ICAT Initiative for Climate Action Transparency

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Initiative for Climate Action Transparency - ICAT

ICAT Transformational Change Pilot Case Study:

Transformational Change

Geothermal Energy Development Policy in Uganda

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AUTHORS

Mathilde Clara Kolenda and Nicolas Desmoitier
UNEP DTU Partnership

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LIST OF ACRONYMS

CREEC	Centre for Research in Energy and Energy Conservation
CTCN	Climate Technology Centre & Network
ES	Earth System
ICAT	Initiative for Climate Action and Transparency
GHG	Greenhouse Gas
GRD	Geothermal Resources Department
LCA	Life Cycle Assessment
MEMD	Ministry of Energy and Mineral Development
PBs	Planetary Boundaries
SDGs	Sustainable Development Goals
SF	Social Foundation
SIA	Social Impact Assessment
SJOS	Safe and Just Operating Space
SOS	Safe Operating Space
TC	Transformational Change

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Cover picture: Sempaya geothermal hot springs, Uganda from https://www.thinkgeoenergy.com/uganda-to-initiate-130-mw-geothermal-development-program/

1. INTRODUCTION

1.1 Transformational change for meeting the global goals

The need to actively and effectively address the global crisis of climate change is becoming more and more critical. The international community has pledged by signing the Paris Agreement to restrain global warming to below +2 degrees centigrade by the end of the century compared to pre-industrial levels, while increasing efforts not to exceed +1.5 degrees centigrade of global warming (UNFCC, 2015). As of today, 187 out of 197 Parties have ratified the Convention (UNFCC, 2019). Each Party ratifying the Paris Agreement has committed to expressing Nationally Determined Contributions (NDCs) (Article 4) to mitigate their share of the GHG emissions, key driver of climate change. Even though NDCs are paramount, current NDCs ambitions, even if met, are proved insufficient to meet the purpose (UNEP, 2019). Furthermore, the Emission Gap Report informs about the gap between the current trend, the possible trend if countries were to meet their pledged commitment to reducing greenhouse gases, and the actual reduction required if the global temperature increase is to be limited. Once more, this report indicates that most countries are not on track to meet their objectives to reduce their contribution to climate change and more worryingly that the gap is larger than ever. Notably, this year's report shows that there is a need for three to five times higher reductions in greenhouse gas emissions than the goals agreed by the world’s countries in the Paris Agreement, in order to limit global temperatures rise to +2degrees or possibly 1.5 degrees (UNEP, 2019).

Amongst key drivers to bridge this emissions' gap, bold policies are unequivocally needed to promptly shift away from high-carbon and more generally unsustainable current practices. In that regard, the Initiative for Climate Action Transparency (ICAT) was established in 2016 to respond to the critical need to accelerate climate actions by providing countries and policymakers with tools and support to measure and assess the impacts of their climate policies and actions. The ICAT refers to such systemic change of paradigm as 'Transformational Change (TC)', defined as follows: "a fundamental change that shifts away from carbon-intensive and unsustainable models of development in order to align with the Paris Agreement's temperature goal and the 2030 Agenda for global sustainable development goals" (ICAT, 2018). The *ICAT Transformational Change methodology* (also called the ICAT TC guidance) gives guidance on how to perform and report transformational impact assessment associated with the implementation of existing or new policies fostering low-carbon economy and sustainable development. Yet, the extent to which the transformation is happening is to be clarified. Furthermore, considerations such as "How can a change be qualified as transformational, radical or disruptive rather than incremental or reformistic?" need to be addressed to fully embrace the concept of TC. Assessing transformational impacts of a policy requires defining the reference for what is 'truly sustainable' and for the associated transformational goal.

1.2 Absolute perspective

1.2.1 Planetary Boundaries framework

The target of limiting global warming to 1.5-2 degrees centigrade compared to pre-industrial level was set based on scientific evidence for the key Earth System (ES) process of *Climate Change*. This limit corresponds to a tipping point, a threshold in a system where a small, additional increase in an external forcing factor triggers internal processes that drive system change –often rapid, abrupt and unexpected, sometimes irreversible (Lenton et al., 2008). Anthropogenic activities are not only affecting this key Earth System process, but also processes such as land use, biodiversity, freshwater resources etc. Aiming at adopting a necessary integrated approach to acknowledging the finite limits of the ES, the Planetary Boundary (PB) framework defines 9 key ES processes important for maintaining the relative 10,000 years stability of the Holocene so suitable for humans to prosper (Rockström et al., 2009; Steffen et al., 2015). Also, it identifies thresholds, in other words tipping points, not to cross in order to remain in the 'Safe Operating Space (SOS)' for humanity. Such framework lays the foundations of absolute environmental impact assessments, in which assessed impacts are expressed in metrics allowing for the comparison with the remaining budgets (so-called assigned share of the SOS) that are left before the PBs are met and pushed into an uncertain state.

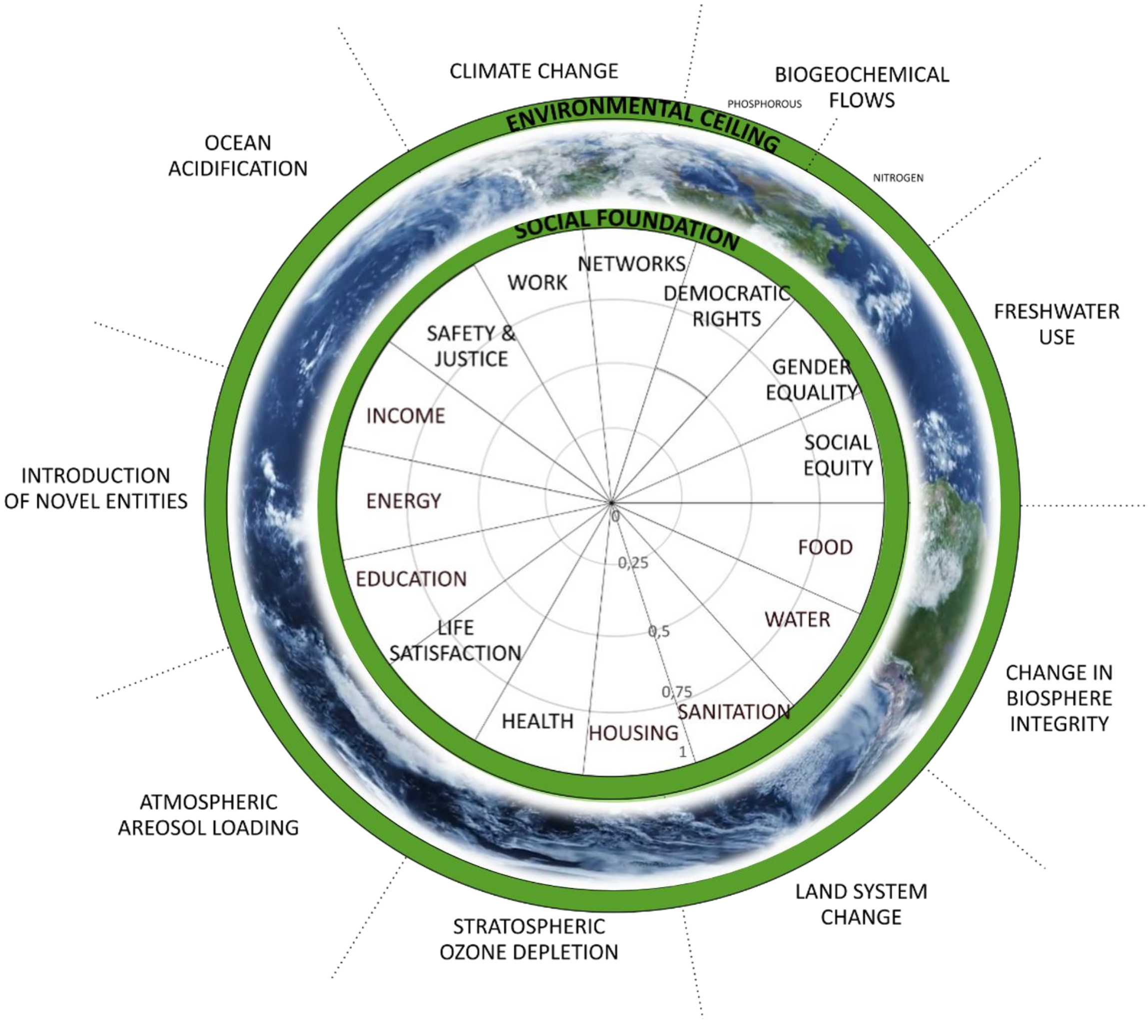
1.2.2 Safe and Just Operating Space

In order to prevent burden-shifting across all dimensions of sustainability (social, environmental and economic), the tremendous challenge of climate change needs to be approached with a multidisciplinary vision. Specifically, such vision can be conveyed by the 'Safe and Just Operating Space (SJOS)', a concept coined by Raworth (2012), which puts the planetary boundaries framework developed by Rockström et al., (2009) together with the Social Foundation (SF), based on humans' deprivations. Ensuring humans' needs to be universally met and to live in decent conditions is therefore embodied in the definition of the 'just space' of the SJOS. The latter is also defined in line with the Sustainable Development Goals (SDGs) agenda of the United Nations for 2030 (Raworth, 2017). This framework was recently reviewed and updated in forthcoming Desmoitier et al., resulting in 15 dimensions representative of the 'just space', with one representative indicator per dimension associated with a newly defined 'social absolute threshold'. The revised SJOS framework can be seen on **Figure 1**. Aligned with the concept of PBs, this piece of work suggests social thresholds to be met for all in order to ensure social sustainability.

