organizations (CPOs) to implement the biogas projects in the provinces.

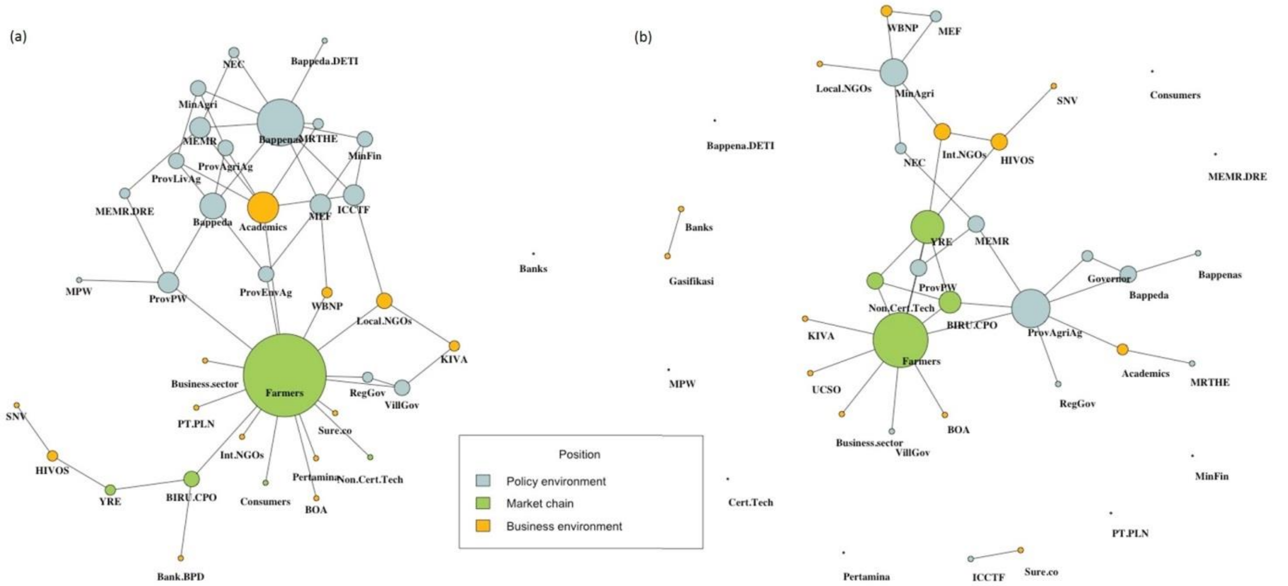


**Figure 4: Collaboration networks showing actors supporting biogas in Bali as perceived by (a) the Focus Group 1 and (b) the Focus Group 2.**

Notes:

The size of the actor node depends on the number of connections of that actor, i.e. the more connections, the larger the node and the more central the actor becomes to the biogas technological system. Node colour relates to the position of the actor in relation to the structure suggested by the system map framework. Actor full names and acronyms are provided in Appendix 3.

Not all actors were well connected in the collaboration networks. Some actors were very weakly connected or not connected at all. *Banks* were actors that were isolated in both the FG1 and FG2 networks which echoes arguments found in literature. Penetration of banks seemed low particularly in rural areas, and many day-to-day financial transactions were carried out without any banks. We also observed that interest rates on loans were very high in Indonesia, ranging between 18-20% a year, and making it difficult for farmers and small-scale business to access credit.

Nevertheless, participants identified mostly state-owned banks like BNI, BRI and Mandiri as potential supporters of biogas technology if conditions to enable credit accessibility would improve. Several credit barriers were mentioned by the private sector informants we interviewed. They mentioned the risk banks perceive in investing in small-scale businesses that may not generate revenue, the fact that farmers often lack a guarantee and assets to back their loan, and the poor evidence around a stable demand for biogas. Land tenure was also mentioned as a barrier to credit access. Land titles could be used as an asset by farmers to access credit, however informants reiterated that land tenure in Indonesia is very insecure:

> "*Addressing the land tenure would be the major change you could do at the local level to open up banks to credits without making them change the way they operate entirely*" [03.Pri, Lawyer, 27 October 2017].

An informant even argued that land tenure insecurity is a barrier for any sort of investment in the land, because farmers are reluctant to invest in a land that may be taken away from them in the future.

Other isolated actors (FG2 network) were Pertamina, Perusahaan Listrik Negara *(*PLN), and certified technicians (Figure 4b). These actors were identified as relevant by the participants, not because of their current support to biogas in Bali, but instead because of their potential future role in biogas development. Participants in the FG2 mentioned that currently technicians involved in the biogas installation were not properly certified. Training of technicians was acknowledged, but it seemed that a formal certification scheme was not in place yet. Therefore, participants added certified technicians in the network to make a point that this highly qualified labour is needed to escalate biogas technology in the short term.

Furthermore, FG2 participants suggested that Pertamina could support biogas through its corporate social responsibility portfolio, and PLN could play a critical role to scale up the electricity generation potential of biogas in the future through a feed-in-tariff quota. Both actors play a key role in the current conventional energy regime of Indonesia. Pertamina is the country's main energy supply company and operates nearly all of the country's refining capacity (EIA 2015). Pertamina also accounts for 13% of Indonesia's natural gas production, while the distribution of natural gas is to a large majority managed by the 57% state-owned Perusahaan Gas Negara, and the semi-private company Transportasi Gas Indonesia.

PLN, on the other hand, is the state-owned electricity utility, which operates 70% of generation capacity and retains quasi monopoly on distribution. The PLN is also in charge of implementing the national system of Feed-in Tariffs (FiTs) for renewable energies, where the government pays for the gap between the production cost and the market price. FiTs differ by source, access to the grid and geographical area covered. Generally, FiTs are more attractive in remote areas that are not well covered by conventional energy supply. There are different FiTs for electricity from biomass and from biogas. The recent regulation 21/2016 amended the FiT system for electricity from biogas by simplifying the application process and lifting caps on capacities to allow plants above 10 MW to benefit as well.[21] Although the FiTs system had not been implemented for biogas in Bali at the time of this study – only a biomass gasification project was reported, which was not able to introduce FiTs due to low interest from the provincial PLN and good electrification coverage in Bali - participants emphasized the potential opportunity FiTs could bring to further

[21] http://documents.jdsupra.com/efacf6f9-4423-4819-9412-74d77aef23cb.pdf

develop biogas and scale it up to generate electricity for remote villages or small-scale businesses.

Interestingly, the National Energy Council was not included in the networks, nor mentioned in the interviews we conducted. This was most likely a reflection of weak direct support to biogas in Bali, and possibly Indonesia in general. The National Energy Council was established in 2007 with the aim to design, formulate and oversee the implementation of energy policy in Indonesia. This includes the diversification of energy resources in order to secure energy supply when reserves of non-renewable energy resources are limited. Some researchers suggest that making use of such special commissions could be a strategy to influence energy decisions and interests in the ministries (Luttrell et al. 2012).

Overall, the structure of the FG1 collaboration network showed higher density than the FG2 network. In particular, actors in the policy environment mapped in the FG1 network (Figure 4a) seemed to show a tighter structure with more connections, better reflecting the government hierarchies and complexity in Indonesia, but also the involvement of different levels of government supporting biogas in Bali. By contrast, in the FG2 network (Figure 4b) the policy environment actors showed less connections among each other. The YRE and BIRU CPOs seemed to be more centrally positioned, better connected to different types of actors, which reflects what we actually captured about these two actors in the interviews. The role of YRE and the BIRU CPOs as 'bridges' between different types of actors is further elaborated in the section 4.1.4 when looking at potential agents/ strategies to catalyse change.

In general, interviews and network maps showed collaboration among actors within each biogas programme. However, there was little evidence of close collaboration between the different biogas programmes in Bali. Nevertheless, there were indications that showed genuine interest for more open collaboration in the near future. For example, we noticed some collaboration between the Public Works programme and the SIMANTRI programme to exchange data on potential farmer candidates, and to find the biogas stoves produced under the BIRU programme. Furthermore, we observed that HIVOS and YRE were actively supporting the MEMR to increase biogas installations in Indonesia. Also, since 2013, YRE and the BIRU CPOs were increasingly engaged in the SIMANTRI programme to provide technical backstop and support the installation of biogas digesters. Most importantly, there was interest among local actors to engage in dialogue and promote cross-fertilisation between the different programmes, as exemplified by the following statement of a researcher in Udayana University:

> *"I think collaboration should happen naturally. I am happy that BIRU is in place, and I am happy that the SIMANTRI initiative approached me so I could help. I hope there will be a meeting point in the future. Conferences or spaces to discuss biogas that bring all of us together have not taken place yet"* [05.Pri, Udayana University, 29 November 2017].

#### 4.1.2.2 Power dynamics

Power dynamics were explored by looking at the distribution and utilisation of three key resources: knowledge (in particular, techno-scientific information), finance and authority. The interviews and networks maps showed power asymmetries between the actors based on the distribution of all three of these resources. Most actors in the networks had few connections (i.e. only 4 central actors had >5 connections) and most resources were distributed among actors with 1-3 connections. In fact, a large part of the financial resources was concentrated among actors that were only weakly connected in the network with only one connection. This could be seen as a general reflection of limited financial flows supporting technological growth of biogas in the country. In the FG1 network, actors with authority and financial resources were slightly better connected (Table 5). Only very few actors in the networks were perceived to have authority and control over techno-scientific information and funding. These actors were involved in the SIMANTRI programme, and included basically actors in the policy environment, namely the Governor of Bali, the Bali Provincial Agriculture Agency and the Bali Provincial Livestock Agency.

We observed some commonalities between the resource distribution in FG1 and FG2 collaboration networks (Table 5):

- A large part of the networks (30% in FG1, and 40% in FG2) were comprised of actors with 0-1 connections, low level of authority and without techno-scientific information and financial resources to support biogas;
- Actors in the policy environment tended to have more resources than actors in the supply chain and business environments;
- Techno-scientific information was distributed among the policy, supply chain and business environments;
- Authority was mainly held by actors in the policy environment; and
- Financial resources were mainly controlled by actors in the policy and business environments, although both focus groups indicated that farmers in the market chain have financial resources for biogas (albeit limited, and sometimes provided in the form of crops and/or labour).

Table 5: Distribution of authority, techno-scientific information and financial resources in the biogas collaboration networks in Bali.

| Resources | | Policy | Supply chain | Business | Total |
|---|---|---|---|---|---|
| **No resources** | fg1 | 5 | 1 | 5 | 11 |
| | fg2 | 3 | 3 | 8 | 14 |
| **Information** | fg1 | 1 | 2 | 2 | 5 |
| | fg2 | 3 | 1 | 2 | 6 |
| **Authority** | fg1 | 2 | | 1 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| | fg2 | | | | |
| **Financial** | fg1 | 4 | 2 | 5 | 11 |
| | fg2 | 1 | 1 | 2 | 7 |
| **Info & Authority** | fg1 | 1 | | | 1 |
| | fg2 | 1 | | | 1 |
| **Authority & Financial** | fg1 | 3 | | | 3 |
| | fg2 | 5 | | | 5 |
| **Info & Financial** | fg1 | | | 1 | 1 |
| | fg2 | | 1 | 3 | 4 |
| **All resources** | fg1 | 2 | | | 2 |
| | fg2 | 1 | | | 1 |

Notes:

The table lists the number of actors under the policy environment, biogas market chain and business environment that were perceived to have legitimate authority and control resources based on the perceptions of Focus Group 1 (fg1) and Focus Group 2 (fg2).

