Future Perspectives on the Energy-Poverty Nexus in the Rural Areas of Ceará, Brazil

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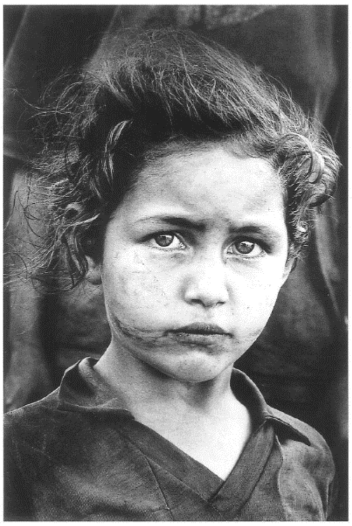
Eles querem que permaneçamos pequenos...

They want us to remain small…

Sie wollen, dass wir klein bleiben…



Pictures: Sebastião Salgado

(Salgado, S., 1997. Terra. 144p. Companhia das Letras)

… mas nosso crescimento é inevitável (autor desconhecido)

... but our growth is unavoidable (unknown author)

…doch ist unser Wachstum unvermeidlich (unbekannter Autor)

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CIB	Cross-Impact Balance Analysis
FEDAF	Development Fund for Family Farming (*Fundo de Desenvolvimento da Agricultura Familiar*)
GDP	Gross Domestic Product
IEA	International Energy Agency
ICTs	Information and communication technologies
kW	Kilowatts
kWh	Kilowatts-hour
LPG	Liquefied Petroleum Gas
NGOs	Non-governmental organizations
MW	Megawatts
PNAD	National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios*)
PRONAF	National Family Farming Support Program (*Programa Nacional de Fortalecimento da Agricultura Familiar*)
SDGs	Sustainable Development Goals
SDG1	Sustainable Development Goal number 1 – No poverty
SDG3	Sustainable Development Goal number 3 – Good health and well-being
SDG4	Sustainable Development Goal number 4 – Quality education
SDG5	Sustainable Development Goal number 5 – Gender equality
SDG6	Sustainable Development Goal number 6 – Clean water and sanitation
SDG7	Sustainable Development Goal number 7 – Affordable and clean energy
SDG10	Sustainable Development Goal number 10 – Reduced inequalities
SESs	Social-ecological systems

Summary

The lack of access to modern and affordable energy services, commonly known as energy poverty, is a worldwide problem often associated with multidimensional poverty. At the household level, at least one in three people rely on inadequate means of cooking and one in ten people lack access to electricity to meet basic human needs. Lack of adequate energy contributes as well to limit several public services, such as medical treatments and educational offers after nightfall. At the economic level, energy poverty impacts on the production of goods and income generation. Thus, there is a general expectation that access to modern and affordable energy services (in many cases based on renewables) can contribute to poverty reduction, especially in the rural areas of developing countries which suffer most from deprivation due to the lack of energy access. This expectation is often based on the assumption that once poor people have access to modern and affordable energy, they can benefit from energy services to move out of poverty.

This study challenges the mentioned assumption. Based on an analysis of the energy-poverty nexus in the rural areas of the Brazilian state of Ceará, it is shown that modern and renewable energies can contribute to increasing or reducing poverty, depending on the context in which they are used in a society. Moreover, this thesis argues that, besides access to adequate energy services, poor people need adequate social and political conditions to develop capabilities that enable them to benefit from energy services to reduce poverty. This is important because people's capacity to develop new capabilities is intrinsically tied to each person's socialization process, which is based on the experiences and opportunities lived by each one.

Also, this study represents one of the few studies that warn that access to and use of modern energy services do not necessarily imply positive effects on poverty reduction. Such a warning does not argue against the universalization of access to modern and affordable energy services, but it highlights the importance of considering possible direct or indirect side effects of energy access and use, along with monitoring and implementing measures that enable people to actually benefit from modern energies and reduce or avoid undesirable side effects. Therefore, a systematic and participatory approach is needed to establish the link between energy access and the causes of poverty. This study presents such an approach, which considers community members as the main actors in local energy projects and provides a systematic view of energy access and local challenges that prevent people from moving out of poverty.