1.2.3 The Doughnut methodology: Quantifying impacts of policies on an absolute scale

Forthcoming Desmoitier et al. aimed at developing a methodology to assess in a quantitative way and with a forward-looking vision (ex-ante) social and environmental impacts of policies on an absolute scale, expressed in the metrics of the revised framework of the SJOS presented here above on **Figure 1**. Such methodology is to be applied for a system (e.g. a country), which firstly requires to assess the current social and environmental sustainability performance of the system (called baseline scenario). The sustainability performance as defined in this methodology refers to the capacity of a system to remain within the SJOS. Secondly, impacts of policies are to be quantified resorting to cause-effect relationships (impact pathways) and expressed in the metrics of the SJOS, which lead to the estimation of the so-called policy scenario (forward-looking). The policy-scenario depicts the expected state of the system in the metrics of the SJOS, if the policy is to be fully implemented (ex-ante assessment). The definition of absolute thresholds entails setting a reference for what is considered 'truly sustainable', to which progress associated with a policy, i.e. expected impacts, can be evaluated against. This boils down to the concept of absolute sustainability, embedded in this methodology. It is referred to as the "Doughnut methodology" in the following. The applicability of this methodology was proven by using the illustrative example of Geothermal Energy Development in Uganda. This led to preliminary results for the ex-ante assessment, that require validation, entailing implementing a participatory approach with Ugandan stakeholders.

Figure 1: Visualisation of the reviewed framework of the Safe and Just Operating Space (SJOS). Adapted from forthcoming Desmoitier et al.

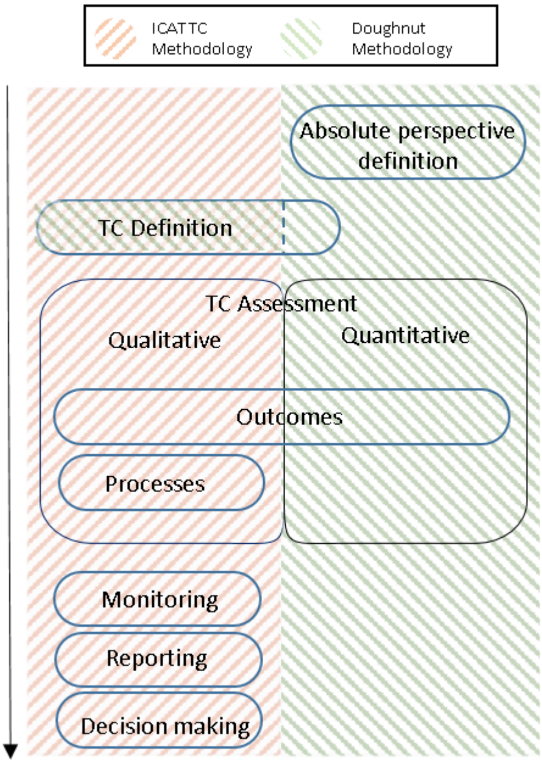


1.3 Doughnut methodology as a complement to ICAT TC assessment methodology

The *Doughnut methodology* focuses on assessing impacts of policies, also referred to as "outcomes of change" in the ICAT *TC methodology*. In the latter, outcomes distinguish the scale from the sustained nature of outcomes resulting from a policy, both characterising the final potential impacts were the policy to be successfully implemented and its objectives completed. The two methodologies overlap since both cover the estimation of outcomes of change, although the ICAT *TC methodology* only suggests a semi-qualitative approach. Therefore, the *Doughnut methodology* can be used as a complement to the ICAT *TC methodology* to strengthen the TC assessment and estimate outcomes of change in a quantitative manner on an absolute scale. Such approach is believed to provide with more robust results, while being in line of the ambition of achieving transformational change. Indeed, the *Doughnut methodology* measures sustainable development impacts on an absolute scale with "absolute thresholds", defining a clear transformational objective. More precisely, for each category of both social and environmental aspects, a single indicator is defined and is associated with an absolute threshold which defines what the sustainable state and the required transformation. As for processes of change, referring to the means with which a policy or action can drive change in society to move towards the transformational goal, are integrated in the ICAT TC methodology while they are not looked at in the

Doughnut methodology. Accordingly, both methodologies could supplement one another to assess the extent to which a policy can contribute to transformational change, by looking at both outcomes and processes of change. Complementary aspects and overlaps of both methodologies are depicted on **Figure 2.** Such approach is applied to the pilot case-study of geothermal energy development in Uganda.

Figure 2: Mapping of methodological steps covered by the ICAT TC and Doughnut methodologies



1.4 Specific case of Uganda

1.4.1 National circumstances

Uganda is located in East Africa (1.3733° N, 32.2903° E) with a total area of 241,551 km2, of which 44,485 km2 is open water and wetlands (UBOS, 2018). The country lies in fact within the Nile region and is located in the African Great Lakes region (with notably a great portion of Lake Victoria included within Uganda's borders). The Ugandan total population is 44.3 million, 21% of population is between the ages of 18 years and 35 years old, and 72.8% of which dwell in rural Uganda (UBOS, 2018). With a current growth rate of around 3.2 %, the total population is expected to exceed 74.4 million by 2040 (UN Population Division, 2019). The country is classified amongst the Least Developed Nation Countries (LDCs), with 21.4% of the population living below the national monetary poverty line in 2016/17 (UBOS, 2018) and likely to increase in cases of extreme climatic and market shocks. Poverty is more concentrated in rural areas especially in northern and eastern Uganda where nutrition, education and sanitation are generally poor. The economy of Uganda is highly dependent on rain-fed agriculture, which contributed 24.8% to the national GDP in 2013/14 and employed about 72% of the total population (GOU, 2015). Environmental degradation is also rampant with loss of forest cover from 24% in 1990 to 18.3% in 2005 due to the high demand for wood fuel (80% of Uganda's rural households use firewood for cooking, UBOS, 2018) and an estimated loss of 4 to 12% of GDP annually due to soil erosion (World Bank, 2018). Even though contributing little to climate change, Uganda is already largely suffering from the effects of a warmer planet. It is particularly subject to decreased rainfalls and rampant droughts in the dry season and to more severe floods in the rainy season, negatively impacting the agricultural crop productivity, thus Uganda's economy, livelihoods and social wellbeing (CTCN, 2018).

Uganda signed and ratified both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP) and signed and ratified the Paris Agreement thus committing itself to the adoption and implementation of policies and measures designed to mitigate climate change and adapt to its impacts.

1.4.2 Energy sector and future prospects

In Uganda, the Energy Sector plays a central role in the economy. Energy is the engine for economic growth and development, and a vital input into all the productive and social sectors of the economy. The Ugandan energy sector (consumable energy) is largely dominated by biomass (84.2% of the total), mainly fuel wood and charcoal, while electricity generation only contributes up to 1.4% of the energy balance (GoU, 2017). The sector has an estimated overall electrical power potential of about 600 MW of which 459 MW are produced from hydropower, 100 MW from thermal (diesel) energy and 41 MW are bagasse-cogenerated (The Government of Uganda, 2015, ERA, 2018). Currently, Uganda’s per capita electricity consumption amounts to 89kWh/year (2014), which is way below the Sub Saharan Africa average of 153 kWh (without South Africa) (MEMD, 2015). Electricity will be critical for Uganda to obtain the growth trajectory and socioeconomic transformation it needs through better access to education, health care, improved quality of life, and personal security among others (UBOS, 2018). Electricity demand is expected to soar in the coming years and is forecast to reach 578kWh/capita by 2020 and 3688kWh/capita by 2040 (GoU, 2017).

The Government of Uganda has envisioned a 30-years strategic plan to "transform the Ugandan Society from a peasant to a modern and prosperous country", resulting in elevating the country from a predominantly low income to a competitive upper middle income country within 30 years (Government of Uganda, 2015). A critical step for this development is therefore “to meet the energy needs of the Ugandan population for social and economic development in an environmentally sustainable manner", which the GoU has pledged to fulfil. Uganda is endowed with a lot natural resources, on which it can rely on to produce clean and reliable energy. In that regard, most of Uganda's power sector is fuelled with hydropower and amounts to 76% of the total electricity generation (ERA, 2018). However, electricity generation in Uganda is expected to extensively be affected by the effects of climate change (USAID, 2013). Consequently, it is of critical importance that the GoU embraces the effects of Climate Change in its global energy strategy for developing the country while containing even reducing its GHG emissions. Such considerations are in particular integrated in the official Uganda Green Growth Development Strategy whose priority areas include energy for sustaining a green growth (GoU, 2017).

1.4.3 Geothermal energy development in Uganda

Uganda is endowed with geothermal resources due to its geographic location in the western arm of the East Africa Rift System (EARS) (Kato, 2016). Geothermal areas are located in remote and rural areas of Western Uganda, which are far from the potential hydropower sites and therefore geothermal energy has the potential to expand the national grid in western Uganda, where few people are connected to the electricity grid (Bahati, 2012). The GoU recognises the potential benefits of geothermal energy in providing a clean, reliable and secure source of energy. In addition of geothermal almost being a carbon-free source of energy, it would additionally contribute to displacing the use of fossil fuels (e.g. through diesel generators) expecting to rise along with the increasing demand of energy. Accordingly, the ambitious goal of developing geothermal energy up to a planned capacity of 450 MW by 2030 and to 1,500 MW by 2040 has been officially set to meet the future energy needs (GoU, 2017).

So far, 3 geothermal areas currently explored, namely Kibiro, Panyimur and Buranga, have reached the stage of drilling and will soon be drilled to discover the resource (CTCN, 2018), while many others have the potential to be exploited in the future. Results from exploration studies have proved that the geological conditions and temperature profiles (low to medium temperatures) were suitable both for direct energy use and electricity generation using binary technology (CTCN, 2018). As of today, geothermal energy development remains at a preliminary stage since major challenges and issues remain in the way of the adoption of such technology, particularly with the current energy policy framework. Licensing for geothermal resources is currently done under the Mining Act 2003, which defines geothermal as a mineral (GoU, 2003). The above legal and institutional framework is not focused on geothermal and there is therefore a need for developing an adequate policy, law and institutional framework to ensure the efficient development of geothermal energy in Uganda (Zakkour and Cook, 2016a).

