Initiative for Climate Action Transparency – ICAT

ICAT Transformational Change Case Study:

Assessment Transformational Impacts of solar power expansion proposed by the Strategy of Energy Transition of the State of Minas Gerais – Brazil

Initiative for Climate Action Transparency – ICAT
ICAT Transformational Change Case Study: Assessment of Transformational Impacts of solar power expansion proposed by the Strategy of Energy Transition of the State of Minas Gerais – Brazil

Deliverable #12

AUTHORS

Guilherme Rodrigues Lima

William Wills

Centro Brasil no Clima

Please cite this publication as
Lima, G. R.; Wills, W. (2021). ICAT Transformational Change Case Study: Assessment Transformational Impacts of the Program for Renewable Energies of the State of Minas Gerais – Brazil

2022

DISCLAIMER

Prepared Under:

The Initiative for Climate Action Transparency (ICAT), supported by Germany, Italy, the Children's Investment Fund Foundation and the ClimateWorks Foundation.

The ICAT Secretariat is managed and supported by the United Nations Office for Project Services (UNOPS)

ACKNOWLEDGEMENT

We would like to express our gratitude to UNEP DTU Partnership (Denis Desgain, Fatemeh Bakhtiari, Mirko Dal Maso) and the State Foundation for the Environment of

Minas Gerais (Larissa Assunção, Morjana dos Anjos) for insightful discussions and their continued support of this report.

Contents

1 General information

This study is aimed to make an ex-ante assessment of the transformational change impacts of the expansion of solar PV proposed in State Strategy for the Energy Transition of Minas Gerais, which is intended to support the process of decision making regarding the transition to sustainable and efficient energy systems in that state. The study has been conducted by Guilherme Lima and William Wills from Centro Brasil no Clima (CBC), with the support of Karen Holm Olsen, Fatemeh Bakhtiari, Denis Desgain and Mirko Dal Maso from UNEP-DTU Partnership, and Larissa Assunção and Morjana dos Anjos from the State Foundation for the Environment of Minas Gerais (Feam-MG).

The state of Minas Gerais is one of the three pilot-states for the ICAT Brazil Project phase 2 and has been selected for this assessment because of three main factors: i) its prominence in renewable energies (in particular solar photovoltaic), and the previous initiatives in the state to promote those energy sources in the last decade; ii) the very proactive engagement of the state representatives in the ICAT Brazil project, with the State Foundation for the Environment as a focal institution; iii) the opportunity to conduct the assessment for a policy that is being elaborated, so that the results can contribute both for its design and its advocate with state policymakers.

The assessment primarily follows the steps outlined in the Transformational Change Guidance developed by the Initiative for Climate Transparency (ICAT) and was benefitted by previous case studies already published from Bolivia, Uganda, Tonga and the NACAG Initiative. The study was intended to assess the transformation impacts expected to take place until 2030, which is the term of the Brazilian NDC.

Table 01 - General information about the assessment

General information	Assessment information
Name of the policy	State Strategy for the Energy Transition of Minas Gerais
Person(s)/organization(s) that did the assessment	Guilherme Lima – CBC William Wills – CBC
Date of the assessment	January 2021 – January 2022
Whether the assessment is an update of a previous assessment, and if so, links to any previous assessments	Not applicable
Intended audience(s) of the assessment	Policymakers, stakeholders from the energy sector

1.1 Objectives

In general terms, the objective of the study is to identify and assess the different aspects that can be impacted by the selected policy towards sustainable development and analyze if this could cause a transformational change. Positive impacts usually identified from renewable energies include mitigation of GHG emissions, and income and job creation.

Based on the ICAT Transformational Change Guidance, the following objectives could be stated:

- **General objectives**
    - Understand how the policy helps achieve multiple goals – the state of Minas Gerais does not have GHG mitigation or job creation targets. The results will be compared with current indexes and may be a basis for the establishment of such goals;
    - Attract finance – the results can be used to show the benefits of the energy transition and attract finance both from the public and private sectors and from investment funds;
    - Report and communicate – one of the objectives of the assessment is to show the benefits of an energy transition and use the results to get support and social acceptance for the policy and for the measures that need to be implemented.
- **Objective of assessing expected impacts before policy implementation**
    - Improve policy selection and design – given that the policy is under construction, this assessment can be useful for its improvement. The policy started to be developed with a focus on GHG mitigation, but the assessment of transformation change impacts can reveal other benefits not considered at first.

In addition, other states in Brazil have already shown interest in developing policies or plans to promote the energy transition, and this assessment can be useful for policymakers.

1.2 Key concepts, steps, and assessment principles

1.2.1 Stakeholder participation

The engagement with stakeholders is recommended by the TC Guidance because it can strengthen the impact assessment and the impact of policies. Through the ICAT Brazil Project phase 2, the team of CBC has been in constant contact with the team of Feam, which is responsible for the development of the policy. Moreover, state stakeholders were involved in the development of the project through workshops that were organized to present preliminary results in two moments:

i) The first workshop took place in November 2020 and was intended to present the preliminary results of a business-as-usual scenario of GHG emissions for the state in the 2030 horizon and gather inputs for a mitigation scenario to be developed;

ii) The second workshop took place in May 2021 and served as a space to present preliminary results of the mitigation scenario and validate them with state stakeholders.

Perhaps more important than the workshops for this assessment, five working groups were formed in April 2021 to deepen the discussions of mitigation actions in the state. These five working groups, one for each IPCC sector (AFOLU, energy, industry, waste and transport), were a request from the participants in the first workshop in November 2020, who showed interest in having more opportunities to discuss the analyses.

The working group for the energy sector was used, among other things, to update the status of state programs for renewable energies and present some ideas of the policy for energy transition under development.

Therefore, this process contributed to addressing some of the benefits that stakeholder participation can deliver according to the TC guidance, especially:

- Establishing a mechanism through which people who may be affected by, or can influence, a policy, have an opportunity to raise issues and have these issues considered before policy implementation;
- Building trust, collaboration, shared ownership and support for policies among stakeholder groups, leading to less conflict and easier implementation;
- Increasing the credibility, accuracy and comprehensiveness of the assessment by drawing on diverse expert, local and traditional knowledge and practices;
- Increasing transparency, accountability, legitimacy, and respect for stakeholders' rights.

1.2.2 Principles

According to the ICAT TC Guidance, the assessment should follow the principles of relevance, completeness, consistency, transparency, accuracy and reflection on ambition. This study embodied those principles as much as possible, as it follows:

- Relevance – the assessment is intended to help the design of the policy and provide inputs for its advocacy with decision-makers;
- Completeness – the assessment includes all those characteristics considered relevant in accordance with the stakeholders engaged in the process;

- Consistency – the assessment uses data available at the state level and that relate to the relevant characteristics that are chosen for this case;
- Transparency – the stakeholders involved in the assessment (particularly from Feam) are properly informed about the assessment, its methodologies, procedures and data needs, as well as the expected results.
- Accuracy – the assessment uses as much as possible official data provided by state institutions; assumptions take into consideration the best projections by renowned institutions.

The principle of comparability, also present in the guidance, does not apply to this study, given that it is not the purpose here to compare and prioritize multiple policies based on their expected transformational impact.

2 Description of the policy and the assessment boundary and period

2.1 The energy sector in Brazil and in Minas Gerais

Economic development is highly connected to the use of energy, and this dependence, together with population growth and expansion of economic activities, increases energy demand. At the same time, the energy sector is responsible for most of the GHG emissions worldwide, with power generation leading this pattern in many countries. Therefore, to deal with climate change it is crucial to adopt actions to reduce GHG emissions in this sector.

Brazil has published its Nationally Determined Contribution (NDC) 2015, through which the country established the compromise with a 37% reduction of its GHG emissions in 2025 (with 2005 level as baseline), and the intention of achieving a 43% reduction in 2030. In December 2020 an updated version of the NDC was published, reinforcing the goal for 2025 and establishing a compromise with the 2030 target. In addition, it introduced an indicative objective to be carbon neutral by 2060. More recently, during the COP26 in Glasgow, the Brazilian government announced new commitments, such as the target of achieving climate neutrality by 2050, the reduction of methane emissions in line with the Global Methane Pledge, and zero deforestation by 2028.

To achieve those goals, it is necessary to implement actions to reduce emissions in the energy sector. The Brazilian energy matrix is composed mostly of fossil fuels, which in 2019 represented around 54% of the energy sources, whereas renewables are responsible for 46% (EPE, 2020). This group is dominated by sugarcane, hydropower, and wood, with other renewables such as solar and wind power representing only 7% of the national primary energy source. However, the energy sector has been gaining more importance in the last two decades as GHG emissions from the AFOLU sector decreased, mostly driven by reductions in deforestation, although it has been increasing again in the last years.