In the last years, the region under study (rural areas in Ceará) has made important progress in reducing energy poverty, such as the universalization of electricity access in 2015, mainly through grid extension. In general, poor rural families use electricity to meet basic human needs (e.g. lighting, food refrigeration and communication). There are also initiatives to increase the access to clean cooking facilities. Yet, the use of unhealthy and inadequate means of cooking is still common in these areas. Despite progress in reducing energy poverty, especially through access to electricity, Ceará is still one of the poorest Brazilian states, with a high level of socioeconomic inequality.

This research therefore proposes an analysis of the energy-poverty nexus, conceptualized in this study as the systematic and dynamic interrelationships between energy and poverty. This conceptualization is important insofar as it goes beyond the concept of energy poverty, widely used in the energy access sector. While the concept of energy poverty focuses on the lack of access to modern and affordable energy services and on strategies to overcome this limitation, the concept of the energy-poverty nexus focuses on understanding the systematic interrelationships between energy access and the societal and institutional causes of poverty with the aim of overcoming barriers to the use of energy to reduce poverty. From this perspective, eradicating energy poverty is essential to eradicating poverty, but it is not enough. In other words, solving the problem of energy poverty is an important piece to solve a more complex puzzle related to the energy-poverty nexus.

In particular, this study deals with the following research question: What are the conditions needed in long-term planning so that modern and renewable energies, in the forms of decentralized electricity generation and clean means of cooking, can contribute to reducing poverty in the rural areas of Ceará? To answer this question, an integrative approach was developed to problematize, systematize and analyse the energy-poverty nexus considering multidimensional factors. During the problematization and systematization phases, based on participatory approaches, rural communities in Ceará were visited and stakeholders were interviewed. In the analysis phase aiming to provide orientation for long-term planning, the scenario technique Cross-Impact Balance Analysis (CIB) was used, which makes it possible to examine interrelationships in complex and multidimensional systems. Lastly, the plausible future trajectories identified through the CIB were analysed using the concepts of resilience, adaptability and transformability of social-ecological systems (SESs) adapted for this research. Although the energy-poverty nexus is not an SES but a socio-energy system, these concepts can be used to show how easy or difficult it can be for society to move the energy-poverty nexus from an undesirable to a desirable pathway.

The resulting future trajectories expressed in five clusters of scenarios ("S1-Conservative", "S2-Migration", "S3-Failed transition", "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará") point out two main social and political conditions – education and governance – that, depending on their states, determine whether modern and renewable energies will contribute to an increase or a reduction in poverty. Accordingly, the possible long-term developments of the energy-poverty nexus in rural Ceará represented in the five clusters of scenarios can be divided into two main pathways: one means the continuance of poverty, the other a reduction of poverty with the support of modern and renewable energies.

In the first pathway, composed of the clusters "S1-Conservative", "S2-Migration", and "S3-Failed transition", it is expected that modern and renewable energies will contribute to maintaining or increasing poverty in rural Ceará. Possible reasons for this are, in particular, *limited* capacity building and education and *non-adequate* governance. Under these two conditions, social groups that are already in a better economic position or are politically well represented can take more advantage of modern and renewable energies than poor and marginalized people, thus maintaining the status quo of poverty and high inequality. The results of this study indicate that rural Ceará is following this first pathway, since there is a historical man-made conjuncture fostering a *limited* education and *non-adequate* governance, which exacerbates poverty and high inequality. This historical conjuncture is resistant to change and is not limited to Ceará, but extends to Brazilian society in general. In this sense, rural Ceará seems to be trapped in the first pathway.

In the second pathway of development, which includes the clusters "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará", it is expected that decentralized and renewable energy systems and clean cooking facilities will contribute to reduce poverty in rural Ceará. The main conditions for this are *contextualized* capacity building and education as well as *adequate* governance. Between these two conditions, the former is indicated as the most prominent to trigger the social value of energy as a driver of poverty reduction. *Contextualized* capacity building and education seeks to encourage and empower people to critically reflect and problematize a particular context. This can lead to a higher awareness of the energy-poverty nexus among community members and planners and to improved strategies to deal with the nexus. *Adequate* governance, in constant dialogue with rural communities, can trigger basic reforms to reduce high social and economic inequalities while maximizing energy access and use for poverty reduction. In combination, *contextualized* education and *adequate* governance open up space to build new capabilities and opportunities among poor people and can lead to a promising pathway to use modern and renewable energies in poverty reduction.