For this reason, the Geothermal Resources Department (GRD) was created in 2014 after restructuration of the Ministry of Energy and Mineral Development (MEMD) and is responsible for exploration and development of the geothermal resources. It has produced a draft for a Geothermal Energy Development Policy in Uganda with support of the support of the Climate Technology Centre & Network (CTCN), which is still pending for approval by Cabinet. More information about the current status of the policy can be found in Section 1 of the Supporting Information (SI).

1.5 Objectives of the study

The pursued objectives of this ICAT pilot case-study focusing on geothermal energy development in Uganda are threefold. Firstly, it is aimed at ex-ante assessing potential transformational impacts related to geothermal energy development in Uganda, with a focus on social and environmental considerations. The methods and results of the assessment are intended to be shared with the GRD. It is likely to support policy design and possibly the decision-making process by policy-makers by demonstrating the potential benefits geothermal energy development could entail at the national level. Secondly, various drivers of change and main challenges Uganda is facing to enforce a geothermal energy development policy are looked at. Such assessment can help as capacity building for transparency, and to provide insights on where to focus time and resources to overcome current barriers to move forward in the policy design process. Lastly, this study demonstrates how a Planetary Boundaries absolute sustainability approach to transformational impact assessment can be applied and used as a complement to the ICAT *TC methodology*. Such approach can lead to quantification of transformational impacts and potential, strengthening the existing qualitative approach. While not a proper objective of this study, it is also contributing to the improvement of the *Doughnut methodology* by applying it to the full case of Geothermal Energy development in Uganda, involving stakeholders' engagement. Key lessons are therefore intended to be highlighted in order to update the *Doughnut methodology* and the results of the preliminary assessment can be validated.

2. Materials and Methods

The ICAT TC guidance is applied to the case of geothermal energy development in Uganda as a pilot in order to provide further clarity on the transformational impacts associated with the implementation of this policy (Section **2.1**). This methodology is supplemented by the integration of the Doughnut methodology to carry out the assessment (Section **2.2**). Local perspectives are included with implementation of a participatory approach in the assessment (Section **2.3**).

2.1 ICAT TC guidance

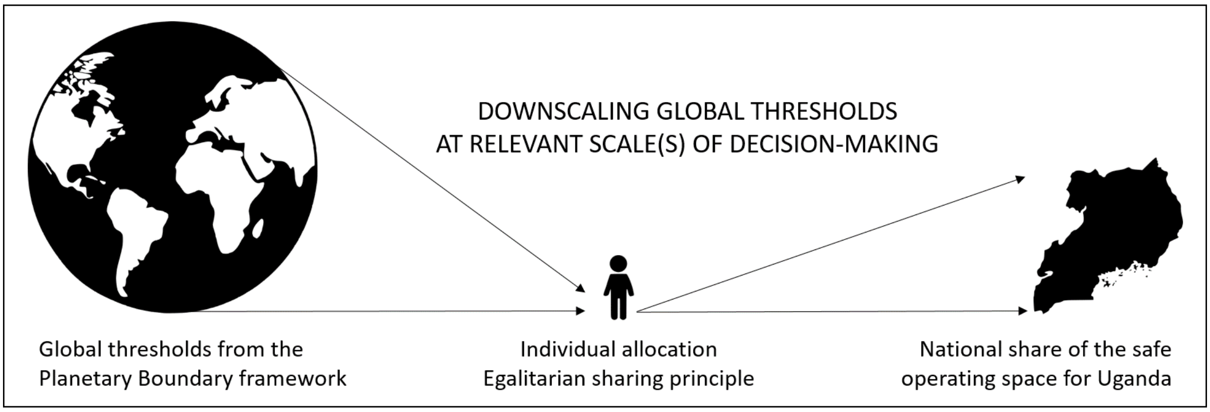
The current study follows the structure of the step-by-step methodology for ex-ante assessments provided by the ICAT *Transformational Change Methodology*. First, the scope of the assessment was defined. This includes a description of the policy (Section **3.1**), the definition of the assessment boundaries, the context in which the policy is designed (Section **3.2**), the vision for transformational change (Section **3.3**) and a thorough description of barriers of change (Section **4.1.1**). Based on these definitions, characteristics of change relevant to assess were chosen both for outcomes and processes. Specifically, each barrier of change was associated with affected with processes characteristics, which laying the foundations for performing the qualitative assessment of the processes of change. Relevance is assessed on a three-step scale (Relevant; Possibly relevant; Not relevant) and is based on the objectives and context of the policy (CTCN, 2018), on the national goals for Uganda's development (Government of Uganda, 2015) and on stakeholders' opinions regarding which types of impacts are deemed most important in the context of the country (see Section **2.3**). Once assessed characteristics have been chosen, indicators were identified to represent each of them (for processes and outcomes), enabling the assessment of the starting situation (2019), referred to as 'baseline scenario'. The ICAT *TC methodology* was strictly followed to assess processes of change, while the *Doughnut methodology* was used to assess outcomes of change (as detailed in Section **2.2**). Then, the expected transformational impacts associated with the individual policy were ex-ante assessed at the end of the assessment period (constituting the 'policy scenario'). The end of the assessment period was chosen to be 2040, based on when the objectives of the policy are intended to be met. Although recommended by the ICAT *TC methodology* to estimate a value for each selected indicator representative of the relevant characteristics to qualify the change in the selected characteristics, this step was not conducted. Instead, scoring to qualify the extent of the transformation was directly performed, based on the five-step scale, called disaggregated score (detailed in Section 3 of the SI). Not providing indicators with estimated values was not deemed influencing the following scoring step, considering the qualitative approach for the assessment. Scoring was given based on the knowledge of the situation and stakeholders' consultation. The last step consisted in aggregating the scores at the category level, resulting in one final score both for the outcomes of change and one score for the processes of change. Aggregation was based on the relative importance of the categories in the context of the policy, translated into weighting. Given the qualitative nature of the assessment and the high uncertainty related to the unpredictable nature of how complex systems evolve over long-term, transparency in the definition, methods and choices is essential in the assessment. Rationale are given for every step of the assessment. Eventually, the transformation associated with the implementation of the policy was depicted in the transformational impact matrix, plotting the extent (outcomes) and the likelihood of change (processes).

2.2 Doughnut methodology - SJOS

The *Doughnut methodology* was used to ex-ante assess outcomes of change associated with the implementation of the Geothermal Energy Development Policy in Uganda, as developed in the forthcoming paper by Desmoitier et al. (unknown). This preliminary assessment led to an ex-ante quantification of social and environmental impacts using the reviewed SJOS framework. Yet, it further requires stakeholders' engagement and results validation to be considered reliable and to potentially support decision-making. The preliminary assessment was used as a basis to assess the outcomes of change.

The *Doughnut methodology* is divided into a social and an environmental assessment. The environmental assessment is based on the Planetary Boundary (PB) framework (Rockström et al., 2009). To downscale the global thresholds to national goals for Uganda, the egalitarian sharing principle was used in this study, as illustrated on **Figure 3.** To assess the expected impacts of the Geothermal Energy Development policy in Uganda, the environmental impacts of the policy were assessed through a Life Cycle Assessment (LCA) study and the Planetary Boundaries-based Life Cycle Impact Assessment (PB-LCIA) method developed by (Ryberg et al., 2018) was used to express the results of the LCA study in the metrics of the PBs. The environmental results of the preliminary assessment were taken as such, since deemed proper to estimate the impacts associated with the development of geothermal energy in Uganda with accuracy requirements adequate with the objectives of the study.

Figure 3: Downscaling of Planetary Boundaries to the national level using the egalitarian sharing principle



A data inventory for Uganda in all 15 indicators of the Social Foundation was carried out to assess the baseline scenario. The impact assessment consists of several steps, i) identification of expected impacts with stakeholders and literature, ii) significance assessment of impacts with experts and stakeholders to ensure policy and country relevance and iii) significant impacts quantification. The preliminary assessment (forthcoming Desmoitier et al.) identified four dimensions of the SF with significant impacts (*Energy, Health, Work, Income)* and achieved quantification for three of them (*Energy, Health, Work*). The added-value of this ICAT pilot case was to conduct stakeholders' engagement to validate the results of the preliminary assessment and to enable the review of the social impact assessment, as described in section **2.3**.

The *Doughnut methodology* is used here as a supplement to the ICAT *TC Guidance* and seeks quantification of the outcomes of TC (the scope of each methodology is depicted on **Figure 2**). So, outcomes of change associated with the implementation of the Geothermal Energy Development Policy in Uganda were assessed on an absolute scale, compared against the defined absolute thresholds. The link with both methodologies was made at the indicator level, meaning that the indicators for the social and environmental categories of the *Doughnut methodology* were used for selecting the indicators for each characteristic of the outcomes of change. The associated determined values were used to describe the baseline and policy scenario. Assessing the extent to which the Geothermal Energy Development Policy could contribute to achieving transformational change in the policy scenario was made by comparing the impacts entailed by the geothermal policy option and an equivalent coal policy (proxy for currently used fossil fuels) aiming at meeting the country's energy needs in 2040 (modelled in forthcoming Desmoitier et al.). Accordingly, scoring was made on the five-step scale as suggested in the ICAT *TC guidance*.