Besides having no sectoral targets for GHG emission reduction, the Brazilian NDC established no regional or state targets. However, it has since then been recognized the importance of state action for the accomplishment of the NDC targets. Therefore, it is crucial to incentive, monitor and assess state actions that target GHG mitigation to contribute to the Brazilian NDC.

The energy sector in the state of Minas Gerais

The state of Minas Gerais is one of the most dynamic states in Brazil, with the second-highest population (after São Paulo) and the third-largest GDP (after São Paulo and Rio de Janeiro). In terms of GHG emissions, Minas Gerais is the 5th state in Brazil, with emissions coming mostly from agriculture and energy. The analysis of the state GHG emissions inventory, presented in the

Deliverable 4 of the ICAT Brazil Project Phase 2, shows that emissions from the energy sector increased by 35% between 2005 and 2014, whereas total state emissions increased by 24%[1].

The energy demand of the state of Minas Gerais represented 12% of the total energy demand in Brazil in 2016, with industry (60%) as the main demanding sector, followed by the transport sector (25%) (CEMIG, 2018). Both have fossil fuels as the main energy source (oil, natural gas and coal). Hydropower and biomass (sugarcane and firewood) are also important energy sources and are considered well established in the state, but solar and wind power are still inexpressive.

Estimates presented by ANJOS (2019)[2] using the Low Emissions Analysis Platform (LEAP) indicated that the final demand for energy in the state is expected to increase by 57% in 2030 and by 173% in 2050 when compared to the 2010 level. Considering the population growth and moderate economic growth (25% in 2030 and 74.5% in 2050), it is expected that the share of the transport sector in the energy demand increases, but the industry will continue to be the main demanding sector. Figure 1 below illustrates the projections.

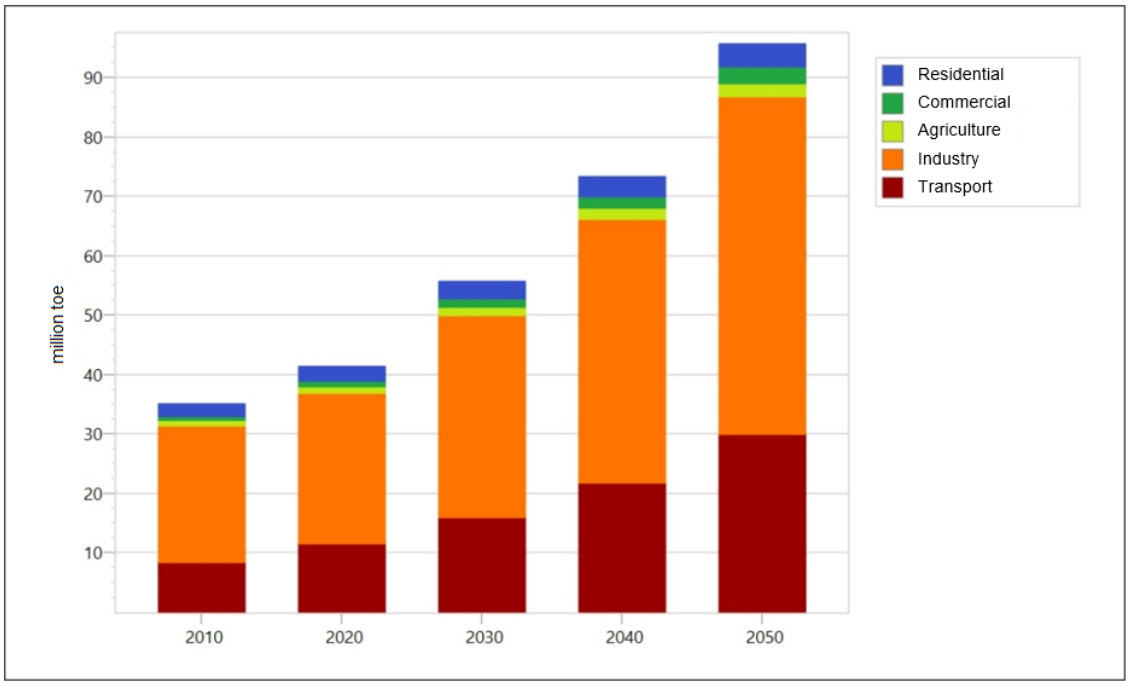


Figure 1 - Final energy demand by sector in the state of Minas Gerais

Source: Anjos (2019)

The state has a huge potential for solar energy, with radiation between 4.5 and 6.5 kWh/m²/day. Regions in the north of the state are most propense for solar photovoltaic, with an average of

[1] This does not consider LULUCF, which was included in the state GHG inventory after 2010.
[2] This dissertation is in Portuguese. However, other sources are available in English: dos Anjos et al. (2019) and dos Anjos et al. (2020).

1.489 kWh/kWp of specific energy, similar to the most propense regions of the country, which are in the Northeast region. Regarding wind power, Minas Gerais has currently only one plant with a capacity of 1MW. However, the state potential is estimated at 39GW with towers of 100m, being able to generate up to 92 TWh/year. However, there are currently no plans for installing new plants in the state because investors prefer other regions of the country with higher technical potential (such as the northeast region), and also because Minas Gerais has few economic and fiscal incentives compared to other states.

GHG Emissions from the energy sector in Minas Gerais come primarily from transport energy use (more precisely from road transport) which represented 57.6% of total emissions of this sector in 2014. After that, industrial energy use is also important, with around 21%, whereas energy supply accounts for approximately 13% of GHG emissions in the energy sector.

According to the business-as-usual scenario presented in the Deliverable 5 of the ICAT Brazil Project phase 2, GHG emissions from the energy sector are expected to increase 29% by 2025 and 41% by 2030, both compared to 2005. However, it is important to notice that between 2015 and 2020 that was a decrease in GHG emissions because of the reduction of economic activity in Brazil, and therefore 2020 emissions were below the 2010 level.

2.2 Minas Gerais State Strategy for the Energy Transition

The state strategy for the energy transition, which is under development, builds on the modelling of scenarios for the energy system in Minas Gerais in the mid and long terms to provide inputs to increase the share of renewable energies and to promote energy efficiency at state and local levels.

The state has previous policies that address the energy sector, such as the State Plan for Energy and Climate Change (PEMC), from 2015, and the 'Mineiro'[3] Program for Renewable Energies (PMER), from 2013. There is also a state decree from 2017 that establishes subsidies for microgeneration from renewable sources.

The strategy is being developed based on the results from ANJOS (2019), which presents three scenarios for the energy sector in the state. The first is a Reference Scenario (REF), which considers the national plan for the energy sector, with projections for the state, and includes the expansion of power generation, demand and final consumption of energy, and energy services. This scenario is based on the national Decennial Energy Plan (PDE 2027) and two National Energy Plans (PNE 2030 and PNE 2050). The second is the Moderate Energy Transition scenario (ETM), which includes goals to contribute to the goals of the Brazilian NDC for the energy sector,

[3] Mineiro refers to someone or something from Minas Gerais.

whereas the third is the Advanced Energy Transition scenario (ETA), which is more ambitious and included goals to go beyond the Brazilian NDC targets.

Projections in the REF scenario indicate that the share of fossil fuels in the final energy demand will increase from approximately 50% in 2010 to 54% and 55% in 2030 and 2050, respectively. On the other hand, in the ETM scenario this share would be stable until 2030, and then decrease to 47% in 2050, thanks to policies that promote the substitution of fossil fuels vehicles for electric and biofuel vehicles. In the ETA scenario, the share of fossil fuels would decrease to 43% and 36% in 2030 and 2050, respectively, whereas electricity[4] would represent 32% at the end of the period, a 100% increase when compared to the REF scenario. This results from a massive penetration of electric vehicles considered in this scenario.

Given this increase in the demand, electricity supply will increase significantly in all the scenarios, but particularly in ETA. In the REF scenario, electricity generation will reach 136 TWh in 2030 and 227 TWh in 2050. In the ETM scenario, those numbers will be slightly higher, but in the ETA scenario, it would reach 267 TWh and 426 TWh, respectively.

It is expected that the state strategy will provide the basis for the design of a policy within the state executive and legislative, creating the governance and the instruments for the energy transition in the state. The State Policy for the Energy Transition (PETE) shall have the goal of promoting the energy transition in the state and will build on the scenario of Advanced Energy Transition (ETA), which has the following targets:

Table 02 - Targets of the State Policy for the Energy Transition

	2030	**2050**
Renewable energy	50% excluding large hydropower plants	60% excluding large hydropower plants
Energy efficiency in the power sector	10% of gains in the power sector	15% of gains in the power sector
GHG emission reduction	12% compared to a baseline scenario	28% compared to a baseline scenario

Source: Draft of the bill provided by Feam-MG

[4] It is important to remember that electricity in Brazil is provided mostly from hydropower, differently from other countries where it is based on fossil fuels.