Although this study suggests that rural areas in Ceará are following (or seem to be trapped in) the first pathway described above, this does not mean that rural Ceará cannot leave this path that generates poverty and oppression of poor and marginalized people. The second pathway shows the possibility to take a new course with the help of modern and renewable energies. This second pathway, however, is not easy to follow because it contradicts the historical conjuncture and the current status quo that promote poverty in Brazil in general and in Ceará in particular. Nevertheless, it is a possible and promising pathway towards an inclusive society with less inequality and no poverty.

Also, the integrative approach developed in this study can make a valuable contribution to further case studies in the fields of energy access and sustainable development because it allows for a better understanding of the dynamics of rural areas in relation to energy and poverty. The approach can, therefore, help improve policies and strategies aimed at maximizing the use of energy for poverty reduction while minimizing the risks of undesirable side effects for poor people. Ultimately, this approach can contribute to integrative and inclusive energy access in poor rural communities.

Zusammenfassung

Der mangelnde Zugang zu modernen und erschwinglichen Energiedienstleistungen, auch bekannt als Energiearmut, ist ein weltweites Problem, das oft mit multidimensionaler Armut einhergeht. Auf Haushaltsebene verfügt mindestens jeder dritte Mensch über unzureichende Kochgelegenheiten und jeder zehnte Mensch über mangelnden Zugang zu Elektrizität, um die menschlichen Grundbedürfnisse zu decken. Darüber hinaus trägt die mangelnde Energieversorgung zu Einschränkungen im Bereich öffentlicher Dienstleistungen bei, wie z. B. medizinische Behandlungen oder Bildungsangebote nach Einbruch der Dunkelheit. Auf wirtschaftlicher Ebene wirkt sich Energiearmut negativ auf die Güterproduktion und die Einkommen aus. Es wird daher allgemein erwartet, dass der Zugang zu modernen und erschwinglichen Energiedienstleistungen (in vielen Fällen auf der Grundlage erneuerbarer Energien) zur Verringerung der Armut beitragen kann, insbesondere in ländlichen Gebieten von Entwicklungsländern, die am meisten unter fehlendem Zugang zu Energie und den damit verbundenen Entbehrungen leiden. Dahinter steht häufig die Annahme, dass arme Menschen, sobald sie Zugang zu moderner und erschwinglicher Energie haben, von Energiedienstleistungen profitieren können, um aus der Armut herauszukommen.

In der vorliegenden Studie wird diese Annahme infrage gestellt. Auf der Grundlage einer Analyse des Energie-Armut-Nexus in den ländlichen Gebieten des brasilianischen Bundesstaates Ceará wird gezeigt, dass moderne und erneuerbare Energien je nach dem Kontext, in dem sie in einer Gesellschaft eingesetzt sind, zu einer Zunahme oder Verringerung der Armut beitragen können. Darüber hinaus wird argumentiert, dass arme Menschen neben dem Zugang zu angemessenen Energiedienstleistungen auch über angemessene soziale und politische Bedingungen verfügen müssen, damit sie Fähigkeiten entwickeln können, die es ihnen ermöglichen, durch die Nutzung der Energiedienstleistungen die Armut zu verringern. Dies ist deshalb wichtig, weil das Vermögen des Menschen, neue Fähigkeiten zu entwickeln, untrennbar mit dem Sozialisationsprozess eines jeden Menschen verbunden ist, der auf den Erfahrungen und Möglichkeiten basiert, die dieser Mensch erlebt hat.