2.2.1 Updates in the Social Impact Assessment part of the methodology

Taking inspiration from the ICAT *TC methodology* regarding the relevance assessment of process characteristics, the Social Impact Assessment (SIA) part of the *Doughnut methodology* was updated to include an additional step prior to the step i) impact identification, enabling proper and efficient allocation of time and available resources. It is referred to as the relevance of dimensions to the policy, dedicated to identifying the most relevant dimensions, in which the most significant impacts are expected to occur due to the implementation of the policy.

The second update in the methodology was made in the significance assessment step, which was performed based on four criteria (*Likelihood, Geographic extent, Duration* and *Intensity*), assessed by experts for all identified impacts within the relevant dimensions. In this study, significance was assessed by experts for merely two criteria were assessed, namely *Likelihood* and *Magnitude*. This simplification was made based on practical considerations in terms of feasibility with the granted time and resources. However, *Magnitude* can serve as a proxy for the aggregation of the criteria *Geographic extent*, *Duration* and *Intensity*. Accordingly, the aggregation rule to calculate the final significance score of an identified impact (forthcoming Desmoitier et al.) was updated as shown in

Updated aggregation rule: Si = 3 * Li * Mi **Eq. 1**:

Updated aggregation rule: $S_i = 3 * L_i * M_i$ **Eq. 1**

Where Si is significance, Li likelihood, Ini intensity, Gi geographic extent, Di duration and Mi magnitude of impact i. M_i *is taken as a proxy average for* $(In_i + G_i + D_i)$*. Li ** M_i *is multiplied by 3 to ensure that the scale used to classify impacts according to their significance [0; 75] is still suitable.*

2.3 Participatory approach

The participatory approach in this study was conducted relevantly for the application of the ICAT *TC methodology* and the *Doughnut methodology*. It was organised taking inspiration for the ICAT *Stakeholders engagement guidance* (ICAT, 2019). It contributes to increasing the policy relevance with consideration of local perspectives as part of the qualitative assessment, which is the objective of the ICAT TC methodology and a prerequisite of the quantification of impacts in the Doughnut methodology. To assess stakeholders' perspectives, three national stakeholders involved in the energy sector were interviewed in November 2019, including policymakers, private and public actors involved in geothermal energy development. Local communities located in geothermal areas, key stakeholders since largely affected by the development of geothermal energy yet with little influence on the decision-making process, were not consulted as part of this participatory approach, since it was deemed too early to be relevant to support the policy design. As the technology is at a very early stage of development in Uganda, awareness level is very low and knowledge about geothermal energy very limited. In addition, 4 MSc students in engineering and 3 staff members from the Centre for Research in Energy and Energy Conservation (CREEC) were engaged at a seminar on geothermal energy at Makerere University in Kampala (see Section 5 of the SI for the list of stakeholders).

A structured interview was conducted for the outcomes of change, which closely follows the method presented in the *Doughnut methodology* in section **2.2**. Relevance of the dimensions of the SF in the context of geothermal energy development in Uganda was assessed by stakeholders on a three-step scale (3 = Relevant, 2 = Possibly relevant, 1 = Not relevant), resulting in a narrower scope for the next steps by focusing only on what matters (i.e. 'Relevant' dimensions). The average relevance of dimensions is calculated among all the stakeholders and dimensions with a relevance higher than 2 out of 3 are considered relevant.

As for the processes of change, a semi-structured interview was conducted, as drivers of change and means highly vary depending on the local context and perspectives, hence the ICAT *TC methodology* being less prescriptive than the *Doughnut methodology*. The interview details can be found in Section 5 of the SI.

3. Description of the assessed system

3.1 Assessed policy

Since no geothermal policy has been enacted yet, the 'policy' assessed in this study refers to a hypothetical individual policy, referred to as the 'Geothermal Energy Development Policy' in Uganda in the following. It is alignment with the ambition of the Government of Uganda's (GoU) vision (Government of Uganda, 2015) and the conclusions of CTCN technical assistance projects (Zakkour and Cook, 2016b), CTCN, 2018). Accordingly, the policy objective was set as "**developing 1,500 MW of geothermal energy in the country by 2040, for direct use of geothermal energy and for electricity generation**". Particularly, this has great potential to help meet greenhouse gases reductions by displacement of biomass and fossil fuels. It will also contribute to improving livelihoods of communities, notably in geothermal areas through direct use of energy.

The 'baseline scenario' represents the state of Uganda for the year 2018, with the latest available data used as a proxy. The policy scenario consists of assessing the impacts associated to the implementation of the policy and the ending date of the assessment period is set for 2040, when the objectives of the Geothermal Energy Development Policy are supposedly met. Only impacts associated with the individual policy are considered in the comparison between the baseline- and policy-scenario and all other conditions that might affect the scores of both PBs and dimensions of the SF were kept constant. The only exception being demographic growth, which is accounted for via population projections.

3.2 Context for transformational change

The development of geothermal energy in Uganda currently lies near the end of the pre-development and is on the verge of entering the take-off phase of transformation, based on the phases' classification of the ICAT *TC methodology*. The degree of system change is still near zero as no law has been passed yet (as the draft is pending for approval by Cabinet) and exploration studies are just about to start that intend to confirm the possibility to exploit geothermal resources in the country. As of today, no geothermal power plants has been built in the country. There is overall low awareness amongst the different strata of the Ugandan society about what geothermal energy is and how it could be beneficial to the country's development driven by a rapid demographic growth, which results in an ever-increasing energy demand paramount to improve social standards in the country. Existing paradigms in the energy sector are not being challenged yet by the emergence of interest towards geothermal energy development. Specifically, hydropower and reliance on fossil fuels and biomass remain the major sources of energy in the country. The latter largely contribute to the overall GHG emissions of the country, which the GoU has officially pledged to reduce (Uganda Vision 2040). No university nor research institution offer curriculum specialised in geothermal energy. Capacity building happens mainly in Kenya and in other countries endowed with geothermal energy (e.g. Iceland). While there is law awareness and little questioning of existing paradigms, steps are being taken to implement a favourable environment supporting geothermal development: GRD is conducting exploration studies, a regulatory framework separating geothermal resources from the mineral act has been drafted and there is strong will from GRD to expand capacity building in the country. If exploration studies (expected to start in December 2019) prove to be successful, geothermal energy development could enter the take-off phase with lower investment risks, further exploration of other geothermal areas and the construction of a pilot geothermal plant. Specific actions to support direct energy use in geothermal areas could also then be incentivised.

3.3 Vision for transformational change

To achieve the targets of the Uganda Vision 2040, the country needs to develop and generate modern, clean and cheap energy to drive the industry and services sectors. The required capacity will be generated from different energy sources namely and **geothermal is expected to account for the generation of 1500 MW**. The access to the national grid will have to be significantly develop to provide access to new households, to connect the added capacity to the increasing energy demand. Eventually, development of geothermal energy aims at contributing to the global vision of zero-carbon and sustainable development towards a zero carbon electricity production and 100% electricity access in Uganda.

Accordingly, the short term goal focuses on building an enabling environment for sustainable, efficient and reliable geothermal energy production by taking action to mitigate the remaining barriers of change. The regulatory framework is currently being developed, with the policy draft pending for approval by Cabinet. Capacity building will have to be expanded, with hiring and training of new staff to support this emerging sector. Exploration studies have a key role to play in the further development and are expected to be completed on the short run (drillings start in December 2019). If geological conditions are proved to be suitable for further exploitation, a pilot geothermal power plant with a capacity of 5 MW is intended to be built as an example to attract investors and private partners (within 2-5 years). Awareness campaign dedicated to policy-makers, the private sector, local communities, academics etc. is also planned on the short term.

As for the mid-term vision, it seeks to generate direct geothermal energy use opportunities in geothermal areas (local geographical scale), which is likely to enhance livelihood of local communities. Business opportunities include drying of agricultural and fishery products, energy supply to greenhouses and fish farms, development of touristic activities and geothermal spas. Expected impacts are increased food and energy security, job creation, higher income, boosted economy. Use of direct energy is also expected to displace the use of diesel generators, contributing to lower GHG emissions and better air quality.

Electricity generation from geothermal energy and supply to the national grid should also start by 2030 as the energy surplus from hydro power should be offset by the increasing electricity demand and electricity consumption per capita and as the distribution network expands.

4. Results

4.1 Qualitative assessment based on the ICAT TC methodology

The key findings of applying the ICAT *TC methodology* to the case of the Geothermal Energy Development Policy in Uganda are presented in this section (see section 4 of the SI for further details).

4.1.1 Processes of change

Several barriers to transformational change related to geothermal energy development in Uganda were identified as an outcome of the semi-structured interviews that were conducted. They are summarized in **Table 1** below.

Table 1: Barriers of transformational change classified by type of barriers in the context of the ICAT TC Methodology in the context of the Geothermal Energy Development policy in Uganda.