The guidelines proposed for the PETE are:

- To identify and overcome the challenges that halt the accomplishment of the targets for renewable energy and energy efficiency;
- To reduce the dependency of fossil fuels as the primary energy source for the state energy demand;
- To promote the accomplishment of the targets for renewable energy and energy efficiency;
- To promote fiscal, financial and credit instruments that increase the economic viability of the projects for renewable energy and energy efficiency in the state;
- To invest in research and development in renewable energy and energy efficiency to contribute to the socio-economic development in the state.

In order to achieve the targets presented above, the PETE shall provide a basis for the regulation and the establishment of mechanisms and instruments and will be organized into seven categories as follows.

1) Regulation – to provide the legal framework to create the rules for the activities involved in the energy transition. It is suggested at least three legal instruments at the beginning: one law that establishes the state policy for the energy transition and two decrees to regulate the law, being one focused on renewable energies and the other focused on low carbon technologies and energy efficiency;

2) Awareness – to engage the stakeholders through a governance strategy that demonstrate the goals and the importance of the energy transition, as well as the need for the involvement of the whole society. It is also necessary the engagement of government and non-government institutions to coordinate the design, implementation, operation and evaluation of the instruments;

3) Research, development and innovation (R&D&I) – to increase and spread the knowledge about energy transition, as well as to promote innovation through direct incentives to projects, participating in the technical and economic improvement of the existing technologies and the development of new technologies;

4) Project demonstration – the state must be an example, promoting projects for renewable energies and energy efficiency to demonstrate the economic, social and environmental impacts of sustainable technologies;

5) Capacity building – the process of energy transition consists of the massive adoption of technologies and best practices that are constantly evolving. Therefore, it is necessary to provide capacity building to guarantee the energy transition not only regarding technologies but also for coordination of policies, programs and projects;

6) Markets and financing – to promote financial mechanisms and fiscal incentives to the establishment of a market for renewable energies and energy efficiency in the state;

7) International cooperation – it is an important instrument for the state, which allows the transfer of resources, knowledge, experiences, and technologies, collaborating with an effective capacity building and strengthening of the state institutions.

3 Defining the assessment

The definition of the assessment, according to the ICAT guidance, includes the description of the policy and the assessment boundary and period, the identification of the phase of transformation, the description of the vision for transformation change, the identification of barriers to transformational change, and the choice of the transformational change characteristics to be assessed.

The State Policy for the Energy Transition, which is the focus of this assessment was described in the previous section. The assessment boundary is the state of Minas Gerais and the sector of solar energy, although impacts beyond the state borders may be considered, whereas the assessment period is from the present up to 2050, which is the last year for which the state policy presents some target. Therefore, based on the ICAT guidance, the short-term is considered from 2022 to 2027 (< 5 years), the medium term goes from 2027 and 2037 (between 5 and 15 years), and the long term goes from 2037 to 2050 (> 15 years).

This section presents the other steps necessary to define the assessment.

3.1 Phase of transformation

The assessment of the phase of transformation is useful to understand whether the analyzed policy can help to overcome barriers and drive transformational change. According to the ICAT Guidance, the phase of transformation refers to the economic, social, institutional and political context in which the policy is being planned or implemented, i.e., in the country or region for which the policy is being designed or where it is being implemented. The fundamental question that this step seeks to answer is "Where we are today and where we are heading?".

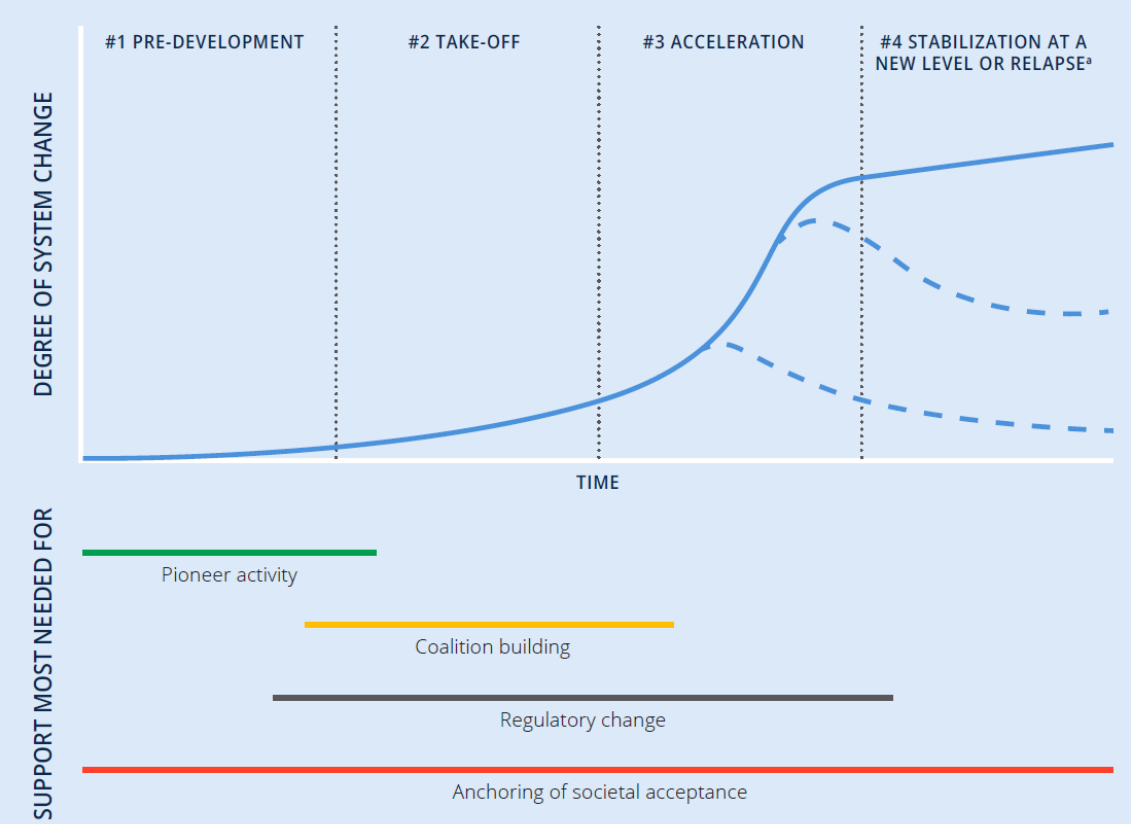
There are four phases in which a system undergoing transformation to zero-carbon and sustainable development can be classified, as illustrated in Figure 2 below.

Pre-development – can be described as a comfort zone phase and is characterized by visible and increasing pressure on the government, and policies aiming at low-carbon and sustainable development. However, this phase can also represent stability, with predominant paradigms not being questioned and stagnation of institutions.

Take-off – in this phase there are clear moves towards the acceptance of new ideas that challenge the high-carbon paradigm. This includes increasing awareness and concrete attempts to devise solutions. However, there is still no consensus about suitable solutions and the lobby against those alternatives is still strong.

Acceleration – new solutions or innovations gain momentum, become widespread, and are accepted and acknowledged. Change is accelerating towards transformative low-carbon solutions, despite the opposition by interests that profit from the high-carbon status quo.

Stabilization or relapse – the system is fully transformed, and the new pathways are embraced broadly in society and the economy. Consequently, the rhythm and speed of change decrease significantly, as people start taking the new situation for granted. However, the risk of relapse is high if the interests of the high-carbon regime remain active, and continual efforts may be needed to maintain momentum.



Source: Mersmann et al. (2014a), adapted from Rotmans et al. (2001).
[a] Dotted lines represent alternative scenarios of relapse.

Figure 2 - Phases of transformation

Source: ICAT (2020)

In the context of Minas Gerais, and particularly for solar power generation, it can be considered that the system is in between the take-off and the acceleration phases, based on the following:

- It is beyond the pre-development phase, given that there is pressure from civil society, questioning the existing paradigm and a moderate level of awareness and mobilization.

In addition, proposed solutions diverge from the predominant paradigm of high-carbon energy sources.

- It has accomplished some steps of the take-off phase, such as increasing pressure for new solutions and changes, innovations and new paradigms are integrated and promoted, and there is a general optimism that new solutions and pathways are feasible and realistic. In addition, there is consensus (and not a disagreement) that renewable sources are the most suitable to address the problems. However, there are still some uncompleted steps, such as open competition for innovation is not yet promoted, Business models that favour low-carbon pathways are not yet predominant, and there is some resistance from those benefiting from the existing paradigms is common.
- It has also performed some steps of the acceleration phase, such as innovations and new solutions openly challenge and start pushing away established paradigms, innovations and new solutions are widely accepted and spreading, the speed of change has increased significantly and is accelerating, and existing paradigms are feeling the pressure to embrace innovation and new pathways or run the risk of being outpaced and pushed aside.