Diese Arbeit ist zudem eine der wenigen Studien, die davor warnen, dass der Zugang zu und die Nutzung von modernen Energiedienstleistungen nicht zwangsläufig positive Auswirkungen auf die Armutsbekämpfung haben. Eine solche Warnung richtet sich nicht gegen die Universalisierung des Zugangs zu modernen und erschwinglichen Energiedienstleistungen, aber sie weist darauf hin, wie wichtig es ist, mögliche direkte oder

indirekte Nebeneffekte des Zugangs zu und der Nutzung von Energie zu berücksichtigen. Die Überwachung und Umsetzung von Maßnahmen, die es den Menschen ermöglichen, von modernen Energien zu profitieren und unerwünschte Nebeneffekte zu reduzieren oder zu vermeiden, ist dabei ebenfalls von großer Bedeutung. Daher wird ein systematischer und partizipatorischer Ansatz benötigt, der den Zusammenhang zwischen Energiezugang und Ursachen von Armut herstellt. Die vorliegende Studie stellt einen solchen Ansatz vor. Dieser Ansatz betrachtet Gemeindemitglieder als Hauptakteure lokaler Energieprojekte und vermittelt eine systematische Sicht auf den Zugang zu Energie und die lokalen Herausforderungen, die die Menschen daran hindern, aus der Armut herauszukommen.

Die untersuchte Region (ländliche Gebiete in Ceará) hat in den letzten Jahren wichtige Fortschritte in der Bekämpfung von Energiearmut erzielt, wie z. B. die Universalisierung des Zugangs zu Elektrizität im Jahr 2015, insbesondere durch den Ausbau des Stromnetzes. Elektrizität wird von armen Familien auf dem Land in erster Linie zur Deckung menschlicher Grundbedürfnisse (z. B. Beleuchtung, Lebensmittelkühlung und Kommunikation) genutzt. Darüber hinaus gibt es Initiativen zur Verbesserung des Zugangs zu sauberen Kochgelegenheiten. Gesundheitsschädliche und ungeeignete Kochstellen sind in diesen Gebieten jedoch immer noch weit verbreitet. Trotz der Fortschritte im Kampf gegen Energiearmut, insbesondere durch den Zugang zu Elektrizität, ist Ceará immer noch einer der ärmsten Bundesstaaten Brasiliens mit einem hohen Maß an sozioökonomischer Ungleichheit.

Die vorliegende Forschungsarbeit schlägt daher eine Analyse des Energie-Armut-Nexus vor, der im Rahmen dieser Arbeit als die systematischen und dynamischen Wechselbeziehungen zwischen Energie und Armut verstanden wird. Diese Konzeption ist insofern von Bedeutung, als sie über das im Energiezugangssektor weit verbreitete Konzept der Energiearmut hinausgeht. Während sich das Konzept der Energiearmut auf den fehlenden Zugang zu modernen und erschwinglichen Energiedienstleistungen und auf Strategien zur Bewältigung dieses Problems konzentriert, liegt der Schwerpunkt im Konzept des Energie-Armut-Nexus auf dem Verständnis der systematischen Wechselbeziehungen zwischen Energiezugang und gesellschaftlichen und institutionellen Ursachen von Armut mit dem Ziel, Hindernisse für die Nutzung von Energie zur Verringerung von Armut zu überwinden. Aus dieser Perspektive ist die Überwindung der Energiearmut für die Überwindung von Armut zwar von wesentlicher Bedeutung, reicht aber nicht aus. Mit anderen Worten, die Lösung des Problems der Energiearmut ist ein wichtiges Puzzleteil zur Lösung eines komplexeren Problems, das mit dem Energie-Armut-Nexus zusammenhängt.

Diese Arbeit befasst sich insbesondere mit der folgenden Forschungsfrage: Welche Bedingungen müssen erfüllt sein, damit moderne und erneuerbare Energien in Form von dezentraler Stromerzeugung und sauberen Kochgelegenheiten langfristig zur Armutsbekämpfung in den ländlichen Gebieten von Ceará beitragen können? Zur