Technical knowledge and influence appeared to be mainly situated within YRE and academics (linked mainly but not solely to Udayana University), and to a lesser extent within the MEMR (Figure 5). Through the exercise of this kind of power YRE and Udayana University dominated the biogas sector development in Bali in terms of technical/logistical and research/ development knowledge and capabilities, respectively. Over time, YRE have exercised this technical influence to become the go-to technical and logistical partner in biogas. For example, in addition to playing a key role in the BIRU programme, YRE has been approached by the SIMANTRI and Public Works programmes to acquire biogas stoves, and for technical knowledge and support for biogas installation. The research and development capacity of academics was also greatly acknowledged, although some informants from the private sector perceived that academics tended to dominate the debate about new technology with theoretical discussion, sometimes at the expense of a more open discussion that can be more transdisciplinary in nature and provide more room for practical outcomes. These informants highlighted the importance of involving other actors in the discussions that can focus on the economics of new technology in order to develop a business case for wider uptake.

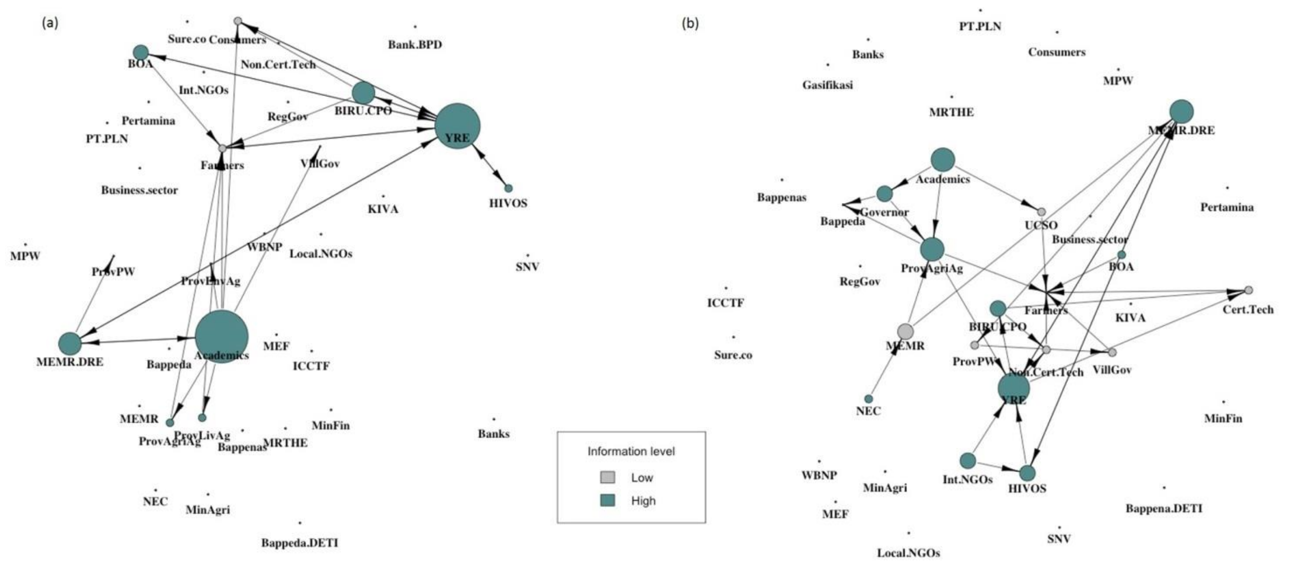


**Figure 5: Flows of techno-scientific information among the actors of the biogas networks in Bali, according to the perceptions of (a) Focus Group 1 and (b) Focus Group 2.**

Notes:

The size of the actor node represents the number of out-going connections from an actor, i.e. the more information is generated and/or shared by an actor, the larger this actor appears in the network map. The actor node is green if participants perceived that the actor controlled high level of information relevant to biogas.

Financial power was largely exercised through provision of full financial support (i.e. SIMANTRI, Public Works, WBNP programmes) or partial funding (i.e. BIRU programme) for biogas installation. As expected, the national and Bali provincial governments were typically viewed as those with most financial power. Udayana University, on the other hand, had more limited financial resources, and academics pointed out that additional grants were needed from the Ministry of Research, Technology and Higher Education to support biogas technological development. International donors also exercised a fair degree of financial power by channelling funds through HIVOS and the BIRU programme. YRE had limited financial resources at their disposal for research, yet considerable funding flows for technical implementation. The financial resources available through BIRU (including those from selling carbon credits in the EU market) were used by HIVOS/YRE to leverage similar financial resources from farmers themselves. This allowed investing not only in biogas installation, but also in maintenance services. This latter investment is a key added value of this programme versus government-led programmes that refused to invest in maintenance beyond a short period after biogas installation.

Financial flows through HIVOS and YRE were also used to leverage funding for biogas uptake through micro-credit schemes. HIVOS and YRE started to work on micro-credit schemes at three levels. Firstly, HIVOS started negotiations with credit unions for small credits and, during our visit, was in the process of signing a micro-credit agreement with Kiva, an international non-profit lending institution. In Bali, tourism was also recognised as a potential source of funding to provide micro-credit for biogas development, where hotels and other tourism agencies showed interest in giving incentives to (cooperatives of) farmers so that they can adopt biogas as an eco-friendly technology to manage waste. Secondly, HIVOS started discussions with local banks at provincial and regency levels, and thirdly HIVOS worked with the national government and banks such as Bank Syariah Mandiri to develop a larger credit scheme and a national policy that forces provincial banks to allow credit for biogas development (Bedi et al. 2012).

In more general terms, we found there was tension between contrasting perspectives around funding for biogas. On the one hand, funding for biogas was available through the government but under the condition that biogas installations should be given for free to the beneficiaries. This strikingly contrasted with the market-based approach adopted under the BIRU programme, which encouraged adopters to finance the technology. Of course, potential adopters that knew of freely-available biogas installations also became more averse to the idea of having to pay for it, which created an additional barrier to new micro-credit schemes that can support uptake. Most importantly, however, informants observed that when biogas installations were partially financed by the adopters, there was more sense of ownership, and thus more interest in maintaining and using the biogas production.

Maybe the most influential factor affecting funding for biogas was its inability to compete with LPG. Many informants from the private and public sectors considered biogas economically unviable, largely because of subsidies supporting the domestic LPG market. The subsidy of LPG to the detriment of biogas competitiveness was an important indicator of the low priority given to biogas in the national energy policies.

The exercise of authoritative power – that is, influence generated from being in a position of authority within a recognized hierarchy – and legitimacy in Indonesia was generally top-down within government institutions, via regulations and initiatives. This also seemed to apply to the biogas technological system, which showed an important presence of government-led programmes. Based on the interviews with representatives of the different government-led biogas programmes, we perceived that most of the regulations, standards, and guidelines for biogas installation at the regency level were coming from the national or provincial levels. Some regency-level government officials we interviewed in Bali did not consider biogas really effective or appropriate for their local context, and they implemented the biogas programmes because they perceived biogas as a 'duty' imposed by the provincial or national governments. These perceptions denoted two key considerations in terms of authoritative power influencing biogas development. Firstly, that government involvement is an important factor to support biogas adoption. Secondly, that there are cultural factors associated with top-down government-led development. One exception to this is maybe the BIRU programme, which showed a more decentralised and horizontal approach to support biogas technological growth.

Finally, authoritative power dynamics also played out in terms of decision-making for the installation of biogas digesters. We observed these power dynamics on two levels: the village/community decision-making and the household decision-making. At the village or community level, we observed that the village head and the Banjar head had high influence on the final selection of beneficiary farmers under the Public Works programme. This programme had implemented a survey in Tukad Aya village, Jembrana Regency, identifying a total of 70 potential candidates for biogas installation. This appeared an open application process for farmers, but the final selection process did not seem to be so transparent. In 2015, a total of 3 beneficiaries out of the 70 candidates were selected based on recommendations made by the Banjar head. During the interviews with these three adopters, they all noted personal connections with the Banjar head. Since we were not privy to the precise selection mechanism used by this or other biogas programmes, it was difficult to ascertain the extent to which personal connection was more important than merit.

Furthermore, farmers that were interviewed indicated that, at the household level, men would be the ones to make the final decision on biogas adoption without necessarily consulting with the rest of the household. They explained that this decision is embedded in a patriarchal Balinese society. Of course, we recognise that adopting biogas is part of an agricultural decision – i.e. it involves the management of livestock to produce feedstock for biogas – and agriculture is traditionally an activity led by men. Nevertheless, it has important implications for women in the household, as biogas replaces firewood (generally collected by women) and is used for cooking, which in Bali is an activity traditionally managed by women. For communal biogas installations in the SIMANTRI programme, the associations that benefited from government funding were also comprised of male farmers. In the interviews with village-level leadership, it was suggested that traditional common law "*Awig-awig*" could help better organise groups of farmers to collectively plan and better manage communal biogas installations.

### 4.1.3 Socio-institutional factors affecting market function

In this section, we combined the maps of the biogas system (see Figure 6) with interview responses to identify different socio-institutional bottlenecks affecting the biogas system function, and possible opportunities to improve its performance. We then list key factors enabling or constraining biogas use from the perspective of the actors in the biogas market chain and finish by identifying some of the key perceived benefits and risks associated with the current function of the biogas system.