These analyses are based on the state conjuncture of the state, which has the larger installed capacity for solar photovoltaic power in the country and has recently achieved 1GW. This number is composed mostly of decentralized solar power generation, which proves the wide acceptance of the technology. The state had already developed in the past policies to incentivize renewable energy sources, particularly for solar energy, and this Strategy for Energy Transition shows the willingness to advance in this agenda.

3.2 The vision for transformational change of the policy

Although the State Strategy for the Energy Transition of Minas Gerais is focused on the promotion of sustainable and efficient energy systems, it can be expected that the measures adopted to implement the policy can generate positive impacts that go beyond the energy sector, particularly for those aimed to promote solar power generation. The primary impact expected with the policy is the mitigation of GHG emissions from this sector. However, other impacts such as income generation, job creation and better air quality can also result as consequence.

The state of Minas Gerais outstands in Brazil with the largest installed capacity of solar photovoltaic energy, expecting to achieve 1 GW this year. The northern region of the state has the highest potential for this source and is among the most prominent regions in Brazil for solar energy. At the same time, this region is the least developed in the state and some areas have HDI among the lowest of the country (e.g. Vale do Jequitinhonha).

Therefore, the transformational vision is that the policy for the energy transition in the state will contribute both to GHG mitigation and to the sustainable development goals, particularly those related to job and income creation. Although the policy is solely focused on reducing GHG emissions and increasing energy efficiency, it is expected that other benefits can derive from that. Table 3 below.The vision for transformational change is further described in Table 4, which presents the process characteristics, as well as in Tables and 5 and 6, which present the outcome characteristics (by societal level and over time, respectively).

3.3 Barriers to transformational change

Barriers to transformational change are obstacles to reaching the full mitigation potential of a policy or action and can either hinder desired effects or lead to undesired effects. The identification and analysis of barriers are important to make a more effective policy, to better prepare users to overcome resistance and make use of opportunities that arise, and to better choose relevant process characteristics. Barriers can be categorized in different ways, including:

- Political barriers;
- Institutional and regulatory barriers;
- Social barriers;
- Technology barriers;
- Capacity constraints;
- Financial and investment constraints.

Table 03 - Barriers to transformational change

Barrier	Explanation	Characteristics affected	Barrier directly targeted by the policy
Lack of empowerment of state institutions to propose a policy	There is a need for political support for the bill to be approved. When it is proposed by the state government it is easier to pass in the state council. However, when it is proposed by some state institutions, such as Feam, it is not simply to have support from the government, and a possible option is to seek support from some state deputy.	Institutional and regulatory	No
Incentives that favour carbon-intensive modes of production	There is some difficulty to propose incentives for renewable energy sources to the Secretariat of Finance if there is no pressure from the market.	Entrepreneurs; economic and non-economic; disincentives	Yes
Constrains to develop regulations	It is difficult to develop programs to regulate some aspects if there is not a previous policy established.	Institutional and regulatory	Yes

Overlapping responsibilities across multiple institutions	In the case of solar energy, there are competencies of the secretariats of the environment, development, finance etc. It is difficult to have a dialogue with several different institutions and achieve a consensus.	Institutional and regulatory	Yes
Lack of coordination between national and subnational agencies	There is no coordination between national and subnational agencies in the area of energy. Most of the regulations are established at the federal level and there are regulations of the National Energy of Power (Aneel) that are reasonable for some states but adverse for others.	Institutional and regulatory	No
Lack of awareness of low-carbon options, benefits and opportunities	Lack of awareness of the population about renewable energies and lack of campaigns to overcome this.	Awareness; adoption	Yes
Lak of local empowerment to make decisions that favour a low-carbon economy	There is a lack of local empowerment because there is no independence to make decisions about power enterprises in the state (decisions come from the federal level).	Institutional and regulatory	No
Dependence on import of low-carbon technologies	Most of the equipment is imported from China and there is no production in the state.	Research and development (R&D); scale-up; economic and non-economic	Yes
Lack of availability of equipment for production and maintenance	Many people install solar PV in their houses but do not know how to make the maintenance or do not do it because of the cost, resulting in losses of efficiency.	economic and non-economic; awareness	Yes

3.4 Transformational change characteristics to be assessed

The framework of transformational characteristics included in the assessment is illustrated in Figure 3 below and described in Tables 4, 5 and 6. The characteristics are organized into two categories (process and outcome characteristics) and are used to assess the transformation impact of the state strategy for the energy transition. Process characteristics describe how a policy can drive changes in systems (technology, agents, incentives and norms) that enable achievement of transformational impacts, whereas outcome characteristics refer to the scale (macro, medium and micro levels) and sustained (long, medium and short terms) nature of outcomes resulting from a policy.

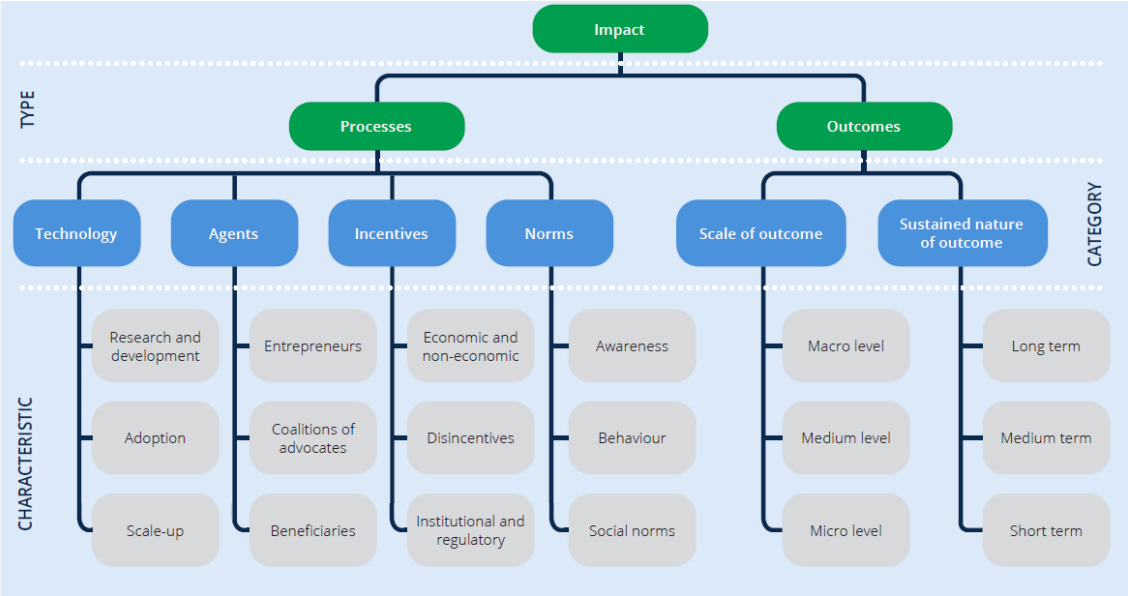


Figure 3 - Characteristics of transformational impact

The choice of process characteristics to be assessed considered the recommendation of the ICAT TC Guidance to base it on their relevance to transformational change in the context of the policy and the society in which it is implemented. Therefore, not every characteristic presented in the figure is necessarily included, and only those considered relevant are assessed. The selection of these characteristics was also not strict to the description of the policy document, in the sense that there was an attempt to include indirect impacts and pathways of change that the policy could trigger. As stated in the TC Guidance, this could challenge policymakers to design policies that help realize a transformational vision. The selection of the relevant process characteristics was based mostly on the seven categories in which PETE is organized as presented above.

Table 04 - Process characteristics

Category	Process characteristics	Characteristic (specific to policy)	Relevance and justification
Technology	Research and development (R&D)	The policy intends to promote investments in R&D for renewable energy and energy efficiency to contribute to the economic development of the state.	*Relevant* R&D resources in Brazil are provided mostly by the public sector, particularly by the federal government, and have been decreasing over time. In the case of solar energy, it is needed because most of the equipment is imported, and the development of the local industry can increase its cost-benefit.