POLITICAL	**Lack of popular support and political will to promote a transition.** Vested interests in existing coal and oil dependent production actively resist climate policies and regulations.
	Lack of awareness at the government level. Inter-ministerial miscommunication and misunderstanding on the benefits of geothermal energy. Also, the policy-makers need to understand clearly what the added value of geothermal (direct use or electricity generation for example) is in order to design an efficient policy.
	Lack of cooperation between the private and public sectors. Vested interests in geothermal-licensed companies and resource extraction companies. The resource extraction may be more profitable than the exploitation of geothermal energy. Also, license may be hold for speculative reason rather than for the sake of development.
INSTITUTIONAL	**Lack of a strategy to discourage fossil fuel based energy.** Existing or foreseeable energy strategy dominantly plans expansion of thermal power plant, and oil related activities. There is a lack of a comprehensive strategy that fosters the development of all accessible renewable resources to meet the targets set in Uganda Vision 2040. For example, Ugandan universities have no offer for curriculum focused on geothermal energy, while to provide a significant share of the electricity capacity in the future.
	Lack of incentives to develop geothermal energy. There is already existing electricity surplus in the national grid (too much production compared to consumption), so no clear incentives to accelerate the development of GE in the short term. The focus should rather be on expanding the grid connection (access to electricity).
	Lack of country specific technical assistance. Technical assistance from international support needs to target the specific needs of the country and incorporate multi-stakeholders groups' consultations.
SOC	**Lack of social acceptance and awareness regarding the technology**, especially from local communities. Hostility from local communities due to lack of awareness and fear of loss of local culture,

	displacement and loss of land ownership. For example, some geothermal sites may present holly features for local communities.
	Conservativeness and fear of change, lobbies
TECHNOLOGY	**Limited availability of geothermal technology and technical resources.** There is no domestic manufacturing and distribution capacity for geothermal energy development in the country so components need to be imported. This is mainly because the technology is not readily available yet in Uganda and the geothermal areas are not well known yet, creating a high risk for investors.
	Potential lack of relevant sites for geothermal energy. Lower temperature profiles have been identified in western African rift compared to the eastern African rift, leading to less electricity generation and more risk for investors in electricity generation from geothermal energy.
CAPACITY	**Lack of technical personnel for installation and maintenance.** Lack of trained technicians for geothermal energy development e.g. the installation and maintenance of the plants, which slows down a potential scale-up geothermal energy generation.
FINANCIAL	**High upfront cost.** Higher upfront costs compared to other renewables (hydro, solar etc.) or fossil-fuel based sources of energy, which make geothermal energy less attractive.
	High financial risk related to geothermal energy. The risk of investment is high due to the uncertain potential of geothermal areas, which lead to a lack of attraction for investors, banks and international support.

Based on these barriers, on stakeholders' consultation, on Uganda Vision 2040 and literature on geothermal energy in neighbouring countries, six process characteristics were identified as 'relevant' (*Research and development; Adoption of technology; Entrepreneurs; Economic and non-economic incentives; Institutions and regulations; Awareness)*, three as 'possibly relevant' (*Scale up; Coalition of advocates; Disincentives*) and three as 'not relevant' (*Beneficiaries; Behaviour; Social norms*). The description of the characteristics in the context of geothermal energy in Uganda and the rationale for the relevance assessment are presented in **Table 2**.

Table 2: Relevance assessment for the process characteristics of the ICAT TC Methodology in the context of the Geothermal Energy Development policy in Uganda. Categories highlighted in green are 'relevant', yellow are 'Possibly relevant' and grey ones are 'Not relevant"

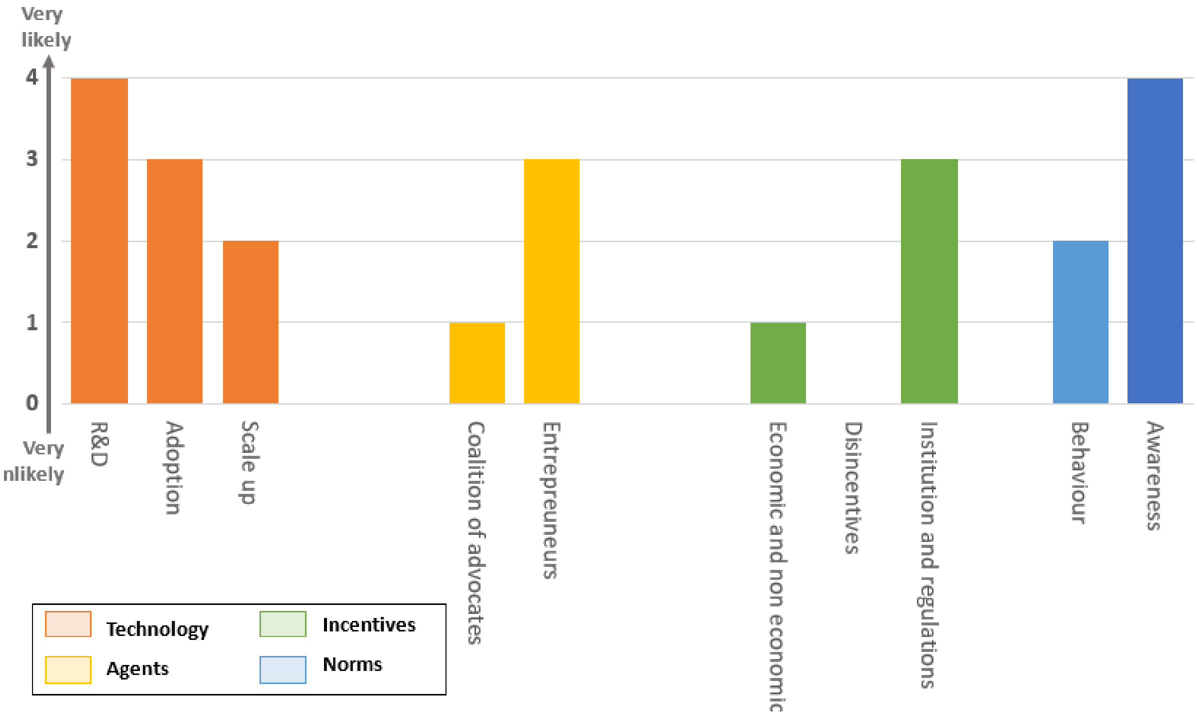
Process category and characteristic		Description - Specific to the Geothermal Energy Development policy	Relevance and justification
TECHNOLOGY	Research and development	The policy will enhance support to R&D for developing geothermal energy via: - Geothermal energy exploration and drilling in two geothermal areas - Procurement of laboratory equipment, data processing software (geophysical, geological, geochemical and environmental equipment) - Further contribution to national database and website to gather all geoscience data and information related to geothermal industry and to the regional database, the Africa Geothermal Inventory Database (AGID, ArGEO) - Capacity building and training of staff members in specialized countries in geothermal energy (e.g. Iceland, New-Zealand, Kenya) and hopefully in Uganda once collaboration with universities gets started.	Capacity building efforts, technical knowledge and skills, development of the technology and geothermal exploration are crucial for the achievement of the objectives of the policy, since geothermal energy remains a new technology remaining largely under developed and unsecured, suffering from large and widespread lack of awareness.
	Adoption	The policy supports the adoption of geothermal technologies by supporting exploration and drilling studies to assess the geothermal water streams and temperature profiles, key to assess the extent of the geothermal potential of targeted geothermal areas. Such results should then facilitate the development of pilot projects in these areas to demonstrate the benefits of exploiting such renewable energy with which Uganda is endowed. Such pilots could turn geothermal energy into a more attractive source of energy for the future, in which the private sector, investors and other relevant authorities would be interested in supporting.	As of today, the adoption rate is non-existent in the country, as no geothermal technology and facility has been implemented yet. Action is required to leverage adoption of such technology, notably to address the issue of high capital costs compared to already largely-developed hydropower, discouraging potential investors and key actors from the private sector to endorse development of geothermal energy.
	Scale up	The policy supports a twofold objective when thinking of geothermal resources development, that have different potential for scaling-up: - direct use of geothermal energy in the vicinity of geothermal areas (local scale), with potential larger scale impacts (short to medium-term vision) - generation of electricity to be injected to the national grid (national scale impact but is a long-term objective)	Before the development of geothermal energy can be scaled up in the country, such technology has to be secured and adopted. To this point, it is not clear whether scaling will be crucial as large uncertainties regarding geothermal areas potential need to be reduced in the first place (decisive use of the results of exploration and drilling studies). Besides, scale-up of geothermal projects is strongly related to the localisation of the geothermal areas (located on the western part of the country), thus the impact is relatively limited to such areas.

AGENTS	Entrepreneurs	By supporting and financing exploration and drilling studies to estimate the geothermal potential of the country, the policy will enable a lowering of the financial and investments risks for investors and should focus on enabling an attractive financial environment to boost private and significant investments in the sector, necessary to geothermal development. Specifically, development of direct use of geothermal energy represents a beacon for the emergence of a significance amount of businesses of various scales in particular in the agricultural, fishery, tourism and energy sectors.	Collaboration between the public and private sector is fundamental to the development of geothermal energy considering the high upfront costs of such technology and the structure of the power sector in Uganda (unbundled, functioning with PPA, see (Meyer et al., 2018) for more information). This currently remains one key barrier of change. The private sector and investors represent very important agents of change for geothermal energy development in the country. There is consensus amongst GoU that geothermal energy must be able to attract investors and highlight strong business opportunities.
	Coalition of advocates	The policy design and implementation involve multiple stakeholder consultations and inclusive practices. Moreover, cooperation between private and public entities is fundamental to such energy development.	Development of geothermal energy has to be done in close collaboration with a various panel of stakeholders, with a focus on local communities in the geothermal areas. However, it is not so clear to this point the extent to which it will catalyse the transformation and the development of geothermal energy.
	Beneficiaries	No description necessary since this characteristic is not relevant	The political context in Uganda makes beneficiaries (from energy, employment, local businesses, etc.) an ineffective group that plays no role in the development and the scaling of geothermal energy.
INCENTIVES	Economic and non-economic incentives	The policy will have to enhance the attractiveness of geothermal energy compared to other sources of energy by defining competitive feed-in tariffs for geothermal energy, favoring access to low-cost finance, subsidizing it. Compensations for land to local communities will also need to be granted. As for non-economic incentives, partnerships with local communities could be put in place ensuring maximization of positive local impacts (government support, limited bureaucracy procedures etc.)	Subsidies, low-cost finance have definitely a key role to play in order to overcome a key barrier of high upfront costs associated with geothermal energy projects. Partnership with the government but also by securing international investment funds dedicated for the development of renewable energy projects will support the development of the technology.
	Disincentives	The policy may support disincentives towards fossil-fuels to make geothermal energy more attractive than carbon-based sources of energy.	For specific applications where geothermal energy and fossil fuels could be in competition, economic disincentives could enable to favour the former over the latter. However, vested interests and lobbying in the fossil and oil sector remain strong, and it is not clear whether disincentives applied to fossil fuels will be strong enough to cause any impact in the geothermal energy sector.