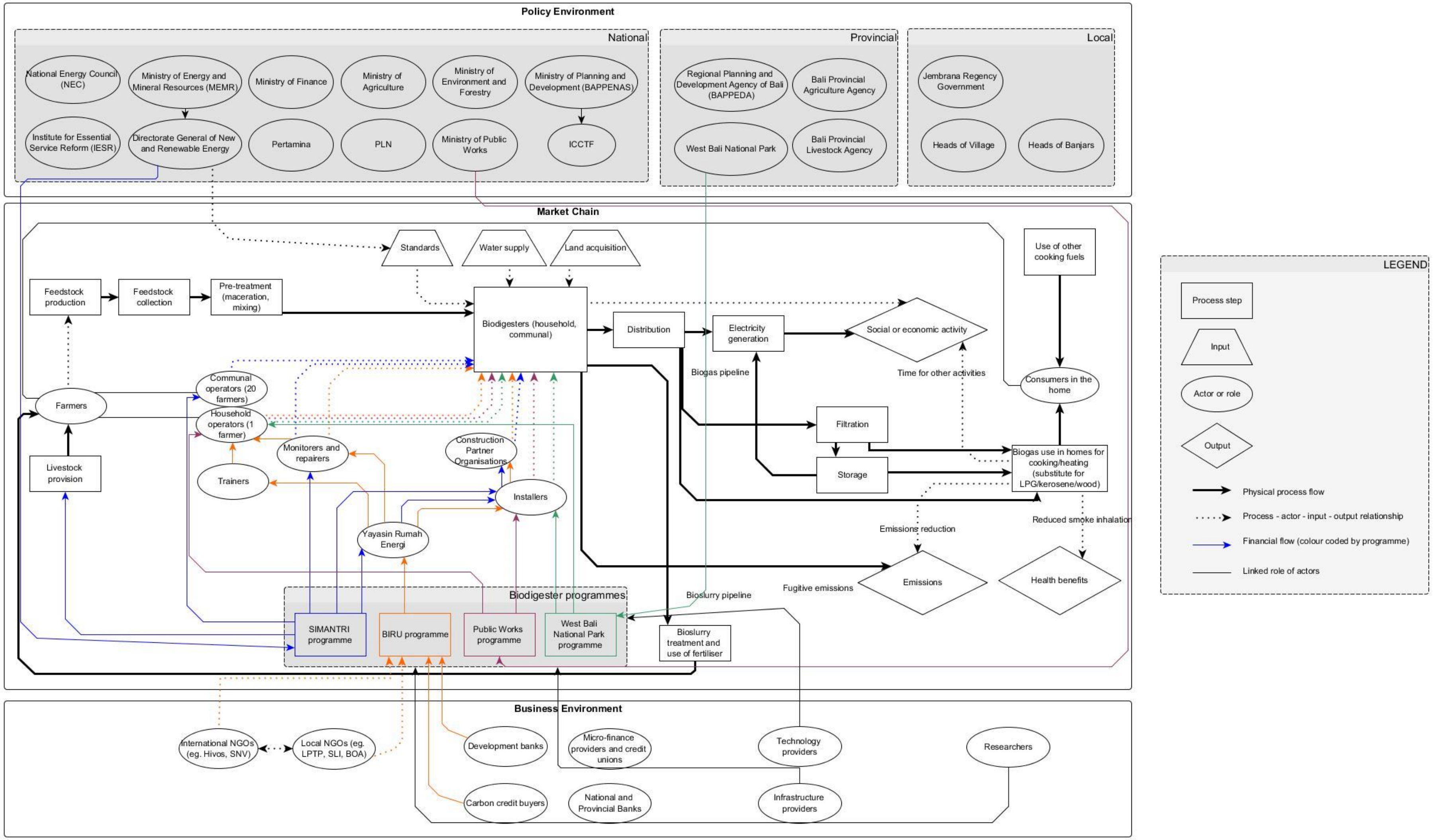


**Figure 6: System map depicting the four biogas programmes operating in Bali, Indonesia.**

Notes: Developed by the authors based on stakeholders' input, the system map presents the biogas market (supply) chain in the context of the policy and business environments affecting its development. Arrows link the concepts across the market chain and policy and business environments. The legend shows the meaning of different shapes used for the concepts in the system map, including process steps, actors, inputs, outputs and the physical, relational and financial links between them. Colours are used to differentiate the financial operations carried out by the four biogas programmes in Bali: the SIMANTRI, BIRU, Public Works and West Bali National Park programmes.

In general, the application process for biogas installations was considered lengthy and bureaucratic, especially in the fully subsidised programmes offered by the government. Technical capacity was also scarce. In the BIRU programme, YRE worked with BIRU CPOs to construct the installations. The government-led programmes hired technicians from other provinces of Indonesia. Since 2013, the BIRU CPOs have been providing technical assistance to SIMANTRI, although this involved mainly construction and not maintenance. Installations under government-led programmes were provided with 100% subsidy. Instead, in the BIRU programme 20% of the installation was subsided through carbon credits, 50% was covered by HIVOS with equipment, and the remaining amount was covered by the user.

Feedstock collection and pre-treatment were reported as time-consuming. This work was generally conducted by the farmers using shovels and water. If the animals were in a barn, collection of manure was easier and involved using water to wash the floor of the animal enclosure and allow the manure water slurry to flow through channels to small open areas beside the mixing tank (Figure 7a). If animal enclosures were not available (i.e. livestock roaming outdoors), farmers needed to carry the manure using shovels and wheelbarrows, which made collection more difficult. A digester with 6m$^3$ capacity required a minimum of 4 cattle (2 cows were allowed, but biogas production stability was considered more vulnerable), 6 pigs or 1000 chickens. However, chicken manure was reported to have a high content of hydrogen sulphide making it less suitable for biogas production. In the SIMANTRI programme, 21 cows and a communal enclosure were provided by the provincial government to farmer associations as part of the integrated farming system. Pre-treatment involved moving the manure by shovel into the mixing tank and adding water in a ratio 1:1. As the biodigester had to be filled every day, the farmer usually added the feedstock gradually into the mixing tank (Figure 7b). Farmers we interviewed considered that the wall of the mixing tank could be lower to ease the physical demand of shovelling.

In terms of the end use, we found a series of factors that were influencing the way adopters were making use of the biogas. Table 6 provides a list of Implementation risks (barriers) and enabling factors. In general terms, biogas in individual installations was used to cook, but usually in combination with other fuels. Biogas had the potential to substitute LPG and wood fuels, however, we did not observe a case where biogas was used exclusively. The main reason was that the amount of biogas produced was not enough to fully cover daily cooking needs. The biogas stove was usually used for short-time cooking, such as boiling water and cooking instant noodles, whilst for long-time cooking (e.g. rice dishes) farmers tended to use firewood stoves. Farmers explained that firewood stoves provide more constant heat for a longer period of time. Cultural and economic factors also played a role in determining how biogas was used (Table 6). Usually women were responsible for cooking with the biogas stoves in the households. In collective installations, biogas was reportedly used for boiling coffee during farmer meetings, but not for cooking on a regular/daily basis. The main reason was the distance between the collective biogas installation/stove and the households.

(a) Animal enclosure, individual domestic installation
(b) Mixing tank and concrete biogas digester
(c) Barn for cattle and collective biogas installation
(d) Pipelines connecting biodigestor with the household
(e) Lamp used to light the household patio
(f) Biogas stove and manometer used in the kitchen
(g) Biogas stove and manometer in communal house
(h) Biogas hydrogen sulphide filtration system
(i) Biogas temporary storage bag system

**Figure 7: Photos taken with permission during our visit to different biogas installations in Jembrana Regency, Bali, Indonesia (October 2017)**

**Table 6: Factors constraining and enabling fuel substitution with biogas in households, Bali, Indonesia**

| Factor type | Implementation risks (barriers) | Enabling factor |
|---|---|---|
| **Technical** | Installation capacity is insufficient (or possibly feedstock is not used in enough quantities or in an optimal manner) to cover daily cooking needs.<br><br>Delays in the cooking activity when the biogas pressure falls low.<br><br>Biogas used only to cook food with short preparation times, such as vegetables and noodles. The conventional fuel stove reportedly gives a more consistent heat and is therefore used in preference for food that requires longer-cooking times.<br><br>Only one biogas stove is available for the household, which is not enough to cook multiple dishes at the same time.<br><br>If long distance from biogas stove to household, then biogas is not used for cooking (the case of collective installations).<br><br>Little knowledge of maintenance, no training on how to use biogas properly (mainly government-led programmes).<br><br>Malfunctioning digesters due to cracking problems (technological choice is not accounting for local dry earth conditions). | The biogas stove produces a good flame with constant heat when pressure is high/ appropriate.<br><br>BIRU programme provides training on how to monitor and maintain equipment, which improves the way biogas is used.<br><br>Biogas is used more routinely when the stove is in the household (e.g. in the case of individual installations) than when the stove is located in a community building closer to farms than to households. |
| **Social/cultural** | Taste of food (rice, traditional dishes) is reported by some users to be better when cooked with firewood.<br><br>More interest in the bioslurry and waste management than in biogas use (particularly in the SIMANTRI programme).<br><br>Hard to use and maintain biogas installation through coordination among many farmers (in the case of collective installations). | Sense of ownership has shown to be a key buy-in.<br><br>Savings in time ordinarily devoted to collecting firewood can be used instead for family and cultural activities. |
| **Economic** | Cost of installation is prohibitive for many farmers' budget.<br><br>When installation is fully subsidised, farmers can take it for granted and may lack a sense of ownership to use it.<br><br>LPG is widely available and cheap due to subsidies, therefore there is no strong | Partial investment by operators (not full subsidy) and training has reportedly led to a higher rate of functioning biodigesters.<br><br>Savings in LPG purchase when substituting it partially with biogas.<br><br>Time savings from avoided firewood collection can be used for education and other productive |

| | | |
|---|---|---|
| | financial incentive for biogas unless very poor household.<br><br>Biogas stove is difficult to find and it costs about 4 times the price of a LPG regular stove, thus farmers cannot afford it. | activities. |

Another important process in the biogas system function related to monitoring and analysing the performance and use of the biogas digesters. We observed that monitoring practices within each biogas programme were in place, although in different forms. Adopter farmers explained that most monitoring activities in the government-led programmes were limited to a quick check to observe if the biodigesters were operating properly, without collecting data on how they were actually used. In the Public Works programme, monitoring was conducted by government representatives of Public Works at the district level on a monthly basis and for a total of 3 months after completing the biogas installation. Monitoring in the SIMANTRI programme was also conducted by the district-level government for the period of 3 months. The BIRU programme, on the other hand, ran a centralised monitoring system that provided guarantee and maintenance services for 3 years after installation. This monitoring included collecting georeferenced data of biogas performance to inform the validation and verification processes required by the carbon market accreditation system. It seemed clear that government-led programmes supporting biogas were not interested in investing much effort in maintenance services and monitoring over larger periods of time. This was also evident in relation to capacity building efforts, where government-led programmes did not seem to invest enough in training adopters to use and maintain biogas systems. The refusal of the government (national and regional) to extend financing for biogas technology maintenance seemed to have significant implications on biogas development with many biodigesters reportedly malfunctioning after the guarantee period had elapsed (e.g. two out of three biodigesters we visited under the Public Works programme). We were told in the interviews that this has limited biogas use because malfunctioning digesters had generated mistrust among farmers.

In keeping with the TRANrisk project's understanding of risk and uncertainty, we conclude with a list of key implementation risks (barriers), consequential risks and co-benefits associated the current function of the biogas system. This list serves to synthesise what we observed or discussed with different biogas market-chain actors during our visit to installations in Bali. These are important to consider in future biogas developments, particularly if scaling up is envisaged. These considerations and their interplay with broader context drivers will be explored in the Section 4.2.

Implementation risks (barriers)

- Lengthy and bureaucratic process to apply for support from biogas programmes
- Time-consuming process of feedstock/waste collection
- Cultural food preferences associated with traditional cooking methods
- More attention given to agricultural aspects of biogas, such as waste management

- Collective management issues in the case of larger biogas systems
- Varied monitoring practices in different programmes
- Poor maintenance

Consequential risks:

- Hydrogen sulphide ($H_2S$) is not filtered in all biogas installations. Over time, this could lead to negative health impacts, environmental pollution, and it will shorten the lifespan of expensive biogas stoves due to corrosion.
- The choice of technology is not always made based on good knowledge of local conditions, e.g. we observed concrete fixed dome biodigesters cracked months after installation due to the dry earth conditions.
- Fugitive methane ($CH_4$) emissions are occurring in some installations where biogas is not used for cooking at the same rate it is produced. As the gas flow from the digester cannot be controlled or easily stored, consumers have reportedly opened the valve to vent biogas to the atmosphere. Such leakage has significant climate change impact, given that methane is much more potent than carbon dioxide ($CO_2$). These emissions can only be prevented by consistent use, flaring or storage of excess biogas.
- Due to the different roles of men and women in Balinese households, the time investments and savings associated with biogas and wood fuel substitution are commonly borne by different members of the household (see co-benefit below on time-saving). However, this change also brings potential risks: after the installation of a biodigesters, the time spent by men would usually increase because they are generally responsible for operating the biodigesters, while time spent by women would usually decrease because they are generally responsible for collecting firewood.