Beantwortung der Fragestellung wurde ein integrativer Ansatz entwickelt, um den Energie-Armut-Nexus unter Berücksichtigung mehrdimensionaler Faktoren problematisieren, systematisieren und analysieren zu können. Während der auf partizipativen Ansätzen basierenden Problematisierungs- und Systematisierungsphasen wurden in Ceará ländliche Gemeinden besucht und Interessenvertreter befragt. Mit dem Ziel, Orientierung für eine langfristige Planung zu geben, wurde in der Analysephase die Szenariotechnik der Cross-Impact-Bilanzanalyse (CIB) eingesetzt, die es ermöglicht, die Wechselwirkungen von komplexen und vielschichtigen Systemen zu untersuchen. Schließlich wurden die mithilfe der CIB identifizierten plausiblen zukünftigen Entwicklungspfade mit den für diese Forschung angepassten Konzepten der Resilienz, Anpassungsfähigkeit und Transformationsfähigkeit sozioökologischer Systeme (SES) analysiert. Obwohl es sich beim Energie-Armut-Nexus nicht um ein SES, sondern um ein sozioenergetisches System handelt, können diese Konzepte genutzt werden, um aufzuzeigen, wie leicht oder schwer es für die Gesellschaft sein kann, den Energie-Armut-Nexus von einem unerwünschten auf einen gewünschten Pfad zu bringen.

Die in Form von fünf Szenarien-Clustern („S1-Konservativ“, „S2-Migration“, „S3-Gescheiterter Übergang“, „S4-Übergang durch kontextualisierte Bildung“ und „S5-Überwindung der Armut im ländlichen Ceará“) dargestellten Entwicklungspfade zeigen, dass es zwei wichtige soziale und politische Bedingungen gibt – Bildung und Governance –, deren Status darüber entscheidet, ob moderne und erneuerbare Energien zu einer Zunahme oder einer Verringerung der Armut beitragen können. Entsprechend lassen sich die möglichen langfristigen Entwicklungen des Energie-Armut-Nexus im ländlichen Ceará in den fünf Szenarien-Clustern in zwei Hauptpfade unterteilen: Der eine bedeutet einen Fortbestand der Armut, der andere eine Verringerung der Armut mithilfe moderner und erneuerbarer Energien.

Beim ersten Entwicklungspfad, der die Szenarien-Cluster „S1 Konservativ“, „S2-Migration“ und „S3-Gescheiterter Übergang“ umfasst, ist zu erwarten, dass moderne und erneuerbare Energien dazu beitragen werden, die Armut im ländlichen Ceará aufrechtzuerhalten oder zu verstärken. Mögliche Gründe hierfür sind insbesondere *unzureichender* Kapazitätsaufbau und Bildung sowie *inadäquate* Governance. Unter diesen Bedingungen können gesellschaftliche Gruppen, die in einer besseren wirtschaftlichen Lage oder politisch gut vertreten sind, mehr von modernen und erneuerbaren Energien profitieren als arme und marginalisierte Menschen, sodass der Status quo von Armut und hoher Ungleichheit verfestigt wird. Die Ergebnisse dieser Studie deuten darauf hin, dass das ländliche Ceará diesen ersten Weg beschreitet, denn die historischen, von Menschen gemachten Strukturen in der Region fördern *unzureichende* Bildung und *inadäquate* Governance, die das Problem von Armut und hoher Ungleichheit verstärken. Diese historischen Strukturen sind resistent gegenüber Veränderungen und beschränken sich nicht auf Ceará, sondern erstrecken sich auf die brasilianische Gesellschaft allgemein. In diesem Sinne scheint das ländliche Ceará auf dem ersten Pfad gefangen zu sein.