	Institutions and regulations	The policy will support structural change in institutions and regulations to create an enabling environment for development of geothermal energy through: - Restructuring of the MEMD (already happened in 2014) to create a dedicated department for developing geothermal energy called the Geothermal Resources Department (GRD) Enforcement of Geothermal Act and Regulation separated from the Mining Act, aiming at declassifying geothermal resources as a mineral and creating regulatory framework that encompasses challenges and specificities of such a resource.	To focus on the development of geothermal energy, it is crucial to have the proper means, resources and infrastructures. Considering the complexity of this new technology and associated costs, the government has a key role to play to create an enabling environment. Notably, through restructuring and law enforcing, it has the potential to overcome crucial barriers such as vested interests that hamper the development of geothermal energy, being directly in competition with extraction of minerals.
NORMS	Awareness	The policy helps raise awareness amongst Ugandan society and disseminate information about geothermal energy to different groups of stakeholders (e.g. technical staff, local communities).	Global lack of awareness about geothermal energy is a major barrier to development of such source of energy at all levels of society. Particularly, at the Governmental level, this hinders co-ministerial collaboration and trust, and creates suspicion about use and relevance of investments. In the academics sphere, this limits the number of skilled staff and increases the difficulty to hire interested and motivated people to work in the sector, which overall slows the development and represents a key barrier. Amongst local communities, there is high misconception and reluctance to adopt such technology, notably in regards of land use and potential displacements of populations.
	Behaviour	The policy might affect the behavior of local residents and businesses to opt for direct uses of geothermal energy.	Behaviour of consumers might be impacted by the policy specifically in the case of direct use of geothermal energy in geothermal areas. For example, creation of public cooking places in villages fuelled with geothermal energy can replace use of biomass for cooking. For electricity generation, this characteristic might not be relevant due to limited influence of the consumers.
	Social norms	No description necessary since this characteristic is not relevant	The distribution will be done through the national electricity grid and thus cultural behaviour will not change the extent of the transformation much. For direct use, norms might change but at a very local scale.

The interpretation of the interviews, discussions and the seminar resulted in scores on a five-step scale for each of the relevant and the possibly relevant characteristics. These scores qualitatively depicts the likelihood that the Geothermal Energy Development policy will have a significant impact on each characteristics by 2040, which is the end of the assessment period. Rationale justifying the scores are given in the supporting Information.

Figure 4: Potential for policies to impact transformational change characteristics over the assessment period (likelihood scored between 0 and 4). Only relevant processes characteristics are represented (Beneficiaries and Social norms not represented).



4.1.2 Outcomes of change

For both the scale and the sustained nature of the outcomes, the characteristics are described in **Table 3** and the boundaries of the assessment define whether each characteristic is relevant to assess. Only the macro level for the scale of the outcome of change is outside the boundaries, as no international or global outcome is expected from the Geothermal Energy Development policy in Uganda.

Table 3: Relevance assessment for the outcome characteristics of the ICAT TC Methodology in the context of the Geothermal Energy Development policy in Uganda. Categories highlighted in green fall within the scope of the assessment, those in grey are outside the boundaries. GHGs stands for Greenhouse Gases and focus on reducing their emissions and SD stands for Sustainable Development.

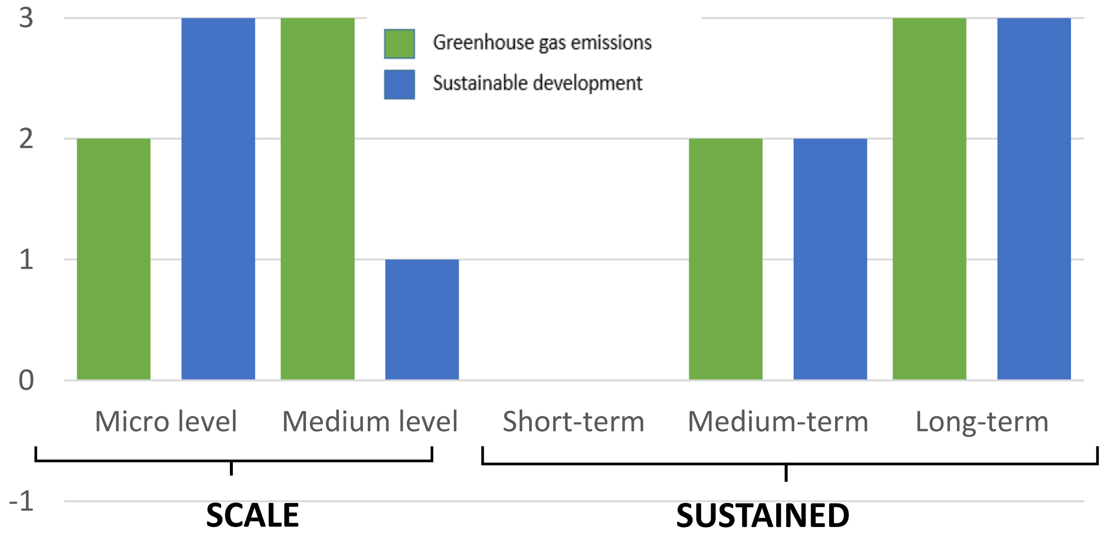
Outcome category and characteristic		Description - Geothermal Energy Development policy
SCALE GHGs	Macro level	The level is outside the assessment boundaries. No assessment necessary.
	Medium level	GHG reduction are expected to be net positive in magnitude at the national level by avoiding the development of fossils fuels energy for electricity generation.

		Micro level	GHG reduction are expected to be net positive in magnitude at the subnational level by avoiding the development of fossils fuels energy for electricity generation and also for direct use of energy.
SCALE	SD	Macro level	The level is outside the assessment boundaries. No assessment necessary.
		Medium level	Sustainable development outcomes are expected to be net positive in magnitude at national and sectoral levels. The policy intend to connect a significant amount of people to electricity: this will create jobs and improve livelihoods of individuals in Uganda.
		Micro level	Sustainable development outcomes are expected to be net positive in magnitude at local levels based on direct use of geothermal energy, e.g. food security, income, work, health, energy, etc.
SUSTATINED NATURE -	GHGs	Long-term > 15 years	The policy aims at achieving its long term objective by 2040, based on Uganda Vision 2040.
		Medium term 5 - 15 years	No medium term specific objectives have been defined but it seems that medium term should focus on adding to the direct use of geothermal energy the development of electricity generation facilities.
		Short-term < 5 years	For the short term, the emphasis is on the direct use of geothermal energy, which can reduce GHGs by replacing fossil fuel energy such as diesel generators.
SUSTAINED	NATURE - SD	Long-term > 15 years	The policy aims at achieving its long term objective by 2040, based on Uganda Vision 2040.
		Medium term 5 - 15 years	No medium term specific objectives have been defined but it seems that medium term should focus on adding to the direct use of geothermal energy the development of electricity generation facilities.
		Short-term < 5 years	For the short term, the emphasis is on the direct use of geothermal energy, which can create economic opportunities with tourism, improve food security and production, etc.

As for the processes of change, the interpretation of the interviews, discussions and the seminar resulted in scores on a five-step scale for each of the relevant and the possibly relevant characteristics. For the scale of the outcome, these scores qualitatively depict the extent of the impacts of the Geothermal Energy Development policy on greenhouse gas emissions and sustainable development. For the sustained nature of the outcome, they depict the likelihood that these impacts are sustained over time. Indicators expected value for the scale of the outcomes and rationale justifying all scores are given in the Supporting Information.

Fehler! Verweisquelle konnte nicht gefunden werden. illustrates a break-down of the assessment results on the level of disaggregated scale and sustained nature of outcome characteristics.

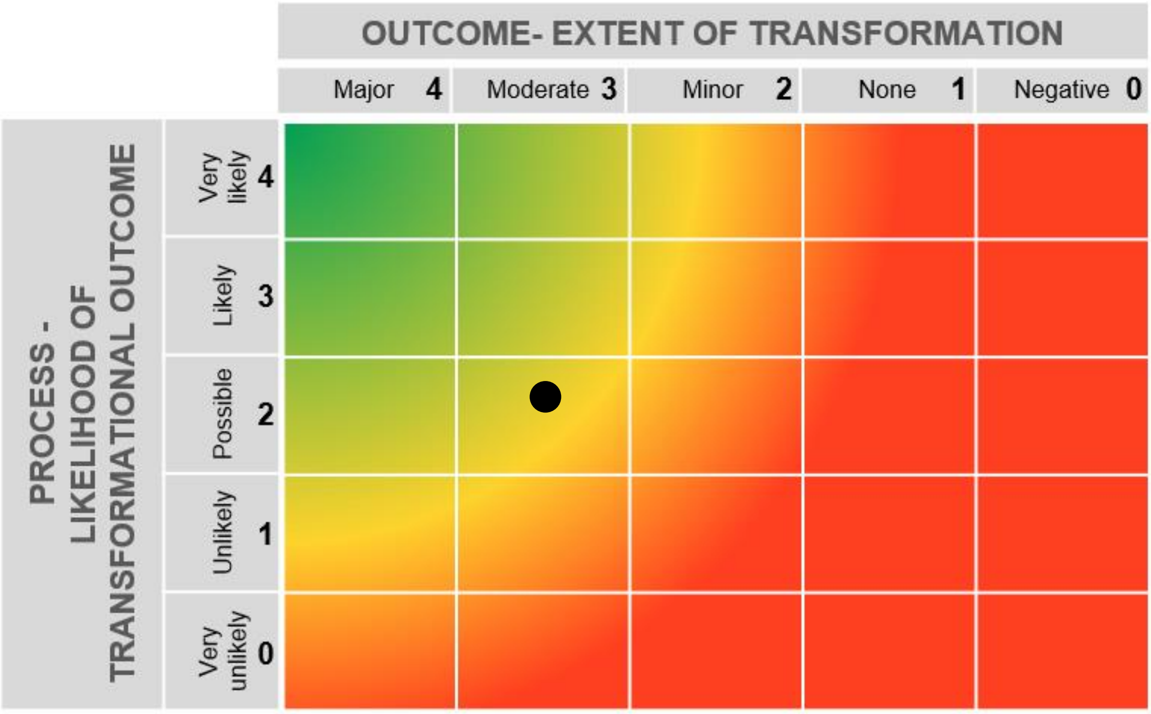
Figure 5: Assessment results on the level of disaggregated scale and sustained nature of outcomes characteristics.