Co-benefits:

- Biogas installations can reduce greenhouse gas emissions if properly managed. According to BIRU, one biogas unit of 6 $m^3$ can reduce 3.2 ton$CO_2$/year (estimates based on Gold Standard). Greenhouse gas emissions that would otherwise come from firewood burning and livestock manure are replaced by emissions from burning biogas.
- Biogas installations have the potential to reduce forest degradation and firewood use. Firewood collection in protected forest areas is technically illegal, but forest rangers reportedly allow this so long collectors promise to take only the broken branches. Firewood use continued in the adopter households we visited due to 'easy access'; however, it seemed to be consumed in lower quantities. Farmers used firewood particularly when cooking traditional dishes, or dishes that required long time to prepare (LPG was considered also too expensive to use for this).
- With biogas units less time was invested in firewood collection. Substitution of firewood with biogas reportedly saved up to 2 hours of a woman's time per day (and a child's time if they accompany their mother). Farmers indicated that this time saving was used for

cooking, to socialise with others, to engage in cultural or community activities, and to spend in child education and household work. The additional time required to operate the biodigester has been reported in one study to be less than the time gained from avoided firewood collection (Guntur, 2015).

- The use of biogas stoves helps avoid indoor pollution when cooking. Smoke produced by burning firewood during cooking had reduced significantly, but not completely as farmers continued to use firewood for particular occasions (e.g. traditional festivities) and routine cooking (See above and immediately below).
- The use of biogas reduced the reliance on LPG in households that were already using LPG before the biogas installation. According to a farmer who had been using biogas since 2013, use of LPG had reduced by half since biogas became available. He still used LPG because the biogas was not enough to cover their daily cooking needs.
- Bioslurry is another product generated with the biogas installation. Bioslurry was used by farmers as organic fertiliser for their own land, and some were considering the option of selling it to other farmers to generate additional revenue. The use of bioslurry for fertiliser rather than commercial fertilisers was perceived to both increase crop yields because it is rich in nutrients and save money for farmers who reported that commercial fertilisers were expensive. One farmer was experimenting with vermiculture, which can be produced with bioslurry for commercialization. At the time of our visit, many farmers were attracted to biogas because of the potential benefits attained from bioslurry.
- Biogas production has the potential to generate electricity with pilot experiments currently on-going in Bali. With electricity, farmers saw opportunity for new small-scale businesses (e.g. production of crafts, fertilizer derived from cow urine) that can generate additional income.

### 4.1.4 Agents and strategies to catalyse change

The combination of agency, power and market function analyses helped us identify potential ‘agents of change’ that could support the transition to biogas in Bali by fostering collaboration among actors and by focusing on key strategies that have the potential to catalyse change. Agents of change involved key players in the biogas supply chain, important actors supporting service provision for the functioning of the supply chain, and strategic influencing actors that can help shape the decision-making context in which the biogas technological system operates. In addition to identifying potential agents of change within the biogas technological niche, we also identified agents within the incumbent regime, because we considered that these actors could play a pivotal role in countering the inertia of the conventional energy system to support the transition or regime shift to biogas. Table 7 lists the agents of change we identified in the study and the possible strategies they could implement to catalyse change.

**Table 7: Agents of change with the potential capacity to catalyse the transition to biogas in Bali, their regime membership, and the strategy they could use.**

| Position | Agent of change | Strategies |
|---|---|---|
| **Incumbent regime** | National Energy Council | Reduce subsidies for LPG to make biogas energy more competitive. Provide a clear sense of commitment and direction in support to renewable energy and biogas in particular. |
| | Ministry of Environment and Mineral Resources and Bappenas | Increase budget allocated to support biogas. Set a specific policy and 2025 target for biogas. |
| | Provincial Public Works Agency | Share the programme reports with the biogas adopters, not only with government agencies. Build a sense of biogas technology ownership through trainings. Include more focus on maintenance services after installation. |
| | Governor and the Bali Provincial Agriculture Agency | Continue the promotion of biogas as part of an integrated farming system, irrespective of a change in provincial government. Promote biogas as a critical component of the system and not as an add-on. Include more focus on awareness raising, training and maintenance services. |
| | Pertamina and PT PLN | Accelerate biogas programmes through CSR. Enforce the implementation of a local FiT system in Bali, starting with pilots in more remote locations. |
| **Niche Innovations and/or Alternative regimes** | HIVOS and Yayasan Rumah Energy | Liaise with (lobby) the national and local governments to mainstream and enforce best practices and maintenance services in the biogas market chain. Support training and maintenance services through a market-based approach. Facilitate a bridge or a space for dialogue between government agencies, research institutes, and the private sector. Build evidence to support the business case to invest in biogas. Help create an enabling environment for the functioning of the biogas market chain by facilitating a healthy business ecosystem and a sustainable financial model through micro-, meso-, and macro-level credit schemes. Support the formulation of a policy that enforces provincial banks to allow credit for biogas development. |

| | | |
|---|---|---|
| | Adopter farmers | Promote peer-to-peer learning to increase adoption of biogas. Work in associations and cooperatives to be able to afford biogas installations through micro-credit schemes. |
| | Udayana University | Advance innovation to improve the use of biogas in Bali and hence its wider adoption. Increase interest and collaboration in electricity generation. Generate and share evidence of biogas benefits, including social, environmental and economic aspects. On the latter, create evidence on the suitability of biogas to contribute to circular economies in integrated farming systems or in small businesses that can generate additional income for farmers. |
| | Local government (village and Banjar heads, regency agencies) | Lobby government agencies at the provincial level to increase the support to biogas in their jurisdiction. |
| | Bali Organic Organisation and other local NGOs | Promote biogas benefits among farmers and contribute to local innovation through win-win projects. Support the trade of bioslurry as an additional benefit to biogas adopters. |
| | Credit unions, social enterprises, provincial banks, national bank | Invest in biogas development supporting farmer associations and small-scale business. Support large-scale feedlots to adopt biogas and potentially generate electricity at larger scales. |

In addition, through the interviews we identified several general strategies that could catalyse the technological growth of biogas in Bali, but would require collaboration among the agents of change. These strategies could be considered specific recommendations for Bali, but they also have relevance for Indonesia in general:

- **Develop a clear political commitment to biogas, which can overcome political uncertainty, unclear targets and short-term political interests/cycles.** The fact that the government was subsidising conventional energy sources like LPG meant for many that the only way to support an energy transitions at a scale that has real impact was through a top-down decision coming from the national government. Biogas innovation through a purely open market-based approach was not considered realistic in Bali given the government regulation, bureaucracy and monopolies like Pertamina. Informants considered that once a clear decision and commitment is introduced by the central government, e.g. a national biogas target, then the operations to support the transition can be more decentralised and include market-based approaches.
- **Address contradictions between a fully-subsidised approach and a market-based approach to support biogas.** The subsidies of the government to support biogas

development were building tension on the ground and slowing down the emergence of a market-based approach. Adopters would refrain from investing in biogas or accessing micro-credits when they observe other adopters getting biogas for free. Although it was widely recognised that many poor farmers could not afford the technology without subsidies, it was also clear that receiving the technology for free seemed to result in lower sense of ownership and less interest to maintain and use the biogas installations. It would appear that there is need for a funding mechanism to support maintenance services that can improve technology function and use can increase interest in biogas over time. It may be that this could be linked to a proper certification system (see below).

- **Improve awareness and knowledge about biogas among the general public, but particularly among the potential biogas adopters.** Several interviewees suggested that biogas programmes could do better at engaging the potential adopters and explaining the social and environmental benefits to promote the technology. Some initial efforts exist but could be reinforced, or scaled up. For example, YRE and the BIRU CPOs mentioned the use of radio to promote the technology among the general public. In general, more trainings and knowledge transfer would improve the interest in biogas, build more sense of ownership among adopters, and build capacity for maintenance and more sustainable use of the technology. Peer-to-peer learning, bringing together adopters and potential candidates, was also suggested as a means to build trust and interest in the technology.
- **Create a proper certification system to ensure high quality standards in biogas installations.** Participants in the focus groups stated that highly qualified labour is needed to escalate biogas technology in the short term. At the moment, only the BIRU programme seemed to provide training to its CPOs, however a certification system was currently lacking. By introducing such system, there could be an assurance that technicians hired for the construction/ installation of biogas digesters are qualified. This certification could also include maintenance skills, which could be transferred to farmers that have adopted the technology through capacity building activities planned under the different programmes. Currently, farmers were lacking technical knowledge on the appropriate use and maintenance of biogas installations, at least under the government-led programmes.
- **Improve and integrate monitoring systems to inform biogas plans and strategies based on evidence and learning.** Monitoring systems are in place under the different biogas programmes, however most are limited to a quick check of the biogas operation without going into more detailed aspects of how it is used and why is it working well (or not). Data could also be collected on the improvements observed in environmental, economic and social conditions to generate more evidence on the benefits generated by the biogas adoption. Monitoring could contribute to the learning needed to improve the technology based on observing and listening to user needs. For example, in the interviews to adopters we learned that they would like to see an increase in the capacity of the biogas installation so that they can use it to cover all their daily needs. They also made very specific recommendations, such as the need to introduce biogas stoves with double

burners and to lower the mixing tank. In addition, the interviews showed that biogas monitoring is managed in isolation by each biogas programme in Bali. To gain a more comprehensive understanding of the performance of the biogas technological system in Bali, it would be useful to integrate the collected data for a cross-programme analysis. This would also greatly help in fostering the transition to biogas based on a wider range of experiences and lessons learned, producing recommendations that could be adopted at the national level.