Beim zweiten Entwicklungspfad, der sich aus den Clustern „S4-Übergang durch kontextualisierte Bildung“ und „S5-Überwindung der Armut im ländlichen Ceará“ zusammensetzt, wird erwartet, dass dezentrale und erneuerbare Energiesysteme und saubere Kochgelegenheiten zu einer Verringerung von Armut führen. Die Hauptbedingungen dafür sind *kontextualisierter* Kapazitätsaufbau und Bildung sowie *adäquate* Governance. Erstere wird als Grundvoraussetzung gesehen, um den sozialen Wert von Energie als Motor der Armutsbekämpfung zu erhöhen. Durch *kontextualisierten* Kapazitätsaufbau und Bildung können die Menschen dazu ermutigt und befähigt werden, einen bestimmten Kontext kritisch zu reflektieren und zu problematisieren. Dies kann zu einem höheren Bewusstsein der Gemeindemitglieder und Planer für den Energie-Armut-Nexus und zu verbesserten Strategien im Umgang damit führen. Durch *adäquate* Governance im ständigen Dialog mit den ländlichen Gemeinden können grundlegende Reformen angestoßen werden, um die großen sozialen und wirtschaftlichen Ungleichheiten zu verringern und gleichzeitig den Zugang zu und die Nutzung von Energie zur Armutsbekämpfung zu maximieren. In Kombination eröffnen *kontextualisierte* Bildung und *adäquate* Governance Raum für den Aufbau neuer Fähigkeiten und Möglichkeiten für arme Menschen und sind ein vielversprechender Weg zur Nutzung moderner und erneuerbarer Energien in der Armutsbekämpfung.

Obwohl diese Arbeit darauf hindeutet, dass die ländlichen Gebiete in Ceará dem ersten Entwicklungspfad folgen (oder darin gefangen scheinen), bedeutet dies nicht, dass das ländliche Ceará diesen Pfad nicht verlassen kann, der Armut und Unterdrückung von armen und marginalisierten Menschen hervorruft. Der zweite Entwicklungspfad zeigt Möglichkeiten auf, mithilfe moderner und erneuerbarer Energien einen neuen Kurs einzuschlagen. Dieser zweite Pfad ist jedoch kein einfacher Weg, denn er steht im Widerspruch zu den historischen Strukturen und dem aktuellen Status quo, auf die die Armut in Brasilien im Allgemeinen und in Ceará im Besonderen zurückzuführen ist. Dennoch ist es ein möglicher und vielversprechender Weg in Richtung einer integrativen Gesellschaft mit weniger Ungleichheit und ohne Armut.

Darüber hinaus kann der in dieser Arbeit entwickelte integrative Ansatz einen wertvollen Beitrag zu weiteren Fallstudien im Bereich Energiezugang und nachhaltige Entwicklung leisten, da er ein besseres Verständnis der Dynamik ländlicher Gebiete in Bezug auf Energie und Armut ermöglicht. Der Ansatz kann somit zur Verbesserung von politischen Maßnahmen und Strategien beitragen, die darauf abzielen, die Nutzung von Energie zur Armutsbekämpfung zu maximieren und gleichzeitig die Risiken unerwünschter Nebeneffekten auf arme Menschen zu minimieren. Letztlich kann dieser Ansatz einen Beitrag zu einem integrativen und inklusiven Energiezugang in armen ländlichen Gemeinden leisten.

Resumo

A falta de acesso a serviços energéticos modernos e de custos acessíveis, comumente conhecido como pobreza energética, é um problema global que muitas vezes esta associado à pobreza multidimensional. A nível doméstico, pelo menos uma em cada três pessoas dependem de meios inadequados para cocção de alimentos e uma em cada dez pessoas não tem acesso a eletricidade para suprir necessidades humanas básicas. A falta de energia adequada contribui também para limitar vários serviços públicos, como atendimento médico e oportunidades educacionais após o entardecer. No nível econômico, a pobreza energética impacta na produção de bens e geração de renda. Desta forma, há uma expectativa que o acesso a serviços energéticos modernos e a custos acessíveis (em muitos casos com base em energias renováveis) contribua com a redução da pobreza, especialmente em áreas rurais de países em desenvolvimento que mais sofrem privações devido à falta de energia. Frequentemente, esta expectativa se baseia na suposição de que, uma vez que os as pessoas pobres tenham acesso à energia moderna e a custo acessível, elas possam se beneficiar dos serviços de energia para sair da pobreza.

Este estudo questiona a mencionada suposição. Com base na análise do nexo energia e pobreza no estado brasileiro do Ceará, este estudo mostra que energias modernas e renováveis podem contribuir para aumentar ou reduzir a pobreza, dependendo do contexto em que são utilizadas em uma sociedade. Além disso, esta tese argumenta que, além do acesso a serviços de energia adequados, pessoas pobres precisam ter condições sociais e políticas adequadas para desenvolver capacidades que lhes permitam se beneficiar dos serviços de energia para reduzir a pobreza. Isso é importante porque a capacidade das pessoas de desenvolverem novas capacidades está intrinsecamente relacionada ao processo de socialização de cada pessoa, o que se baseia nas experiências e oportunidades vividas por cada um.