	Adoption	The adoption of low-carbon technologies can benefit most from the categories of R&D&I and project demonstration, although it can also be impacted by international cooperation and markets and finance.	*Possibly relevant* Solar rooftop PV is quite adopted in some regions of the state and is not a novelty. However, there is still a huge potential to be explored and a portion of the state population and private sector may not be aware of its benefits. This can also be relevant because of technological advances trough that could make solar energy even more competitive.
	Scale-up	This characteristic is not directly addressed in the policy, but it can in some extension be promoted by actions in the categories of R&D&I, demonstration of projects and markets and finance.	*Relevant* It would be important to scale-up solar energy because it would help overcome barriers related to the dependence on import of equipment and the lack of availability of equipment and a skilled workforce. Another barrier not particular to the state is the need to integrate the operation of solar and hydropower.
Agents of change	Entrepreneurs	The policy does not address this characteristic. Although this can benefit from the category of markets and finance, the policy is not intended to promote entrepreneurship.	*Relevant* Promoting entrepreneurship can help overcome the barrier related to the need for market pressure to have economic incentives for renewable energies from the government. Moreover, entrepreneurship is crucial to have a sustained development of this sector.
	Coalition of advocates	This characteristic can be impacted by the category of awareness, although at a low level, given that the policy does not state that it will seek the promotion of networks and coalitions.	*Not relevant* Renewable energy sources are already supported by several institutions, including business associations (eg. ABSOLAR) and think tanks.
	Beneficiaries	The policy is expected to support different groups of the society, such as producers of facilities related to renewable energies, householders who install solar panels in their homes, workers who will be trained for these new opportunities (category of capacity building), and researchers (category R&D&I).	*Relevant* This characteristic is relevant particularly regarding capacity building and job creation, given that the region of the state with the highest solar potential is also one of the poorest regions.
Incentives			*Relevant*

	Economic and non-economic	The policy will promote tax and financial instruments to enhance the economic viability of renewable energy projects	Renewable energy is still expensive to install, especially in the case of off-grid solar, although its economic return in the long term is already proved. It is important to provide instruments that make it available for the population.
	Disincentives	The policy does not establish any disincentive for high-carbon activities.	*Possibly relevant* The federal government has recently encouraged thermopower plants. However, it is not sure to which extent the state government can oppose this incentive.
	Institutional and regulatory	This characteristic can be affected particularly by actions in the category of regulations, given that the policy intends to provide a legal framework for the energy transition in the state, including instruments such as the program for the expansion of renewable energies; the program for low carbon technologies and energy efficiency; the strategy for coordination of the energy transition; and the strategy for financing the PETE.	*Relevant* This characteristic is relevant and relates to two barriers. First, because there is an overlapping of responsibilities across multiple institutions, it is difficult to achieve a consensus. Second, there is a constrain to developing programs if the is not a policy established. There is also an additional barrier related to the lack of coordination between national and subnational agencies, but the state has lower capacity to overcome this.
Norms	Awareness	This characteristic will be affected by actions in the category of awareness of the policy.	*Possibly relevant* Solar energy is already popular in the state, and maybe most important is the demonstration of its economic viability (adoption) and economic incentives that enable the population and private sector to adopt it.
	Behaviour	The policy does not address this characteristic. The category of awareness is focused on sensitization and does not include measures such as economic incentives for consumers, whereas the category of markets and financing is restricted to incentives to promote renewable energies and energy efficiency.	*Possibly relevant* Although it is expected that most people will adopt solar PV because of its economic benefit, and not because of recognition of climate emergency, this process can contribute to a change of behaviour in the population.
	Social norms		*Relevant*

		This characteristic can be affected by actions in the category of awareness, given that the sensitization of the population can change low-carbon practices that are now acceptable and will not be in the future.	As well as for the previous characteristic (behaviour), promoting renewable energies can contribute to changing people's acceptance of low-carbon technologies and pose more restrictions to high-carbon practices.

Table 05 - Scale of outcomes characteristics

Category	Outcome characteristics	Relevance and justification
Renewable Energy Deployment	Macro level Deployment of renewable energy outcome is insignificant at the international/global level	*Not relevant* This level is outside the assessment boundary. No description is necessary.
	Medium level Deployment of renewable energy outcome in the state has a small magnitude at the national level	*Relevant* This level is outside the assessment boundary. However, the expansion of solar power can have some contribution to the national level and to achieve the goals of the Brazilian NDC.
	Micro level Deployment of renewable energy outcomes are significant at the state level	*Relevant* The strategy will contribute to the increase of the share of renewable energies in the state, with solar power as the main source in this process. In addition, the strategy projects the increase in the electrification of economic sectors, particularly transport, making the expansion of solar power even more important. This level can obtain results in the face of regional strategies regarding Renewable Energies, because there are significant innovation aspects and natural resources, with great potential for renewable energy generation, in particular solar photovoltaic. The implementation of renewable energy results has a broad magnitude because with the State Policy for Energy Transition (PETE) there will be the possibility of analyzing social and economic factors. At this level, there is the possibility of understanding the scale of environmental impacts, the financing strategies and the functioning of the renewable energy sector itself in Minas Gerais. With this, strategies to promote the energy transition can be added to the actions in front of: research and development, awareness-raising, regulation, financial instruments, demonstration projects and capacity building.
	Macro level	*Not relevant*

Mitigation of climate change	Mitigation of climate change outcomes are insignificant at the international / global level	This level is outside the assessment boundary. No description is necessary.
	Medium level Mitigation of climate change outcomes in the state can have a small contribution to mitigation at the national level	*Relevant* This level is outside the assessment boundary. However, the mitigation of GHG emissions provided by the expansion of solar power in the state can have some impact at the national level, given that Minas Gerais is the 5th emitter state, and that the energy sector represents a large share of the state emissions. The state represents around 8,5% of the country emissions in the energy sector.
	Micro level Mitigation of climate change outcomes are significant at the state level	*Relevant* The expansion of solar power in the state grid, together with a higher level of electrification in the economic sectors, must contribute significantly to the mitigation of state GHG emissions, given that the energy sector is the second in GHG emissions in the state, after agriculture.
Sustainable Development	Macro level Sustainable development outcomes are insignificant at the international / global level	*Not relevant* This level is outside the assessment boundary. No description is necessary.
	Medium level Sustainable development outcomes are the state may contribute to sustainable development outcomes at the national level	*Relevant* This level is outside the assessment boundary. However, it is expected that the impacts of income generation and job creation (among others) at state level can contribute to SDGs at national level.
	Micro level Sustainable development outcomes are significant at the state level	*Relevant* Renewable sources like solar have the potential to create jobs, both directly and indirectly. Minas Gerais is the main state in Brazil in solar power installed capacity, and it is concentrated in the north of the state, which is the poorest region of the state. Therefore, it is expected that the expansion of solar energy can contribute to creating jobs and increasing the income for that population.

Table 06 - Outcome characteristics sustained over time

Category	Outcome characteristics	Description
Renewable Energy Deployment	Long term (>15 years) Deployment of renewable energy outcomes are expected to be achieved and last for over 15 years	*Relevant* It is expected that the increase in the share of renewables will be permanent after achieved. The strategy foresees 60% of renewable energies (excluding large hydropower plants).
	Medium term (5 – 15 years) Deployment of renewable energy outcomes are expected to be achieved and sustained within 5-15 years	*Relevant* In the mid-term, it is expected that renewable energies (excluding large hydropower plants) will represent 50% of the energy supply.
	Short-term (< 5 years) Deployment of renewable energy outcomes are not expected to be achieved within less than 5 years.	*Relevant* In the short-term, it will be possible to achieve some outcomes in the expansion of solar power (particularly distributed systems), but it may not be significant. The strategy does not establish goals for this category in the short term.
Mitigation of climate change	Long term (> 15 years) Mitigation of climate change outcomes are expected to be achieved and last for over 15 years	*Relevant* It is expected that mitigation of GHG emissions promoted by the energy transition in the state will advance with time and last in the long term. The strategy has a goal of 28% of GHG emission reduction by 2050 compared to a baseline scenario.
	Medium term (5 – 15 years) Mitigation of climate change outcomes are expected to be achieved and sustained within 5-15 years	*Relevant* In the mid-term, it is expected that there will be some outcome in climate change mitigation provided by the energy transition. The strategy states a goal of 12% of GHG emission reduction in 2030 compared to a baseline scenario.
	Short-term (< 5 years) Mitigation of climate change outcomes are not expected to be achieved within less than 5 years.	*Relevant* Although GHG emission reduction can be achieved with the expansion of solar power, this outcome may not be significant within less than 5 years. The strategy does not establish goals for this category in the short term.

Sustainable Development *Outcomes* Scale	Long term (> 15 years) Sustainable development outcomes are likely to be achieved and sustained in the long term	*Relevant* It is expected that in the long term the expansion of solar power generation can generate a significant number of jobs and increase income. It must be taken into consideration though that jobs in this sector are mostly temporary and related to the activities of installation and maintenance. Sustainable development will be perceived by the absorption factor of the environmental guidelines, made possible by the energy transition since GHG reduction system options can be achieved under local and even foreign incentives such as those suggested in the SDG bonuses.
	Medium term (5 – 15 years) Sustainable development outcomes are possible to be achieved in the medium term, but not necessarily it will be sustained	*Relevant* As explained for the long term, a significant number of jobs can be created with the expansion of solar power. This outcome can be achieved in the medium term.
	Short-term (< 5 years) Sustainable development outcomes are not likely to be achieved within less than 5 years	*Relevant* It is not expected that a significant number of jobs or income generation can be achieved in the short-term, given the time necessary for the changes to occur.

4 Estimation of transformational impacts ex-ante

The State Policy for Energy Transition is a policy under development with targets for 2030 and 2050, and this document aims to understand future transformational impacts that could be delivered by the policy. Therefore, we apply an ex-ante assessment of those impacts following the steps presented by the ICAT guidance, which include two key recommendations:

- Assess and qualitatively score each characteristic and explain the underlying assessment;
- Aggregate the results for all characteristics and barriers to the process and outcome level.