- **Boost biogas adoption through an incentive-based system.** The incentives would provide recognition to farmers that are pioneers in adopting environmentally friendly technologies. This approach would contribute to a sense of ownership of the technology and a willingness to maintain it and actively promote it among peers.
- **Create a space for transdisciplinary exchange.** A space for dialogue and exchange of ideas can help build bridges across different disciplines and sectors interested in biogas. Although opportunities to exchange ideas around biogas were available in Bali, interviewees indicated that they were dominated by academics and consultants, or alternatively by government agencies, but there was generally a lack of presence of the business sector. For example, both the BIRU and Public Works programme indicated that they had organised workshops to evaluate their performance in Bali. However, the main audience attending these workshops were government officials. It was emphasised that more involvement of the business sector (i.e. farmers) and NGOs would be beneficial in order to build a business case for biogas and work towards its economic sustainability. Some interviewees suggested that YRE could play the role of 'bridging agent' linking different types of actors, such as actors interested in research, actors interested in the social benefits of biogas, and actors interested in the economics/ business aspects of biogas. Such bridging function and spaces for transdisciplinarity would facilitate the creation of a healthy business ecosystem where different actors could fulfil different parts of the biogas system.
- **Invest in more pilots to further innovation.** Pilot projects were considered a meaningful way to create interest based on evidence and learning. Pilots, or demonstration projects, existed, for example, for electricity generation based on biogas; however, they were very few and lacked sustainable funding. Evidence generated through pilots could be used to influence policy at local but also national level, as well as creating interest among potential adopters. Pilots were also seen as mechanisms to support innovation, such as electricity generation to support small-scale businesses, or vermiculture (cultivation of earthworms) to enhance bioslurry and organic agricultural production.
- **Build on tourism to leverage investment in biogas.** This is particularly the case in Bali, where eco-tourism could promote the adoption of environmentally-friendly technologies among farmers. For example, hotels in Bali expressed interest in supporting farmers to adopt biogas and use bioslurry as organic fertilizer for the food they can use to serve tourists. This opportunity could benefit farmer cooperatives by ensuring a market and creating the conditions necessary to access credit.

## 4.2 Transition pathways for biogas in Bali

Transitions do not happen in a vacuum, but are embedded in a wider institutional, economic or even cultural context. This context includes the existing regime and the broader socio-technical landscape, as understood under the MLP approach (Geels 2002, Geels 2011). For instance, political leaders and their election could either promote or hinder sustainability transitions while economics of bioenergy are influenced by developments on national (and global) energy markets. The transition to biogas in Bali must therefore be viewed in this wider context. The literature review, as well as data collected during the interviews and the focus group discussions, have yielded several insights about those contextual drivers. We observed, for example, that changes in leadership within the MEMR had an effect on the political commitment towards bioenergy, and subsidies to LPG introduced at the national level hindered the adoption of biogas at the local level.

In previous sections we focused on current dynamics of the biogas system, and how these were affected by developments in the wider context. While this analysis helped understand how the system functions and allowed identification of bottlenecks and strategies that can help catalyse the transition, we also recognise that it only provides a snapshot of the current situation and therefore miss some opportunities that future changes in the wider context may bring. For this reason, in this section we take a forward-looking approach, where we consider possible changes in the national and global context (i.e. stabilising and destabilising forces) and the implications for biogas in the future. In this section, we explore the broad economic and political drivers of change in Indonesia and consider the implications of these on different possible biogas transition pathways in Bali. By asking '*What can happen*?' (Höjer et al. 2008), we explore scenarios informed by observed trends and empirical evidence collected from different perspectives.

### 4.2.1 Contextual drivers of change in Indonesia

In this section, we explore the broader economic and political context of Indonesia, within which the biogas niche is struggling to grow.

#### 4.2.1.1 Economic drivers

On a national level, Indonesia's good economic performance (see Section 3.3.1) is expected to be sustained. This will be assisted by president Joko Widodo's ambitious infrastructure plans, despite recent strain on the state budget.[22] According to the Indonesian Investment Coordinating Board, the government's National Medium-Term Development plan foresees 42 GW of new electricity generation capacity, 1000 km of toll roads, 3258 km of railways, as well as 15 new

[22] https://www.bloomberg.com/news/articles/2016-07-01/indonesia-steps-up-infrastructure-rollout-as-budget-takes-strain

airports amongst other investments up to 2019.[23] But it is important to note that, for instance, most of the electricity capacity additions are planned to be coal-fired power, thus choosing conventional regime technologies over bioenergy or other niche renewable options. This is one of the main dilemmas many emerging economies face where economic development and the continuation of the regime might take precedence over environmental sustainability and the fostering of niche technologies. In our Bali case study example, biodigesters have to compete with subsidised LPG and agricultural land is coming under pressure to be used in more lucrative endeavours such as tourism development. We therefore expect that economic development, which favours the fossil fuel based regime, will be a strong contextual driver in the near future.

However, other key contextual drivers at the national level (highly influenced by international energy market developments) might be more beneficial for bioenergy developments. Being a net importer of oil and oil products such as LPG (see Section 3.3.1), Indonesia is currently looking to shift fossil fuel use from export markets to internal consumption in order to counter imbalances between import and exports, particularly of oil and oil products (IEA 2015). Yet economic development and population growth will make future energy policies a delicate balancing act (IEA 2015). While an increase in fossil fuel energy production might drive up domestic emissions, there might be a need to satisfy increasing domestic demand with renewable energy sources that are greatly unexploited in the country. On a household level, biogas installations could alleviate the import dependency on LPG. Electrification from biogas might also be a viable option, even though several enabling factors have to be met, such as a reform of the electricity market to facilitate renewable energy uptake on the grid and viable financing opportunities for biogas electrification projects.

On a regional level in Bali, economic drivers are somewhat different since 76% of the local government's revenues come from tourism.[24] This service-based economy is especially attractive for young people, who find more opportunities working in the hospitality industry than in agriculture, the main source for feedstock and the main target group for biogas in Bali. While a typical hotel clerk can earn up to IDR 3,500,000 per month, the average salary for a farmer amounts to not more than IDR 1,500,000 (Shiotsu 2015). This has led to a shift in the labour force from the agricultural to the tourism sector. Hiotsu et al. (2015) estimated that between 2003 and 2013, the farming population in Bali shrank from 430,000 to 400,000 where most of those remaining (60%) were small scale farmers (<0.5 ha). With a decrease in farming population, fields of rice paddy declined as well (compensated somewhat by increased productivity) from 83,000 ha in 2003 to 82,000 ha in 2012, a loss which corresponds to the size of more than 1,000 football stadiums (Shiotsu et al. 2015). Moreover, farmers sometimes find it more lucrative to sell land for tourism developments. This means that upscaling biogas in Bali might meet several barriers such as labour and land shortage. On the other hand, looking for win-win strategies particularly in the tourism sector by linking ecology and sustainability to

[23] http://www.iesingapore.gov.sg/~/media/IE%20Singapore/Files/ASIR/Workshop1_Tamba_Hutapea.pdf
[24] http://www.antarabali.com/berita/13076/7619-persen-pad-berasal-dari-pariwisata

tourist development (eco-tourism) might provide for some interesting opportunities for bioenergy in Bali, as explored in Section 4.2.2.

#### 4.2.1.2 Political drivers

Looking at economic drivers is only one side of the story. As mentioned in Section 3.3.1 and the integrated analysis, Indonesia's governance structure is highly complex and characterised by shifting alliances and power plays between national government and regional provinces. This makes policy making a rather complex issue often yielding only sub-optimal results. But while the push for decentralisation has created some challenges it also led to some windows of opportunity opening for the development of renewable energy sources, particularly on the local level. For instance, the SIMANTRI biogas programme was initiated by an ambitious governor on a provincial level. Moreover, Bali has been chosen as the home of the Indonesian Clean Energy Centre of Excellence[25] and national renewable energy and emission reduction targets still hold. Identifying local agents of change who are capable of driving the renewable energy agenda forward might be a promising strategy to capitalise on the autonomy granted to Bali and other regions in certain policy fields. Local politicians might be brought on board using the decentralisation policies of Indonesia to their advantage.

Of course, these local 'renewable energy champions' cannot deploy their full potential without sufficient support from the national government, as we learned through the integrated analysis. But recently, there has been some positive developments in that perspective, particularly when it comes to ameliorating the insufficient funding opportunities for adopters willing to use bioenergy installations. Informal exchanges with Indonesian policy stakeholders point to the fact that the government is preparing a new regulation which would mandate banks to make loans to bioenergy adopters and developers more accessible.[26] Of course, these recent discussions certainly do not qualify as sound case study evidence, however, they illustrate the importance of having both policy support on the national level as well as policy entrepreneurship on a local level to drive bioenergy development and uptake forward. It remains to be seen whether tackling climate change and increasing the share of renewable energy will manage to stay on the agenda of the reform-minded president who seems to have much more on his agenda than initially anticipated, especially since economic growth slumped with plummeting international oil prices (Chalmers 2016) - sectarianism is on the rise (Emont 2016) and the ambitious reform agenda has not yet started (Connelly 2016).

[25] http://cleanenergy.litbang.esdm.go.id/
[26] Engagement with stakeholders during the 2nd GreenWIN Dialogue in Vienna, February 2017

### 4.2.2 Possible future pathways

Based on the insights generated with the integrated analysis of the current biogas technological system in Bali, and considering the context drivers described in the previous section, we explored several possible transition pathways to biogas in the mid-term future (2025-2050). These transition pathways account for potential developments in the wider context, and at the same time they build on potential internal advancements in the performance of the biogas system in response to or in anticipation of the context forces. These pathways begin in the present and explore trends into the future. Some of these could develop concurrently, but trade-offs are likely for pathways to coincide, and in some cases they may be mutually exlcusive. Others still will require more time and additional costs to mature. Figure 8 depicts these possible transition pathways considering both time horizon and up-front monetary investment.

Without attempting any future prediction, this section intends to explore possible future pathways. These can be considered ‘exploratory scenarios’ (also known as descriptive scenarios), or even ‘normative scenarios’ describing a picture of the ‘desirable future’ which could be achieved only through certain actions and if certain enabling factors are in place (Höjer et al. 2008). These descriptions could be considered narratives about potential future transitions to biogas that are relevant in the context of Bali, and Indonesia in general, given current observed system dynamics and key context drivers. Although, to a limited extent, this exploration of possible transition pathways can also help evaluate potential positive externalities under different conditions. Finally, these narratives could also be used to inform assumptions used in simulation of future scenarios with different modelling techniques, which eventually would be able to produce predictions to inform decision-making.