4.1.3 Transformational impact matrix

The results indicate the extent of transformation expected by the policy or action and how likely it is that this expected transformation can be realized. Figure XXX illustrates the matrix of possible qualitative scores for process and outcome impacts and includes the final aggregated score for the transformational potential of the Geothermal Energy Development policy. When the result for the policy or action falls in the green area, it indicates that the policy or action is expected to be transformational. When it is situated in the red area, the policy cannot be considered transformational. The color gradient of the matrix reflects the qualitative nature of the analysis and the high uncertainty associated with the assessment.

Figure 6: Transformational impact matrix illustrating the potential of the hypothetical Geothermal Energy Development Policy in Uganda to contribute to transformational change.



4.2 Quantitative assessment of the scale of the social outcomes of change

4.2.1 Relevance of dimensions

The results of the average relevance of dimensions, based on 10 stakeholders' answers, highlighted eight relevant dimension, namely Food, Health, Income, Work, Education, Energy, Social equity, Life satisfaction.

4.2.2 Impacts significance assessment

The results of the significance assessment carried out by stakeholders are presented in Table 4.

*Table 4: Identified impacts from the participatory approach and significance assessment based on the updated methodological steps presented in section **2.3.***

Dimension	Interview	Impact	Likeli-hood	Magni-tude	Signifi-cance
Food	8	Increased in fish farming activity	3	3	27
		Increased in food production from greenhouses	2	2	12
	9	Better water access for agriculture when droughts (pumping)	3	2	18
		Heat for food processing e.g. drying, pasteurisation	4	4	48
		Longevity of agricultural and fishery products	4	4	48
		Offering access to more remote markets for sale of locally produced food products	3	2	18
		Land use change: decreased land availability for agriculture and for grazing land for life stock	2	2	12
Health	8	Reduction of health issue with the replacement of unhealthy practices (e.g. kerosen lamps, firewood, charcoal etc.)	5	5	75
		Improved indoor climate from fossil fuel systems	5	5	75
	2	Increase in health quality in the long term	5	4	60
	3	Direct, positive	4	4	48
	4	Increase health quality due to increased number of hospital with electricity	4	3	36
	5	Increase in health provision	3	3	27
Income	8	Increase income from direct use, e.g. sell agricultural products	5	5	75
		Increase income from tourism, e.g. geothermal bath	3	4	36
	9	Increased salaries for directly or indirectly involved employees	3	3	27
		New economic opportunities for local people e.g. sell of agricultural products	3	3	27
		Creation of shopping center and cultural center for tourists resulting in in-creased income levels	3	3	27

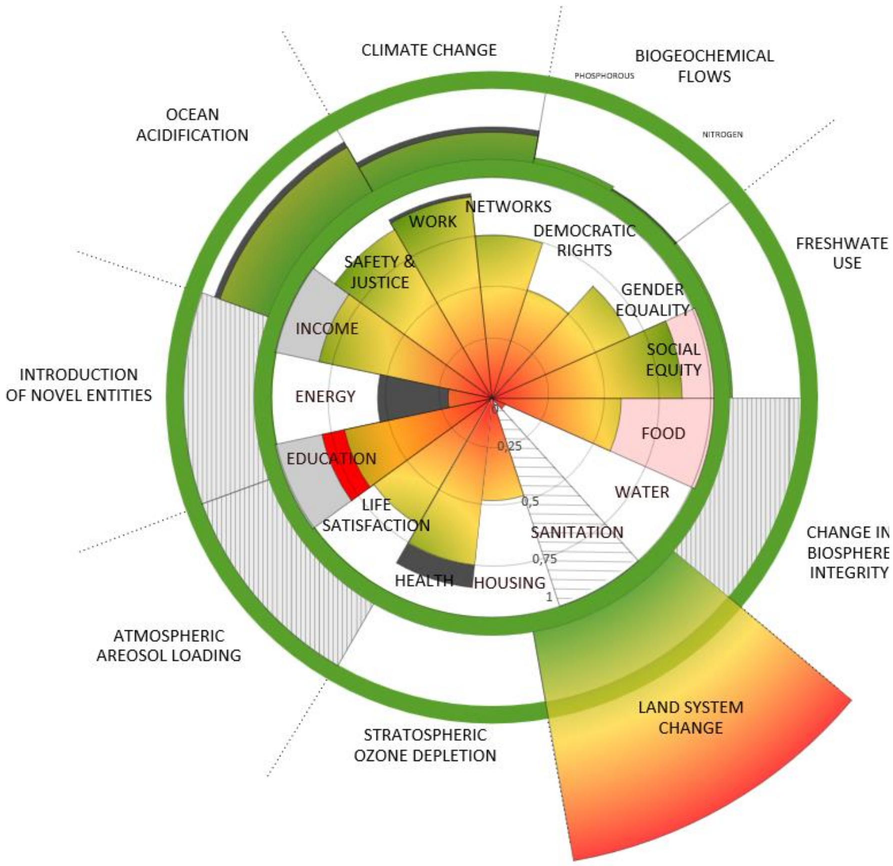
		Income from rent and transport services)	3	3	27
		Decreased energy expenses (from direct use of energy)	3	2	18
		Income from tourism (spas, baths, pools, etc.)	3	3	27
	2	Increase in business opportunities	5	4	60
	4	Increase income with more working opportunities	5	5	75
	5	Increase number of opportunities	5	2	30
	6	Increase in business opportunities and exports	5	2	30
Work	8	Increase in regulatory jobs related to geothermal energy	4	5	60
		Increase in technical jobs related to geothermal energy	3	5	45
		Increase in employment fron direct use of energy, creating new jobs and economic opportunities for local communities (e.g. heating greenhouses, fish farming)	4	5	60
	9	Direct and long-term job creation	4	3	36
		Direct and short-term job creation	4	3	36
		Hire local employees	4	2	24
		Direct use of energy: local business opportunities	4	3	36
		Stimulated jobs (indirect)	3	3	27
	1	Increase employment in graduate in energy studies	5	4	60
	2	Increase in jobs in the long term	5	5	75
	4	Increase in employment	5	5	75
Education	8	Increase in training, green jobs skills, curiculum related to geothermal energy	5	5	75
		Increased in skills from direct use (e.g. fish farming, greenhouses, agriculture etc.)	3	4	36
	1	Increase in trainings in energy sector	4	4	48
	3	Short term, positive	5	5	75
	7	Increase in education quality with access to electricity	3	4	36

Energy	8	Increase electricity generation and share of clean energy	5	5	75
		Increased access to energy in households	4	4	48
	9	Decreased levelised cost of energy, electricity cost	4	3	36
		Increased energy security (national independence and stabilisation)	4	3	36
		Increased access to energy (households, public infrastructures etc.)	3	3	27
		Increased share of clean energy (low greenhouse gas emitting energy source)	4	3	36
		Locally produced energy	4	3	36
		Direct use of energy: cooking	3	3	27
		More people connected to the grid	3	3	27
		Direct energy: EV	3	2	18
	1	Increase in low energy mix and lower the cost of energy	5	4	60
	2	Increase in access to affordable clean energy	5	5	75
	3	Long term, positive	4	5	60
	5	Increase in reliable electricity in households and public buildings	5	2	30
	6	Increase in access to affordable energy	5	2	30
	7	Increase in energy accessibility	5	5	75
Social equity	8	Decreased inequality for marginalised people (e.g. ethnies in remote geothermal area), by giving them the opportunity to have a voice during the implementation of the policy	3	4	36
	4	Decrease geographical inequalities, in remote areas	5	4	60
	6	Increase opportunities of development for all	5	2	30
Life satisfaction	6	Increase of tourism and productive use of electricity	5	2	30
	7	Increase in wellbeing thanks to clean energy	4	4	48

4.2.3 Updated visualisation of the results

Results from the implementation of the participatory approach led to the following visualisation of the updated results, as shown on **Figure 7**: Visualisation of the policy scenario, whose social assessment is updated.. Impacts matched two different geographical scale, both local and national. Impacts happening at the local scale are induced by the development of direct use of geothermal energy, which cannot be represented in the final results as the scale of the assessment is national. This is the case for the dimension *Food* and *Social Equity*, which are expected to be significantly impacted by the policy at the local level but in which impacts at the national scale may not be visible. The results at the national scale are close to those of the preliminary assessment, with significant impacts identified in the dimensions *Work, Energy, Health, Income, Education and Life Satisfaction*. Therefore, the same dimensions have been identified as in the preliminary assessment, in addition to *Education* and *Life Satisfaction*.

Figure 7: Visualisation of the policy scenario, whose social assessment is updated.