4.1 Assessment of characteristics

The qualitative assessment of the outcome and process characteristics is a key recommendation of the ICAT guidance and is presented in Tables 7, 8 and 9 and illustrated in Figures 4, 5 and 6 below. The scoring of each characteristic uses the scale provided by the ICAT guidance, which states the values for process and outcome characteristics as it follows:

i) Process characteristics (likelihood that the policy will have a significant impact):
   a. Very unlikelly – 0
   b. Unlikelly – 1
   c. Possible – 2
   d. Likelly – 3
   e. Very likely – 4

ii) Outcome characteristics (scale of impact)
   a. Net negative impact – -1
   b. Nule impact – 0
   c. Minor positive impact – 1
   d. Moderate positive impact – 2
   e. Large positive impact – 3

The attribution of the scores was based on the targets of the policy, the barriers identified, assumptions about indirect impacts (e.g. job creation), and discussions carried out with state stakeholders during the implementation of the project. The rationale for defining the score for each characteristic is provided in Tables 4, 5 and 6 above, which describe the predicted impacts of the policy, and recalled in Table 7 below.

Regarding process characteristics, it is expected that PETE will have a higher impact on those related to the categories of Incentives, Technology and Agents of change, particularly on institutional and regulatory (incentives), economic and non-economic (incentives), adoption

(technology), and beneficiaries (agents of change). This is fundamentally related to the structure of the seven categories of mechanisms and instruments proposed for the policy described before.

Table 07 - Scoring of process characteristics

Category	Process characteristics	Score	Rationale
Technology	Research and development (R&D)	2	The policy addresses this characteristic. R&D is provided mostly by the federal government and have been decreasing, and the policy may help to increase R&D with state funds.
	Adoption	3	The policy addresses this characteristic. There is still a huge potential for solar energy to be explored in the state and a portion of the state population and private sector may not be aware of its benefits.
	Scale-up	1	The policy does not directly address this characteristic, but it can be impacted by the policy. Scaling-up solar energy would help overcome barriers related to the dependence on import of equipment and the lack of availability of equipment and a skilled workforce.
Agents of change	Entrepreneurs	2	The policy does not directly address this characteristic, but it can be impacted by the policy. Promoting entrepreneurship can help overcome the barrier related to the need for market pressure to have economic incentives for renewable energies from the government.
	Beneficiaries	3	The policy addresses this characteristic. Different groups of the society can be impacted, such as producers of facilities related to renewable energies, householders who install solar panels in their homes, workers who will be trained for these new opportunities.
Incentives	Economic and non-economic	3	The policy addresses this characteristic. Renewable energy is still expensive to install, especially in the case of off-grid solar, although its economic return in the long term is already proved.
	Disincentives	0	The policy does not directly address this characteristic, and it is not expected that this will be impacted by the policy.
	Institutional and regulatory	4	The policy addresses this characteristic. The policy intends to provide a legal framework for the energy transition in the state with a set of programs.
Norms	Awareness	1	The policy addresses this characteristic. However, solar energy is already popular in the state, and the impact of the policy may not be significant.
	Behaviour	1	The policy does not directly address this characteristic. However, the adoption of solar PV because of other incentives may contribute to a change in the behaviour.

	Social norms	0	The policy addresses this characteristic. However, the expected impact is minor (between 0 and 10%).

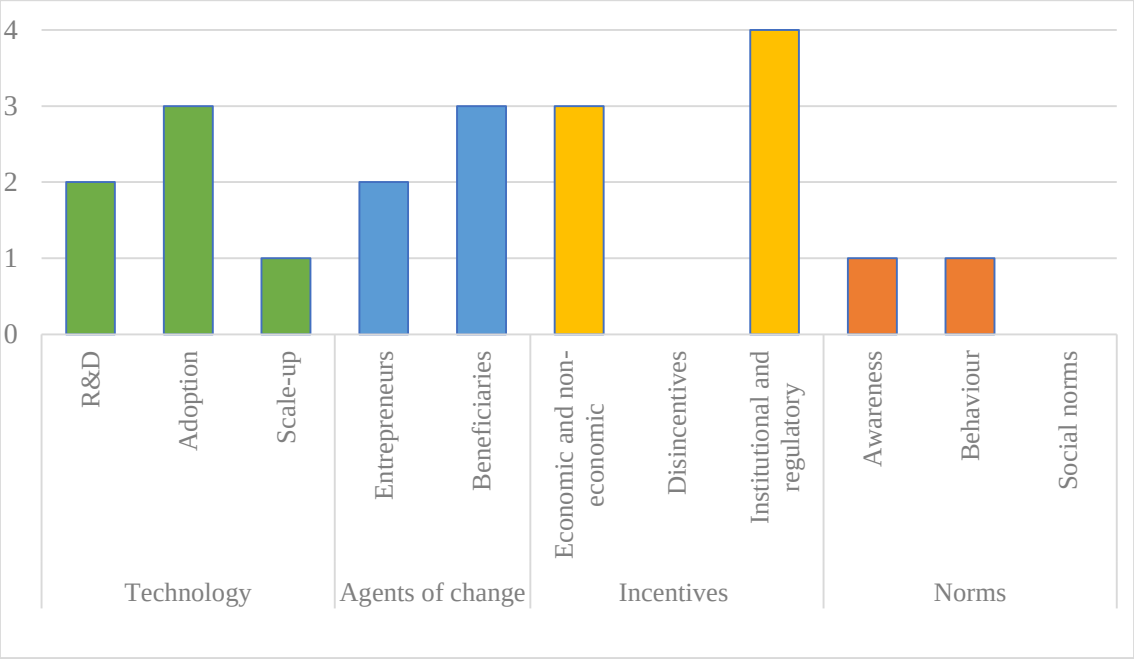


Figure 4 - Scoring of process characteristics

Regarding the outcome characteristics, scale outcomes are expected mostly at the micro (state) level because this is a state policy, although it can have some degree of significance at the national level, given that Minas Gerais is one of the most important states in the country (2nd population, 3rd GDP and 5th in GHG emissions). For outcomes sustained over time, most are expected in the medium and long term, which is inherent to the nature of actions proposed by the policy (in the energy sector).

Table 08 - Scoring of outcome characteristics – scale

Category	Macro level	Medium level	Micro level
Renewable Energy Deployment	N/A	1	3
Mitigation of climate change	N/A	1	2
Sustainable Development	N/A	1	1

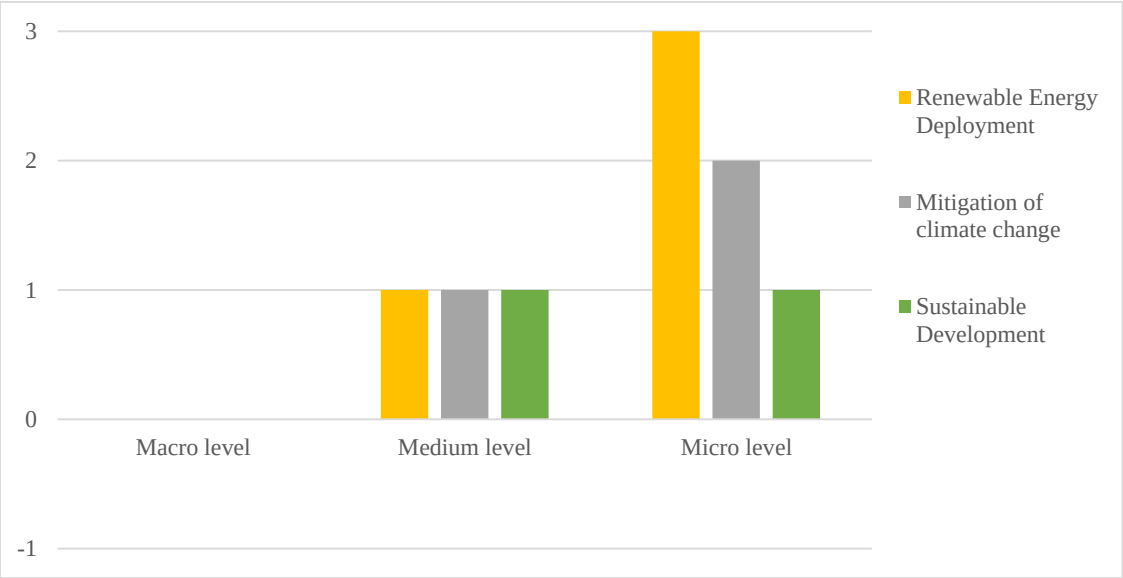


Figure 5 - Scoring of outcome characteristics – scale

Table 09 - Scoring of outcome characteristics – time for which outcome is sustained