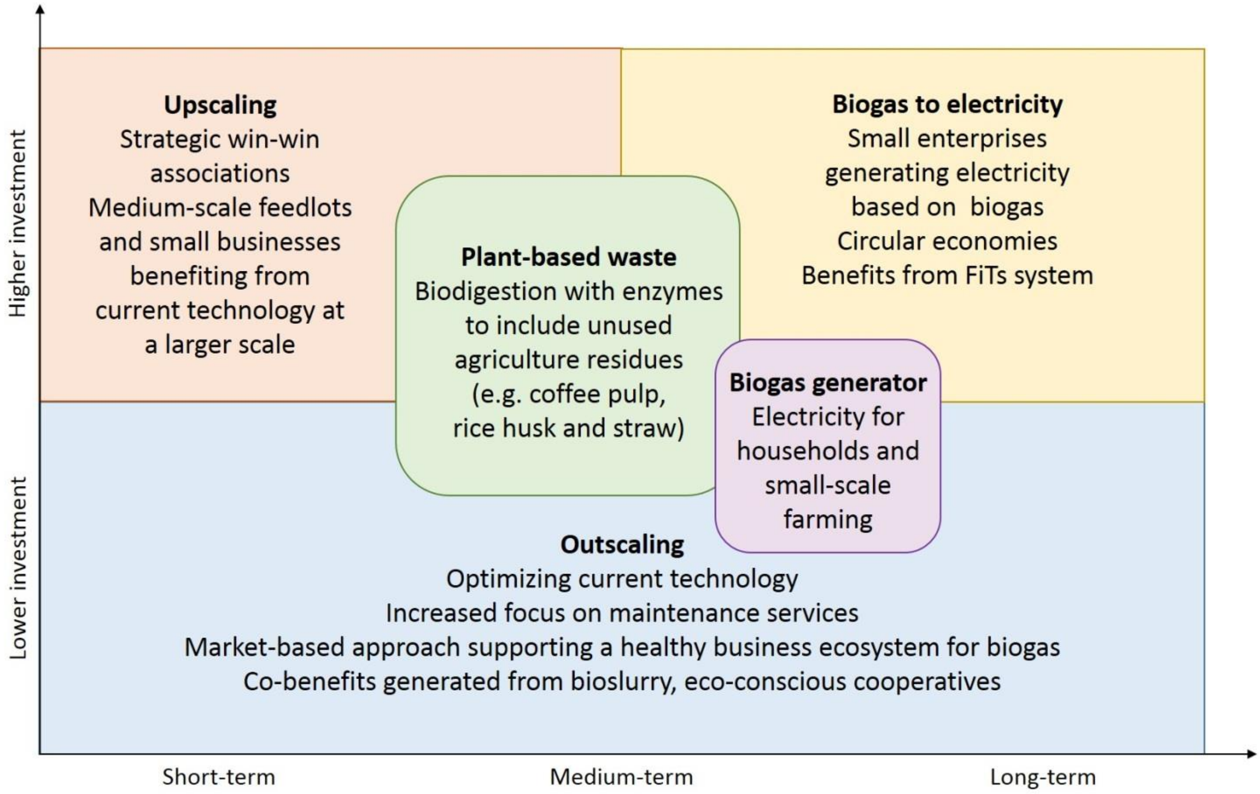


**Figure 8: Possible transition pathways for biogas in Bali, Indonesia.**

Notes:

Transition pathways are depicted in relation to the time horizon required for a pathway to develop and be implemented and the financial investment such development would demand. Some transition pathways may require lower up-front monetary investment and be easier to implement in the short term (e.g. optimization and replication of current biogas digesters through improved awareness and technical capacity, accelerated adoption and better maintenance), while others may be considered in the longer-term because they require more time and capital to mature (e.g. electricity generation from biogas to power small-scale enterprises or to feed the grid).

The **'outscaling' pathway** could be considered an enhanced and accelerated replication of what is already taking place in Bali in terms of biogas technology deployment. The sheer scale and success of the BIRU programme implementation compared to fully-subsidised biogas programmes suggests that the market-based approach to biogas development, when combined with attention to proper deployment and maintenance, is most likely going to lead toward economic sustainability and hence dominate Bali's biogas outscaling pathway. This also responds to context drivers such as the development of micro-credit schemes to support biogas uptake. A market-based approach would also lead to more cost-effective optimisation of the biogas installation performance and a growing interest in and market opportunity for maintenance services. This in turn, could support the development of a healthy business ecosystem around biogas, which could include not only the market around biogas technology, but also the commercialisation of bioslurry.

While the level of adoption in the outscaling pathway would remain primarily at the micro scale (including household level and farmer associations), farmer cooperatives may emerge as an outcome of opportunities provided by economies of scale within the system in alignment with alternative funding streams (e.g. from the tourism sector, CSR portfolios) supporting 'eco-conscious investment'. In addition to local economic benefits, this pathway has the potential to partially substitute the use of LPG at the local level. Given that the majority of Indonesia's LPG consumption is imported[27], pathway partial substitution would certainly contribute to energy security, even more so if oil prices start to rise. Even if the effect is not large enough to have an impact of significant magnitude at the national level, this local transition has the potential to significantly contribute to energy security among adopter households, particularly poor households that would be more seriously affected by a raise in LPG prices. The pathway could also contribute to greenhouse gas emission reductions if firewood consumption were curtailed to a significant extent through improved enforcement of forest and land regulation, and biogas storage and distribution would become possible.

In less than two decades, it is likely that biogas technology in Bali will include the biodigestion of agriculture residues in addition to manure. Actors involved in the biogas technological development and research, such as Udayana University, HIVOS and YRE, showed interest on this **'plant-based waste' pathway**. Currently, no plant-based materials like rice husk and straw are fed into the biodigesters. However, this waste represents a huge untapped opportunity that could be better utilised in the future. At present, rice husk and straw are used to feed animals, burned and used as fertilizer, and/or utilised in brick production. Technology to use plant-based waste like rice straw for biogas production is currently under research in other countries (Mussoline et al. 2012, Ye et al. 2013). This technology is still under development, but when available it could build on the biogas infrastructure that would already be in place through the outscaling and upscaling pathways. Of course, this does not factor in the lost value if rice husk and straw is not used for animal feed, fertilizer or brick production. There will inevitably be trade-offs in how these resources are utilised, with risks and benefits weighed not just in economic terms, but in political and social terms as well.

The **'upscaling' pathway** involves increasing the scale of infrastructure to produce biogas based on currently available technology. Because of the greater scale, this pathway would require higher capital investment. This could be achieved through partnerships between different producers looking for win-win opportunities. These producers could be medium-scale feedlots (e.g. pig or chicken farms) that have the potential to provide a larger amount of manure for biogas production, and small-scale enterprises interested in using the biogas for heat production in their operations (e.g. tofu or coffee roasting factories). Industrial-scale biogas production is not currently deployed in Bali, but it has been observed in other provinces of Indonesia. The potential is therefore real and could be introduced in the short-term with the right policy and financial incentives. The fact that the governor of Bali is pushing for cleaner and greener initiatives under the Bali Green & Clean programme provides a political umbrella for these

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[27] http://www.cnbc.com/2017/01/17/reuters-america-update-1-indonesias-pertamina-looks-to-us-for-lpg-imports.html

initiatives to emerge, and the tourism industry could become part of the win-win partnerships. This pathway would set up the basis for electricity generation from biogas, which could complement the economic and social gains in the longer-term.

Two pathways could be considered when thinking of electricity generation based on biogas production. The **'biogas generator' pathway**, which would involve local-level developments, could probably take place at a lower cost than the **'biogas to electricity' pathway** explored at a higher scale. The biogas generator pathway involves the development of modified generators that can run on biogas to produce electricity, which can be used at the household level either to cover daily needs or to support farming activities (e.g. running a pump for small-scale irrigation or to produce biourine, a fertilizer derived from cow urine). Pilot experiments to develop such biogas generators (based on modified diesel generators) are currently implemented in Bali using biogas installations in the SIMANTRI programme. The pilots have demonstrated successful results for 1000W engines, which were locally developed at 1000 USD - including maintenance for one year - compared to 5000 USD for an imported Brazilian engine. Ideally, a 2000W generator would be required to power household activities, and even small-scale income-generating activities such as crafting wood and souvenirs. To achieve this capacity, biogas produced by different households would need to be combined and appropriately stored. Alternatively, a collective biogas installation could be used through an association or cooperative. Eventually, this could transform into a large-scale electricity production as explored under the biogas to electricity pathway.

The biogas to electricity pathway entails the generation of electricity at a scale that can power small enterprises and villages, and even feed the grid if surplus is available. The production of electricity, which is typically small-scale, could provide off-grid solutions or help to encourage grid connections for remote mountain villages of Bali that have not been connected to the electricity grid yet. Otherwise, most areas of Bali are well covered with high electrification rates. In these areas there could be the possibility to feed the grid if the FiT system introduced by the national government would be implemented by PLN. Currently, this is not the case due to a lack of economic and political incentives. However, top-down regulation could drive enforcement, even if cost of electricity from biogas may be higher than the (subsidised) electricity price of the grid. Only a command from the national-level government would move PLN to sell the electricity at a loss, as compensation mechanisms would probably need to be negotiated.

The main advantage of feeding the grid with electricity from biogas is that decentralised generation sources would help make the grid more flexible to meet power demand at peak times and improves energy security by diversifying sources. This is particularly important if we account for population growth and seasonal tourism fluctuations in Bali. In addition, the biogas to electricity pathway has the potential to encourage the development of small enterprises acting in circular economies where the biogas produced by the operations in an enterprise (or a partnership of enterprises) could be used to power the same operations. Such longer-term technology could build on the infrastructure and win-win partnerships developed under the shorter-term upscaling pathway.

Finally, given that several changes would need to happen at the local level and the wider context, the biogas to electricity pathway would certainly demand the highest capital to develop in the long-term. One mechanism that could help accelerate this process is the production of biogas from biomass gasification. Such technology is available and has already been tested in small scale in Bali. The interesting aspect of this technology is that it makes use of plant-based waste, such as rice husk and straw, which is widely available in Indonesia. Some challenges to produce electricity using gasification technology at a megawatt range would entail collection, handling, and storage of biomass waste, and dealing with susceptibility to supply and demand (and price) fluctuations for rice husk or other feedstocks. This also would apply in the case biogas is eventually produced in biodigesters with plant-based waste. In any case, for this 'desirable' pathway to take place, a stable demand (e.g. through a FiT system or renewable energy auctions) for biogas-generated electricity would need to help ensure economic sustainability.

# 5 Discussion

## 5.1 The benefits of using the toolkit for an integrated analysis

Adopting an integrated approach and using the toolkit to study the socio-institutional factors that influence technological transitions has proven useful in several respects. Firstly, it allowed us to understand not only the internal dynamics of the technological system, but also the broader drivers that are currently affecting these dynamics. In the Indonesia case study, for example, the integrated analysis allowed us to understand the current function of the biogas market and the service providers, while at the same time it helped us gain insights into national and provincial policies and strategies that were shaping the biogas system. Most importantly, we were able to gain this understanding through the perspective of multiple actors representing different sectors and interests in the technology, which helped identify synergies as well as current tensions and bottlenecks.

Secondly, the integrated approach and the use of the toolkit helped explore agency and power dynamics in more detail, unpacking the way in which they are influencing the technological transition. This was a gap which TIS and MLP approaches had only partially addressed. The methods suggested in the toolkit have proven useful to study agency and power in a more explicit way, while considering multiple scales (i.e. national to local) in the analysis. Moreover, the methods we applied from the toolkit in the case study (i.e. semi-structured interviews, focus group discussions and network mapping) helped collect enough data to address the three research questions we had formulated to study transition to biogas in Bali.

Thirdly, the use of the system map framework in combination with the TIS and MLP approaches has proven beneficial when conducting an empirical study. The mapping the supply chain helped participants agree on ‘boundaries’ in the system and identify components within the market chain, business and policy environments. As a result, using the map allowed participants to relate to their role in the biogas system and share their views and perspectives on how the system functions. The participatory nature of some of the methods in the toolkit (e.g. system mapping and network mapping) also helped create a sense of interest and engagement with the study, which hopefully will serve to foster further discussion with the participants on how to improve collaboration and support the technology based on the findings.

Overall, we found the toolkit flexible enough to be adapted to a specific case study context. It offered structure, which helped plan an appropriate schedule for fieldwork with local partners, while at the same time providing a step approach with checkpoints, which we found useful to encourage reflection and deliberation among the research team on the findings and the process. The step approach was also a useful way to introduce management and financial considerations in the decision-making about the next set of methods to use.