5. Discussion

Applying the Doughnut methodology in supplement of the ICAT TC methodology with stakeholders' engagement led to the assessment of impacts expected from the implementation of the still hypothetical Geothermal Energy Development Policy. The extent to which such results could contribute to transformational change in Uganda is discussed, along with how such assessment could support decision-making. Finally, the relevance of supplementing the ICAT TC methodology with an absolute quantitative approach to impact assessment is elaborated on.

5.1 Transformational potential of geothermal energy in Uganda in achieving goals of Uganda vision 2040

The expected state of policy scenario in 2040 shows that developing geothermal energy up to a capacity of 1,500 MW both for direct use of energy and electricity generation could lead to significant improvements of social standards in Uganda, getting closer to meeting the thresholds of social sustainability defined in the Doughnut methodology. These can be put in perspective with the ambitious targets expressed by the GoU in Uganda Vision 2040, guiding the development strategy of the country until 2040 (Government of Uganda, 2015). Absolute social thresholds and some of the targets set by the GoU can be compared and are presented in Fehler! Verweisquelle konnte nicht gefunden werden..

From the table, it can be concluded that implementing the objective set by the still hypothetical Geothermal Energy Development Policy in Uganda could significantly contribute to achieving the development targets set for the country in Uganda vision 2040. Particularly, it could critically enhance the fraction of population with access to electricity (from 19.0% in 2018 to 56% in 2040) and the life expectancy (from 57.0 years in 2018 to 66 in 2040), as aimed at in Uganda Vision 2040. It is worth reminding that such results are merely accounting for the impacts expected from developing geothermal energy, while disregarding any other type of policy and action in other sectors who may also contribute to enhancing social standards. Yet, by looking at the baseline values for the years 2010 and 2018 giving insights on the current trend, it seems unlikely that such ambitious targets are to be met in 2040. Besides, geothermal energy represents a reliable, renewable, clean and cheap (as regards operational costs) source of energy with which Uganda is endowed with, reinforcing energy security in the country, by diminishing reliance on exported fossil fuels subject to prices fluctuation. However, the extent to which such source of energy could be developed remains largely uncertain. After two decades of research and exploration of Ugandan geothermal resources, the technology has not been adopted yet, resulting in no geothermal infrastructure in the country (Zakkour and Cook, 2016a). Even though a law is in the process of being drafted to overcome some of the barriers of change hampering the development of geothermal energy, major barriers remain unaddressed.

Table 5: Comparison of the development targets set by GoU for 2040 with the expected outcomes of implementing the geothermal policy for some sustainable development impacts (mostly covering the social dimension)

Uganda Vision 2040			Doughnut methodology		
Indicator	**Baseline status (2010)**	**Target for 2040**	**Indicator**	**Baseline status (2018)**	**Policy score**
Percentage of population below the poverty line	24.5	5	Fraction of population living below the national poverty line (%)	19.7	Impacts of policy not quantified
Income distribution(GINI Coefficient)	0.43	0.32	Palma ratio (Social equity)	1.2	2.0
% population with access to electricity	11	80	Fraction of population with access to electricity (%)	19.0 %	56.8 %
% population with access to safe piped water	15	100	Fraction of population using safely managed drinking water services (%)	6.44 %	6.44 %
Life expectancy at birth (years)	51.5	85	Life expectancy at birth (years)	57.0	66.1
Literacy Rate (%)	73	95	Children aged 12-15 out of school (%)	31.4 %	Expected positive impact but not quantified
Corruption Perception Index	2.5	7.1	Voice and accountability index	-0.6	Impacts of policy not quantified
Forest Cover (% land Area)	15	24	Area of forested land (% of original forest cover)	18 %	18%

5.2 Potential of ex-ante integrated assessments to support policy-making

- Policy alignment with national long-term targets (e.g. 2040 in Uganda)
- Insights on how to use this assessment in the policy design and implementation cycle to overcome some of the identified barriers
- Highlight the importance of ex-ante assessment to inform about potential barriers and suggest how to overcome them for a policy to be successful and achieve transformational goal
- Inform interlinkages across dimensions of sustainability to better inform and manage trade-offs

5.3 Potential to support transparency requirements and ambition raising

- Methodology sound assessments (LCA, SIA), with robust indicators that provide a framework for doing comparable assessments
- ICAT and Doughnut IA methodologies aligned with the global goals (SDGs/PA/PBs)
- Focus on "mitigation" requirements of the ETF for developing countries?

5.4 Reflections on Doughnut methodology

- Quantification not always sought, sometimes qualitative or semi-qualitative enough considering the objectives of the assessment
- Use of case-study to update methodology
- Doughnut visual could be adapted to fit at different scale: here make it fit to the local scale to depict impacts related to use of direct geothermal energy.

6. Conclusion

Applying the step-by-step approach of the ICAT *Transformational Change methodology* to the case of the individual and remaining hypothetical policy (since not enacted yet) leading Geothermal Energy Development in Uganda to ex-ante assess GHGs and sustainable development impacts has proven that such policy will possibly entail transformation while the outcomes of change will be moderate.

Such results highlight the challenges and barriers leaders of geothermal energy development are facing. While ambitious objectives have been set regarding the development of this new technology and source of energy in the official document Uganda vision 2040, i.e. to build an additional capacity of 1,500 MW from geothermal resources for both direct use of energy and electricity generation, barriers of change remain numerous and significant (hence the likelihood of change being characterized as "Possible"). The main barriers identified consequently to stakeholder engagement are due to high vested interests, notably to support the oil and gas business, hampering the development of this new technology, lack of private funding and investors paramount to financially support the adoption and development of this new technology, critical lack of awareness in the different strata of the Ugandan society and finally lack of skilled technical staff to support drilling and exploration studies, key in the confirmation of the exploitability of geothermal areas. While some barriers of change are to be addressed by the policy enactment, others remain not tackled, undermining the likelihood of change.

However, if geothermal energy were to be developed, the extent of the transformation is expected to be Moderate, with large mitigation of GHGs emissions compared to other sources of energy used to meet the energy needs (e.g. diesel generators) and the expected positive outcomes for different sustainable development impacts, such as in the Health, Work and Education dimensions.

Finally, it was proven with this assessment how an absolute sustainability Planetary Boundaries approach adopted here to ex-ante evaluate the outcomes of change could complement the existing version of the ICAT TC methodology, by suggesting a framework to assess the scale of the outcomes. The extent of the transformation is therefore scored based on estimated impacts entailed by the policy compared against absolute thresholds defining a truly sustainable state for Uganda. This approach is believed to strengthen the assessment and the characterisation of expected transformational outcomes entailed by a policy, supporting the initial definition of transformational change.

REFERENCES

Bahati, G., 2012. Geothermal Energy Development in Uganda: A Country Update.

CTCN, 2018. Technical Assistance for direct use: Assessment of Panyimur and Buranga geothermal areas, Uganda.

ERA, 2018. Uganda Electricity Sector [WWW Document]. URL https://www.era.or.ug/index.php/sector-overview/uganda-electricity-sector (accessed 11.28.19).

GoU, 2017. The Uganda Green Growth Development Strategy 2017/18 - 2030/31.

GOU, 2015. Government of Uganda: Second National Development Plan. Natl. Plan. Auth. Uganda 1, 65–70.

Government of Uganda, 2015. Uganda Vision 2040.

ICAT, 2019. ICAT Stakeholder Participation Guide.

ICAT, 2018. Transformational Change Guidance - Guidance for assessing the transformational impacts of policies and actions.

Kato, V., 2016. GEOTHERMAL EXPLORATION IN UGANDA.

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S., Schellnhuber, H.J., 2008. Tipping elements in the Earth's climate system. Proc. Natl. Acad. Sci. U. S. A. 105, 1786–1793. https://doi.org/10.1073/pnas.0705414105

MEMD, 2015. Ministry of Energy and Mineral Development: Uganda's Sustainable Energy For All (SE4All) Initiative Action Agenda.

Raworth, K., 2017. A Doughnut for the Anthropocene: Appendix. Heal. Lancet Planet.

Raworth, K., 2012. A Safe and Just Space for Humanity: Can we live within the doughnut? Oxfam Policy Pract. Clim. Chang. Resil. https://doi.org/10.5822/978-1-61091-458-1

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. A safe operating space for humanity. Nature 461, 472–475. https://doi.org/10.1038/461472a

Ryberg, M.W., Owsianiak, M., Richardson, K., Hauschild, M.Z., 2018. Development of a life-cycle impact assessment methodology linked to the Planetary Boundaries framework. Ecol. Indic. 88, 250–262. https://doi.org/10.1016/j.ecolind.2017.12.065

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L.M., Ramanathan, V., Reyers, B., Sörlin, S., 2015. Planetary boundaries: Guiding human development on a changing planet. https://doi.org/10.1126/science.1259855

The Government of Uganda, 2015. The national climate change policy 2015.

UBOS, 2018. Statistical abstract.

UN Population Division, 2019. World Population Prospects [WWW Document]. URL https://population.un.org/wpp/ (accessed 12.12.19).

UNEP, 2019. Lessons from a decade of emissions gap assessments.

UNFCC, 2019. Paris Agreement - Status of Ratification [WWW Document]. URL https://unfccc.int/process/the-paris-agreement/status-of-ratification (accessed 11.21.19).

UNFCC, 2015. ADOPTION OF THE PARIS AGREEMENT.

USAID, 2013. UGANDA CLIMATE CHANGE VULNERABILITY ASSESSMENT REPORT.

World Bank, 2018. Closing the Potential-Performance Divide in Ugandan Agriculture: Fact Sheet

[WWW Document]. URL https://www.worldbank.org/en/country/uganda/publication/closing-the-potential-performance-divide-in-ugandan-agriculture-fact-sheet (accessed 12.12.19).

Zakkour, P., Cook, G., 2016a. Formulation of Geothermal Energy Policy, Legal and Regulatory Framework in Uganda.zakkou