Category	Long term	Medium term	Short-term
Renewable Energy Deployment	3	3	1
Mitigation of climate change	3	2	1
Sustainable Development	1	2	1

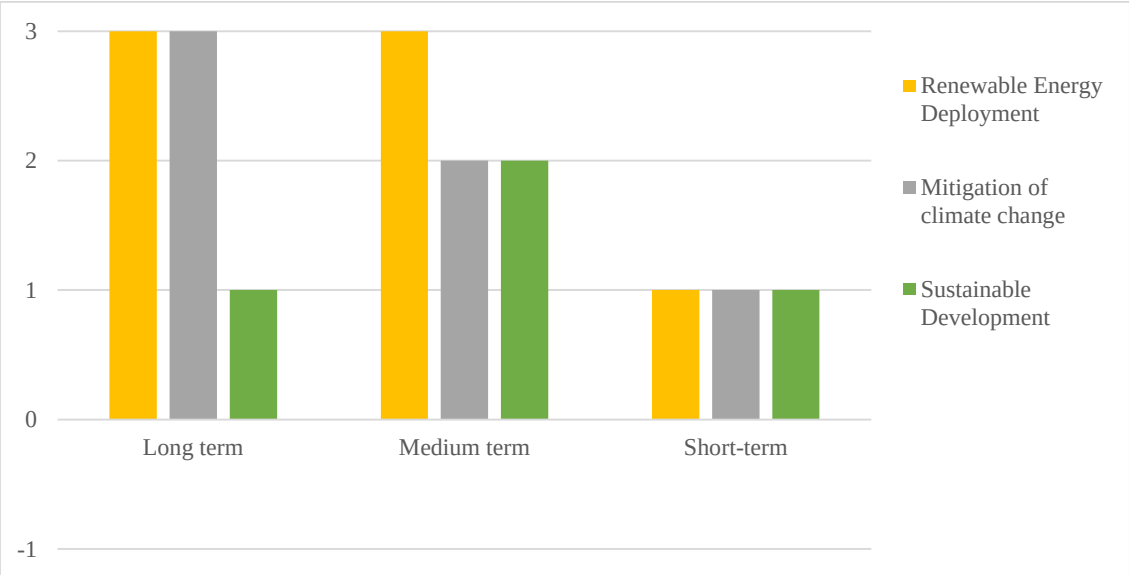


Figure 6 - Scoring of outcome characteristics – time for which outcome is sustained

4.2 Aggregation of results

The aggregation of the results (scores) obtained in the previous step is necessary to have a more general conclusion of the transformation potential of the policy. The results are first aggregated at the category level, and next, they are aggregated at the impact level.

4.2.1 Aggregation to the category level

The first step is intended to provide scores at category level both for process characteristics (technology, agents of change, incentives and norms) and for outcome characteristics (scale of outcome and outcome sustained over time). The aggregation uses the same range of values of the assessment of characteristics. In the case of the categories of process characteristics, it is necessary also to define the relative importance of each category. The scores for process and outcome categories are presented in tables 10 and 11 below.

Table 10 - Aggregated and weighted scoring of process characteristics

Category	Score	Rationale for scoring	Relative importance of category and rationale
Technology	2	The policy is intended to promote R&D investments, whereas adoption and scale-up can be impacted by actions related to R&D, project demonstration, and markets and finance, all of which are lines of action of the policy.	30% R&D resources in Brazil are provided mostly by the public sector, particularly by the federal government, and have been decreasing over time. There is still a huge potential to be explored for solar rooftop PV and technological advances could make solar energy more competitive. Scale-up solar energy would help overcome barriers related to the dependence on the import of equipment and the lack of availability of equipment.
Agents of change	2,5	Characteristics of this category are not much targeted by the policy, except a coalition of advocates which can be impacted by the line of action related to awareness. However, entrepreneurship can be promoted in the solar sector once the expansion of the source is incentivized. Beneficiaries can be impacted as well, given that the policy can benefit, for instance, householders who install solar panels in their homes, workers who will be trained for these new opportunities.	20% Actions promoted by the policy in this category could help overcome the barrier related to the need for market pressure to have economic incentives for renewable energies from the government. The category is also important because of the potential for capacity building and job creation of the policy.

Incentives	3	The policy intends to promote tax and financial instruments to enhance the economic viability of renewable energy projects. It also proposes a legal framework for the energy transition in the state.	40% Actions related to this category can help overcome barriers of overlapping of responsibilities across multiple institutions, constrain to develop programs if the is not a policy established, and the lack of coordination between national and subnational agencies. Moreover, installing solar rooftop PV is still expensive, and economic and non-economic incentives can make it more affordable for the population.
Norms	1	This category can be impacted by actions promoted by the policy related to the line of action of awareness.	10% Although the promotion of renewable energies by the policy can have some impact on behaviour and social norms, those are not exactly barriers to its development in the state.

When aggregating the outcome categories, some characteristics were given more importance than others. In the case of the scale of outcome, micro-level outcomes are more relevant, given that the policy is designed for the state level, although some impact can be observed at the medium level (macro level is outside the assessment boundary). For the sustained nature of the outcomes, long term outcomes are more relevant, given that the changes proposed by the policy are expected to take some time to occur. Further explanation about the scores for each outcome category is provided below in the conclusion.

Table 11 - Aggregated scoring of outcome characteristics

Category	Score	Rationale for scoring
Scale of outcome - Renewable energy	3	The policy has the potential to generate significant expansion of renewable energies at the state level, which can also have some significance at the national level
Scale of outcome - GHGs	2	The policy can contribute to reducing GHG emissions at the state level up to 28%, given that the energy sector is the second in GHG. It can also have some impact at the national level, considering that the state is the 5th in GHG emission and represents around 8,5% of the country emissions in the energy sector.

Scale of outcome - Sustainable development	1	The region that concentrates the highest potential for solar energy is also the poorest region of the state. Therefore, promoting renewable energies may contribute to creating jobs and increasing the income of that population.
Outcome sustainable over time - Renewable energy	3	Impacts of the policy in terms of expansion of renewable energies are projected for the medium and long terms and are expected to be sustained over time.
Outcome sustainable over time - GHGs	2	It is expected that the policy will lead to a sustained reduction of GHG emissions over time in the state.
Outcome sustainable over time - Sustainable development	1	Although the policy can contribute to SDGs through job and income creation, it will not necessarily be sustained over time, given that many times those jobs are most related to the phase of installation.

4.2.2 Aggregation to the impact level

The final step of the assessment is the aggregation to the impact level, which is made through the assessment of process and outcome categories as a whole. The aggregation of process categories will lead to the understanding of the likelihood of transformation ranging from very likely (score 4) to very unlikely (score 0), whereas the aggregation of outcome categories provides the extent and sustained nature of transformation and ranges from major (score 3) to negative (score -1).

The transformational impact matrix is illustrated in Figure 7 below and shows that the likelihood of transformation is possible, and the extent and sustained nature of transformation is moderate. When the final result for the policy falls in the green area, the policy is expected to be transformational, whereas if it is in the red area, the policy is not expected to be transformational. The final result achieved for PETE is in an intermediate area (yellow) between these two cases.

It is important to mention that the size of the dot in Figure 7 reflects the uncertainty of the results, which in this case could be considered medium, given that this was mostly a qualitative assessment. Because of the lack of data at state level for the relevant indicators, it was not possible to quantitatively assess the starting situation and to project the future situation. Therefore, the qualitative assessment was based on the contributions from experts in the workshops organized as part of the project and has some degree of uncertainty.