Finally, the methods and analytical approach we applied to the Indonesia case study helped generate general and specific recommendations to support and catalyse the biogas technological development and adoption in Bali, based on an empirical understanding of socio-institutional bottlenecks and opportunities. These insights on the current biogas system dynamics also helped explore considerations that could play out in future biogas transition pathways, which would require further attention and study.

## 5.2 Key challenges and lessons about the process

Applying the toolkit for an integrated analysis of transition to biogas in Bali helped us identify limitations and ways that could strengthen the methodological approach. We also acknowledge that we have not completed the application of all the methods included in the toolkit yet. Therefore, the reflections hereafter only allude to a partial implementation of the toolkit. The forthcoming workshop in Bali in May 2017, and the potential application of the Q-method (i.e. final implementation phase considered in the toolkit), may provide additional insights on how to revise our approach. Because the Q-method is still missing, we have put less attention on the legitimation component in our integrated analysis. However, it remains to be tested if the Q-method could help us analyse how different understandings and expectations of the technology influence the recognition of selection pressures on the regime and the coordination of strategies that anticipate future changes. We also have to see if the Q-method can help us understand why some visions and expectations gain greater legitimacy than other, supporting of blocking the transitions. This would also complement the power analysis. Nevertheless, we learned important lessons that are worth highlighting, particularly because these lessons can be used to inform the Kenya case study where we have recently started applying the toolkit to study socio-institutional factors affecting transition to geothermal power development. We believe there is potential to do the same in other TRANSrisk case studies.

Probably the most important findings with regards to methods and application of the toolkit were the need for high quality facilitation of focus group discussions and the preference for diverse sources of data. The data collected using the methods depended largely on the informants engaged in the process and the questions asked by the researchers. For this reason, it is recommended that the persons leading the research have facilitation experience and a broad understanding of the new technology and the context before adapting the toolkit to their case study. Involving local partners in adapting/ tailoring the methods to the local context can help to ensure they are relevant and appropriate and to make sure representatives of different sectors are engaged in the interviews, focus group discussions and participatory mapping exercises. Combining qualitative and quantitative methods ensured a good balance of depth and breadth in terms of data and analysis. Of course, different contexts will require tailoring the methods to the precise needs of the case and the time and resources available.

Implementing the toolkit and process the data for the integrated analysis was considerably time-consuming. Liaising with local informants requires time and preparation, and working with local partners proved to be a helpful way to reach a diverse range of stakeholders in a cost-effective manner. Translating and summarising interview responses and tabulating network maps can also be time intensive, although the templates included in the toolkit helped accelerate this process. We learned it was important to also include guidelines explaining how to use these templates (see Appendices 1 and 2). If additional assistants support the fieldwork, it is important to provide sufficient training and, if possible, to conduct 'mock up' tests of the methods with a small number of informants to further tailor them to the context before implementation.

It was also challenging to piece together different theoretical considerations with (participatory) tools in a way that can serve as a practical, logical, and structured guide for the analysis of agency, power and institutions in technological transitions. While building on different theoretical considerations, our aim was to develop an approach that can guide empirical studies. As a result, we considered it important to develop a practical toolkit that could be applied in different contexts with a range of actors, but at the same time generate information that, once integrated, could respond to different theoretical frameworks.

While the application of our approach to study biogas in Indonesia has demonstrated the potential of the toolkit to achieve our aim, we recognise that further improvements can be done, both to the toolkit and the integrated analysis. For example, the toolkit was helpful in analysing trends and current dynamics of the technological system, but we considered the information generated insufficient to explore future possible dynamics without being speculative or exploratory. A scenario visioning exercise and back-casting method could be included in the toolkit to partially address this gap. We also found that the analysis provided interesting insights into the agency, power and institutional dynamics influencing transitions, but less insights were gained on the positive externalities generated by the transition. The survey, which we did not use in the Indonesia case study, could probably put more emphasis on this aspect. Application in other TRANSrisk case studies will help us to continue refining the toolkit. The more recent application to geothermal in Kenya will provide an interesting opportunity to compare findings, and also reflections about how to improve our approach.

# 6 CONCLUSION

The toolkit and integrated approach proposed in this report proved helpful to understand agency, power and socio-institutional dynamics affecting a technological transition with consideration of changes in the broader context. This is of great relevance given that theoretical frameworks used to study socio-technological transitions have been criticised for not having been able to address power and agency in a direct and comprehensive way.

The integrated approach drew inspiration from three theoretical perspectives: the multi-level perspective, in which innovation dynamics are represented as 'niche' technologies seeking to break into the mainstream 'regime'; technological innovation systems, in which innovation is determined by the extent to which certain system functions are fulfilled, and; the system mapping approach, which helps to identify the enabling environment for a given technology market chain. A methodological toolkit was developed to provide a structured way in which to apply the integrated approach in practice. The toolkit detailed a range of data collection and analysis methods, including interviews, surveys, focus group discussions, social network analysis and q-methodology. It also set out a logical step-wise process for applying these methods, depending on the particular research questions, needs and context of any given case study.

We then applied the toolkit and integrated approach to explore the case of biogas development in Bali, Indonesia. The integrated analysis allowed us to understand the current function of the biogas market and the service providers, while at the same time it helped us gain insights into national and provincial policies and strategies that were shaping the biogas system. In doing so, we were able to better understand the perspective of multiple actors representing different sectors and interests in the technology. This helped us to identify key implementation risks (barriers) and opportunities, as well and potential agents of change both at the 'niche' level and within the incumbent 'regime'.

While this first application of the toolkit and integrated analysis of biogas in Indonesia has generated insights and lessons about the benefits of our approach, the challenges we encountered also demand improvements. We believe that further practical use in other case studies could strengthen the integrated approach and practical toolkit, which we deem relevant for different contexts and technologies. Fieldwork in Kenya has recently started to conduct a similar socio-institutional study of energy transitions associated with upscaling to geothermal power development using this approach. We will encourage other TRANSrisk case studies to take up this integrated approach to keep applying and improving the toolkit.

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# Appendix 1

Guidelines used for the semi-structured interviews included in the toolkit adapted for the Indonesia case study.

**Guideline**

**Semi-structured interviews**

This document provides a short instruction for the semi-structured interviews that will be implemented in Bali as part of the TRANSrisk Task 6.2.

**Objective**

To collect information on different aspects of the biogas technology system from the perspective of different actor types, including government and funding agencies, non-governmental organisations and farmers that have adopted or could potentially adopt the biogas technology.

**Activities**

*Before the semi-structured interviews*

1. Identify a set of actors that (1) play a key role in the biogas technology system, (2) have a good understanding of the biogas technology system from the point of view of a specific sector or social group, and (3) have at least five years of experience of working in the sector they represent. Ideally, the participants represent different positions in the biogas system (i.e. actors relevant to different positions in the market chain, business and policy environment).
2. Contact the participants in advance to plan the interview meeting.
3. Prepare information sheets and consent forms to share with the participants, so they come prepared to the interviews.
4. Print the interview guides and, before each interview meeting, highlight the questions that are very relevant/important to ask to the actor about to be interviewed.
5. Organise roles within the team and agree on who is going to take the lead in asking the questions, note taking, summarizing, etc.
6. Produce a participation sheet to include all participants to that will be interviewed.
7. Prepare the support material you will bring to the interview, including printed material, voice recorder, notebooks, pens, etc.

*During the interview meeting*

1. Provide a brief introduction to the TRANSrisk project and the objective of the interview. Mention how the outcomes are going to be used. Ask participants to sign the consent forms and start the voice recording.

2. Start asking the questions using the interview guide. Use the highlighted questions as a reference, but improvise questions as you see necessary.
3. Take note of the questions AND the responses given by the interviewee.
4. The person taking notes may also ask questions if they want to follow up on a particular point that the person leading in asking the questions is missing.
5. If the interviewee does not speak English, translation will be needed. In this instance, the person leading in asking the questions needs to speak Bahasa.
6. Close the meeting by letting the participant know about specific follow up activities.

*After the focus group discussion*

1. Revise that the consent form is filled out properly.
2. Revise your notes to make sure you have not missed any important point. Add notes based on what you remember of the meeting. Do this just after the interview meeting.
3. Use the templates created for interview responses to transcribe your notes. Select the template that corresponds to the type of actor you interviewed. Use the voice recording if you need to complete information that is missing in your notes.
4. Open the template and edit the 'Actor CODE' first, then add the personal information of the interviewee. Click on 'Save as' and name the file with the Actor CODE you used.
5. The template contains all the 'Generic questions' included in the interview guide (in Blue). Add the responses under the Generic questions that were asked during the interview (in Black). If questions were improvised, add the 'Improvised question' and the response to that Improvised question under a Generic question that is more closely related (in Black). The content you add is always in Black. Please do not change the heading styles used in the templates.
6. After you finish completing a template, go to the Reference file in excel for that particular actor type. Create a New sheet and rename it using the Actor Code.
7. In the New sheet copy paste only the relevant Generic questions that were used in the interview from the table provided in the first sheet of the file. Copy the Generic question (in Blue) and the number '1' under each research component addressed by that question.
8. In the New sheet, then add the Improvised questions (in Black) under the relevant Generic questions (in blue) that you had copied. Add number '1' under the research components that you think the Improvised question is addressing.
9. Upload the voice recording and your updated files to Dropbox or save them in Google drive.

**Material**

- Interview guides
- Notebooks and pens
- Support material printed
- Voice recorder(s)
- Consent forms and info sheets

**Outputs**

- Voice recording and summaries of all interviews using templates provided
- Reference sheets completed for each participant
- List of all interviewees with schedule

# Appendix 2

Guidelines used for the mapping exercises implemented in focus groups during the fieldwork conducted in Bali, Indonesia. These guidelines were included in the toolkit.

**Guideline**

**Focus Group Discussion 1**

This document provides a roadmap for the first focus group discussion (FGD) we are implementing in Bali as part of the TRANSrisk Task 6.2 to map the network of actors relevant to the biogas technology system.

**Objectives**

- To discuss and validate the overall structure of the biogas technology system for Bali.
- To validate and complement the list of actors that are relevant to the biogas technology system in Bali, considering the market-chain and the wider context (business and policy environments).
- To map the interactions among these actors, taking into consideration both collaboration linkages (undirected edges) and flows of different resources (directed edges).
- To discuss and understand main needs and preferences of the actors in the network to improve the performance of the system.
- To discuss strategies that could be implemented to facilitate the wider adoption of biogas technology in Bali.

**Activities**

*Before the FGD:*

8. Identify a set of 5 to 7 actors (including actors from the pool of interviewees) that (1) play a key role in the biogas technological system, (2) have a good understanding of the biogas technology system from the point of view of a specific sector or social group, (3) have at least three years of experience working in the sector they represent. Ideally, the participants represent different positions in the biogas system (i.e. actors relevant to different positions in the market chain and actors relevant to the business and policy environment).
9. Contact the participants in advance to plan the meeting.
10. Prepare information sheets and consent forms to share with the participants, so they come prepared to the FGD.
11. Prepare the material that needs to be used during the FGD using the interview responses as input.
12. Agree on roles and responsibilities within the team for facilitation, note taking, summarizing, logistic support, etc.
13. Produce a participation sheet for participants to fill out at the FGD.

*During the FGD:*

*Part 1 (2 hrs)*

7. Provide a brief introduction to present the TRANSrisk project and the objectives of the FGD. Mention how the outcomes are going to be used and any follow up activities. Ask participants to complete the participation sheet, read and fill out the consent forms.
8. Using the biogas system map for Bali as a reference (printed on a flipchart paper), discuss with the participants the overall structure and changes based on the interview responses.
9. Using a plastic film on the flipchart paper, add the relevant actors (printed on post-it notes) to the biogas system map making sure they are in the appropriate position (i.e. part of the market-chain, policy context or business context). Post-it notes should be prepared in advance using the list of actors generated with the interviews. Discuss and complement the list if necessary (add more post-it notes). Use one colour for all the actors.
10. As you add the actors, write their roles and needs (to fulfil the role in their best capability) on a separate table prepared on a flipchart.
11. Draw connections between the actors and the market chain. If the connection is currently consolidated, then draw a tick black arrow, if the connection is still under development (weak) then add a dashed black arrow. If there should be a connection but currently is not existent, draw a red arrow.

*Part 2 (2 hrs)*

12. Remove the plastic film and add a white paper sheet in the background. Ask participants to allocate resources to the actors. Select from the resources suggested by Avelino and Rotmans (2009): monetary capital (funds, cash, subsidies), human capital (manpower), artefactual resources (equipment, infrastructure, etc.), natural resources capital, and authority (in making demands upon the behaviour of others). We also want to map techno-scientific information as a resource. Use post-it notes of different colours to represent the resources. Add these post-it notes to the actors according to the group consensus.
13. Add a new plastic film on top of the flipchart. Ask participants to draw (using a non-permanent marker on the plastic film) the interactions (collaboration) among the actors listed in the post-it notes. This entails drawing undirected edges among the actors. Participants need to discuss and reach consensus before they can draw a connection. [Photo]
14. Using a different plastic films and colours, ask participants to draw the flow of resources among the actors in the biogas system. This entails drawing directed edges among the actors. For each resource flow, use a different colour and plastic film. Possible resource flows include the mobilization of resources selected in step 6. Again, participants need to discuss and reach consensus before they can draw a flow. [Photo]
15. At the end of the exercise, superpose all the plastic film used to draw resources on top of the white flipchart with posit-it notes. Discuss the network with participants. Discuss if there are any important links (or actors) missing that should be created or added in the future to improve the performance of the system and the potential growth of the biogas technology in Bali. [Photo]

16. Close the workshop with an open discussion on strategies that could be implemented to facilitate the growth of biogas technology in Bali (including its generation, diffusion and use).
17. Summarize key remarks gathered during the exercise and end with motivational closing words.

*After the FGD*

10. Revise that all consent forms are filled out properly.
11. Produce a list of participants to keep as a record.
12. Revise notes and fill out any gaps during a debriefing meeting with the team.
13. Discuss the need to conduct a quantitative social network analysis (including surveys) or if it is appropriate to use only the qualitative analysis if quality is good.
14. Follow up with participants to thank them for their time and inputs (If surveys will be conducted, use the opportunity to notify them).
15. Summarize the focus group discussion in a report using the notes and photos of the different maps produced with the participants.
16. Produce adjacency matrices for the network maps generated during the FGD.
17. Use the summary report and matrices as input for the analysis of agency, power and market function.
18. If relevant, contact participants to invite them to a second FGD where results will be shared for a broad round of discussion and feedback.

**Material**

- Flipchart paper
- Non-permanent markers of different colours
- Plastic film
- Large table
- Notebooks
- Voice recorders
- Consent forms
- Participation sheet

**Outputs**

Summary report (and supporting files) containing:

- Validated biogas system map for Bali
- Map of the relevant actors in the biogas technological system, including roles
- Network of actors in the biogas system and key resource flows among these actors
- Insights into needs and strategies that could be implemented by key actors to enhance the growth potential of biogas technology in Bali

# Appendix 3

List of actors relevant and the role they (could potentially) play in the biogas technology system in Bali, Indonesia, based on interview responses and focus group discussions.

| Actor | Acronym | Attributes | Role |
|---|---|---|---|
| **Ministry of Finance** | MinFin | P[F*] | Provides funding for biogas implementation in coordination with Bappenas/Bappeda. Allocates the international funding for biogas at the national level. |
| **Indonesia Climate Change Trust Fund** | ICCTF | P[F*] | Provides funding to programmes and projects linked to climate change. |
| **National Development Planning Agency** | Bappenas | P[A*,F]§ | Approves the funding streams at the national level, which are going to the provincial level. Coordinates the ministries at the national level. |
| **National Energy Council** | NEC | P[I,A]± | Produces a report of biogas installation distribution at the national level |
| **Ministry of Agriculture** | MinAgri | P[I]± | Influence in defining the agriculture national policy. Provides funding for biogas programmes. |
| **Ministry of Research, Technology and Higher Education** | MRTHE | P[F]^ | Distributes research grant for biogas development. |
| **Ministry of Environment and Forestry** | MEF | P[F*,A]§ | Coordinates a biogas project through the West Bali National Park in Bali. |

| | | | |
|---|---|---|---|
| **Ministry of Energy and Mineral Resources** | MEMR | P[F*,A*] | Provides funding support for a biogas programme implemented by the Public Works Agency at the provincial level. |
| **Ministry of Public Works** | MPW | P | General oversight on the construction of biogas digesters in Indonesia. |
| **Bali Provincial Environmental Agency** | ProvEnvAg | P[I]^ | Oversees that activities do not have a negative environmental impact, including biogas installations. Coordinates with the Ministry of Environment and Mineral Resources. |
| **Bali Provincial Agriculture Agency** | ProvAgriAg | P[I*,F,A] | Oversees the implementation of the biogas programme (up to the point of bioslurry utilization) as an extension of the SIMANTRI farming/livestock programme. Coordinates the monitoring and evaluation. |
| **Provincial Development Planning Agency** | Bappeda | P[F*,A*] | Approves the funding streams at the provincial level, which are going to the regency level. Reserves the right to make a final decision on the biogas funding approved by Bappenas. |
| **Directorate of Energy, Telecom and Information - Bappenas** | Bappeda.DETI | P | Oversees the implementation of technical standards for biogas based on regulations introduced by the competent ministries. Evaluates regulation and financial plans for renewable energy in coordination with relevant ministries. |
| **Directorate of Renewable Energy - MEMR** | MEMR.DRE | P[I*, A] | Oversees the policies related to capacity building, monitoring, and controlling activities in geothermal, renewable energies, and energy conservation. |

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| **Bali Provincial Public Works Agency** | ProvPW | P[F,A]± | Planning, implementing and monitoring the biogas programme funded by the MEMR. Reporting to the MEMR. Planning public consultations in relation to biogas installation. |
| **Bali Provincial Livestock Agency** | ProvLivAg | P[I,F,A]^ | Supports the Agriculture Provincial Agency in the implementation of SIMANTRI. |
| **Regency-level government** | RegGov | P[F*,A] | Define the location of biogas installations working with the Provincial government under a signed MoU. |
| **Village-level government** | VillGov | P[A,F]§ | Supports the identification of sites and farmer candidates for biogas installation under the programme managed by the Public Works Agency. |
| **Governor** | Governor | P[I,F,A]± | Plans the SIMANTRI programme. Provides funding for biogas installation in Bali. |
| **Non-certified biogas technician** | Non.Cert.Te ch | M | Provides hand labour in the installation of biogas digesters. |
| **Certified biogas technician** | Cert.Tech | M | Installs and provides maintenance to biogas installations under the BIRU programme, after receiving proper training. Provides and supports in trainings. |
| **Biogas consumers** | Consumers | M[F]^ | Provide funding or in kind resources for biogas implementation in the rural area. |
| **BIRU Construction Partner Organization** | BIRU.CPO | M[I*] | Directly involved in the biodigester construction process helping Yayasan Rumah Energi, and also involved in the |

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| | | | maintenance. One CPO consists of a builder, a plumber, a welder and a supervisor. In addition, there is a fertilizer officer responsible to train and manage the use of bioslurry. |
| **Farmers** | Farmers | M[F*] | Provide biogas feedstock (manure) and labour to operate the biogas installation. |
| **Yayasan Rumah Energi** | YRE | M[I*,F]§ | Involved in every step of the biogas market chain. Provides logistic and technical resources for biogas implementation. Raises awareness about the importance of having a clean environment and technical knowledge. Supports the development of a biogas installation standard that can be used as reference by the different biogas progammes at the national level. |
| **Academics** | Academics | B[I*] | Conduct theoretical and applied research, focus on improving the technology. Lead some pilots implemented with farmers and university students. Provide back-stopping to governmental biogas initiatives. |
| **West Bali National Park** | WBNP | B[A]^ | Supports the establishment of biogas installations around the West Bali National Park. |
| **KIVA Lending Team** | KIVA | B[F*] | Provides loan and saving schemes. |
| **Regional Bank Indonesia** | Bank.BPD | B[F]^ | Provides funding for biogas in the rural area |
| **Banks BNI, BRI, Mandiri** | Banks.BNI. Man | | Provides funding but only to project of significant size that can demonstrate |

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| | | | an appropriate guarantee. |
| **Bali Organic Association** | BOA | B[I*] | Supported the supervision of technicians during the installation of biogas systems and the development of biogas standards. Engages farmers in agricultural production supporting fair trade and access to more stable prices. Provides support with bioslurry trade and vermiculture. |
| **Local NGOs** | Local.NGOs | B | Support the biogas project implementation in the rural area. |
| **International NGOs** | Int.NGOs | B[I,F]± | Provide funding for biogas implementation in the rural area. |
| **HIVOS Indonesia** | HIVOS | B[I*,F*] | Helps develop a biogas industry where manufacturers can make a profit. Provides funding for biogas through Yayasan Rumah Energi. Interacts with the national government to build the policy for biogas standards. |
| **SNV Netherlands Development Organisation** | SNV | B[F]± | Started to work in biogas in 2009 and created Yayasan Rumah Energi in 2012. |
| **Su-re.co** | Sure.co | B | Conducts research related to biogas. |
| **Perusahaan Listrik Negara** | PT.PLN | B[F]^ | Implements CSR programmes that (may) support biogas technology development. |
| **Business sector** | Business.sector | B[F]^ | Supports the functioning of the biogas market chain. |
| **Pertamina** | Pertamina | B[F]^ | Implements CSR programmes that (may) support biogas technology |

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| | | | development. |
| **Gasifikasi Prima Energi** | Gasifikasi | B[I,F]± | Provides consultation and supports installation (biomass gasification) |
| **Udayana Community Service Organization** | UCSO | | Coordinates knowledge transfer involving all actors related to biogas. |

Note: P=Policy environment, M=Market chain, B=Business environment, [I]=Information, [F]=Finance, [A]=Authority, *=attributes indicated in both focus groups, §=combination of attributes given by the different focus groups, ^=attribute noted only in the focus group 1, ±=attribute noted only in the focus group 2