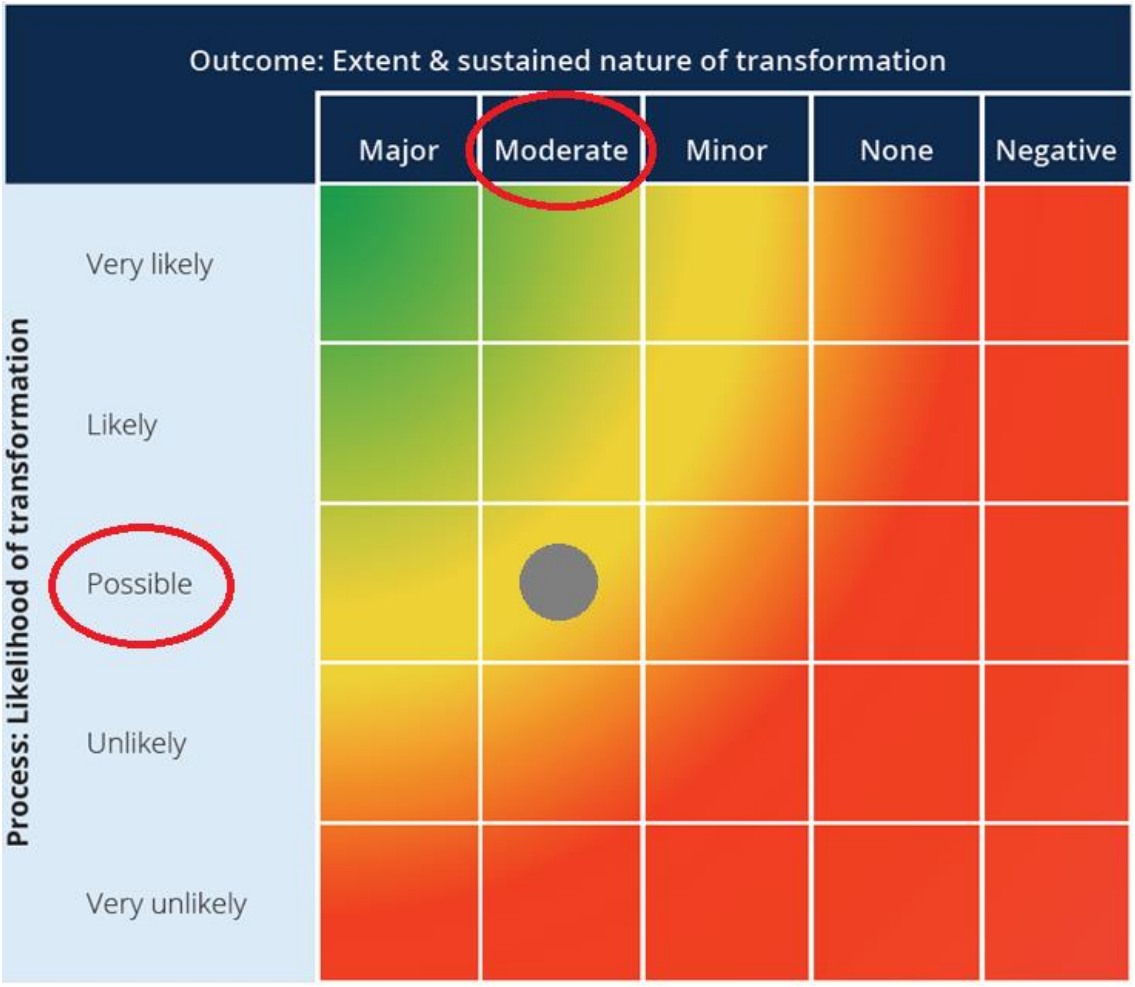


Figure 7 - Transformational impact matrix

5 Conclusion

This study presented an ex-ante assessment of the transformational change impacts of the expansion of solar PV proposed in the State Strategy for the Energy Transition of Minas Gerais. The objective was to identify and assess the different aspects that can be impacted by the policy towards sustainable development and analyze if this could cause a transformational change. Positive impacts that could be triggered by the policy are related to renewable energy expansion, climate change mitigation and sustainable development.

The PETE builds on the modelling of scenarios for the energy system in Minas Gerais in the mid and long terms to provide inputs to the energy transition in the state, which should include the increase in renewable energies (50% in 2030 and 60% in 2050, both excluding hydropower plants), promotion of energy efficiency in the power sector (10% of gains in 2030 and 15% in

2050), and reduce GHG emissions (12% in 2030 and 28% in 2050, both compared to a baseline scenario).

The assessment was based on the ICAT Transformational Change Methodology guide, which provides the steps for the assessment of the transformational change potential of policies. It included the definition of the assessment (phase of transformation, vision for transformational change, barriers to transformational change and transformational characteristics to be assessed) and the estimation of the transformational impact of the policy (assessment of characteristics and aggregation of results).

The results show that the extent and sustained nature of transformation expected with the policy is moderate. This result is most positively impacted by the outcomes in terms of renewable energy expansion, which are considered major both in extent and sustained nature. Impacts in terms of mitigation of climate change are considered moderate, whereas sustainable development outcome is considered minor. None of the categories is expected to be negatively impacted by the policy.

In the case of renewable energy expansion, the scale of outcome is major given that this is one of the main objectives of the policy and because of the huge potential of the state to promote solar energy. Sustainability over time is also major (medium and long terms) because once those sources are implemented, it is not expected a return to fossil fuels in the future.

In terms of GHG emissions, the scale of outcome was considered moderate based on the target of 28% of reduction, considering that the energy sector is the second in GHG emissions in the state. On the other hand, the impact is limited to the micro (state) level, with some minor impact at medium level. The sustained nature is considered moderate because the impacts will be achieved mostly in the long term (the policy targets 12% of GHG emission reduction in 2030 and 28% in 2050).

Sustainable development outcome was considered minor in scale because, although the solar sector has a significant potential to create jobs and income (which was the impact considered in the assessment), the potential is concentrated in a portion of the state, which could limit the transformational potential. In terms of sustainability over time, it was also considered minor because most of the jobs created in this sector are related to activities of installation and are not permanent.

Regarding process characteristics, the likelihood of transformation is defined as “possible”. The category of “Incentives” presented the best result in the assessment (likely), particularly because of the characteristic of “economic and non-economic” and “institutional and regulatory”. This derives from the type of actions proposed by the policy, such as tax and financial instruments,

because it creates a legal framework for the energy transition in the state. At the same time, this was considered the category with the most relative importance, given that the policy could help overcome barriers related to this category, such as overlapping of responsibilities across multiple institutions, constrain to develop programs if the is not a policy established, lack of coordination between national and subnational agencies, and the high costs for installing solar rooftop PV.

The category "Technology" also contributed positively to the result, with a score of 2 (possible), particularly because of the potential impact of the policy to expand the adoption of solar energy across the state, but also because of R&D investments that can be promoted. The category "Agents of change" had a score of 2 (possible) because of the number of beneficiaries of the policy, such as householders who install solar panels in their homes, workers who will be trained for these new opportunities. Entrepreneurship can also be positively impacted once solar energy expands in the state and incentivizes new businesses. Finally, the category "Norms" had a score of 1 (unlikely), given that this is the least addressed by the policy, although some impact can be expected in the characteristics of awareness and behaviour.

The conclusion is that the policy is potentially transformational, which is mostly because of the impacts it can have for expansion of renewable energies and GHG mitigation at the micro level. The transformation impact could be improved in the following ways:

- Regarding the outcome characteristics, more attention could be given to impacts in terms of job and income creation. This is expected to be triggered by the policy, but if not well managed, it tends not to be sustained in the long term. In terms of scale, the policy should not have much to improve, given that its scope is restricted to the micro (state) level.
- For process characteristics, some attention could be given to those related to the categories "Agents of change" and "Norms". However, maybe most important would be to target those of "Incentives", which has more relative importance, particularly in terms of disincentives carbon-intensive practices. Also, some improvements could be made in characteristics related to "Technology", such as R&D and scale-up.

6 References

Anjos, Morjana Moreira dos. **O papel das energias renováveis no processo de transição energética do Estado de Minas Gerais [recurso eletrônico]: modelagem de sistemas energéticos para o horizonte 2030-2050**. Dissertação (mestrado) - Universidade Federal de Minas Gerais, Escola de Engenharia, 2019.

CEMIG, Companhia Energética de Minas Gerais. **32° Balanço Energético do Estado de Minas Gerais - BEEMG 2017: Ano Base 2016**. Companhia Energética de Minas Gerais. Belo Horizonte: Cemig, 2018.

dos Anjos, M. M.; Tenenwurcel, D. R.; Santos, L. A. O.; Ferreira, W. R.; Costa, A. L.; Pereira, E. M. D. **The Role of the Renewable Energy Program in the State of Minas Gerais in the Process of Renewable Sources Expansion**, Global Journal of Energy Technology Research Updates, 6, pp 1-11, 2019, DOI: http://dx.doi.org/10.15377/2409-5818.2019.06.1

dos Anjos, M. M.; Tenenwurcel, D. R.; Santos, L. A. O.; Ferreira, W. R.; Costa, A. L.; Pereira, E. M. D. **Low Carbon Transition through Renewables Sources – An Overview of the Renewable Energy Program in the State of Minas Gerais**, J. sustain. dev. energy water environ. syst., 8(2), pp 252-267, 2020, DOI: https://doi.org/10.13044/j.sdewes.d7.0295

EPE, Empresa de Pesquisa Energética (Brasil). **Balanço Energético Nacional 2020: Ano base 2019** / Empresa de Pesquisa Energética. – Rio de Janeiro: EPE, 2020. **Brazilian Energy Balance 2020 Year 2019** / Empresa de Pesquisa Energética – Rio de Janeiro: EPE, 2020

ICAT (Initiative for Climate Action Transparency) (2020). **Transformational Change Methodology: Assessing the Transformational Impacts of Policies and Actions**, Olsen, K.H. & Singh, N. (Eds.) Initiative for Climate Action Transparency (ICAT), Copenhagen: UNEP DTU Partnership; Washington, D.C.: World Resources Institute. https://climateactiontransparency.org/icatguidance/transformational-change