Este estudo também representa um dos poucos estudos que alertam que o acesso e uso de serviços modernos de energia não implicam necessariamente efeitos positivos na redução da pobreza. Este alerta não argumenta contra a universalização de serviços de energia modernos e acessíveis, mas destaca a importância de considerar possíveis efeitos colaterais diretos ou indiretos do acesso e uso de energia, juntamente com o monitoramento e implementação de medidas que permitam às pessoas se beneficiarem de energias modernas para reduzir ou evitar possíveis efeitos colaterais. Portanto, uma abordagem sistemática e participativa se faz necessária para estabelecer a ligação entre o acesso à energia e as causas da pobreza. Este estudo apresenta tal abordagem, que considera os membros comunitários como os principais atores em projetos locais de energia e fornece uma visão sistemática do acesso à energia e os desafios locais que impedem as pessoas de saírem da pobreza.

Nos últimos anos, a região em estudo (áreas rurais do Ceará) obteve avanços importantes na redução da pobreza energética, como a universalização do acesso à eletricidade em 2015, principalmente por meio da extensão da rede elétrica. De uma forma geral, as famílias rurais pobres utilizam eletricidade para suprir necessidades humanas básicas (por exemplo, iluminação, refrigeração de alimentos e comunicação). Também existem iniciativas para aumentar o acesso à meios adequados de cocção de alimentos. Todavia, o uso de meios insalubres e inadequados de cocção de alimentos ainda é comum nessas áreas. Embora avanços tenham sido alcançados para reduzir a pobreza energética, principalmente no que diz respeito ao acesso à eletricidade, o Ceará ainda é um dos estados brasileiros mais pobres, com um alto índice de desigualdade socioeconômica.

Assim, esta pesquisa se propôs a analisar o nexo energia e pobreza, conceituado neste estudo como as inter-relações sistemáticas e dinâmicas entre energia e pobreza. Este conceito é importante no sentido de que ele vai além do conceito de pobreza energética, amplamente utilizado no setor de acesso à energia. Enquanto o conceito da pobreza energética se concentra na falta de acesso a serviços de energia modernos e a custos acessíveis assim como em estratégias que visam superar essa limitação, o conceito do nexo energia e pobreza se concentra na criação de inter-relações sistemáticas entre energia e as causas sociais e institucionais da pobreza, tendo como objetivo superar as barreiras do uso de energia para reduzir a pobreza. Nesta perspectiva, erradicar a pobreza energética é essencial para erradicar a pobreza, mas não é suficiente. Em outras palavras, resolver o problema da pobreza energética é uma peça importante para resolver um quebra-cabeça mais complexo relacionado ao nexo energia e pobreza.

De forma particular, este estudo trata da seguinte pergunta de pesquisa: quais são as condições necessárias no planejamento de longo prazo para que energias modernas e renováveis, na forma de geração de eletricidade descentralizada e meios adequados para cocção de alimentos, possam contribuir para a redução da pobreza no meio rural cearense? Para responder à pergunta proposta, foi desenvolvida uma abordagem integrativa para problematizar, sistematizar e analisar o nexo energia e pobreza considerando fatores multidimensionais. Durante as fases de problematização e sistematização, baseadas em abordagens participativas, comunidades rurais no Ceará foram visitadas e atores locais entrevistados. Na fase de análise com o objetivo de orientar o planejamento de longo prazo, foi utilizada a técnica de cenários *Cross-Impact Balance Analysis* (CIB), que permite examinar

inter-relações em sistemas complexos e multifacetados. Por fim, as trajetórias futuras identificadas por meio do CIB foram analisadas a partir dos conceitos de resiliência, adaptabilidade e transformação de sistemas sócio ecológicos adaptados para esta pesquisa. Embora o nexo energia e pobreza não seja um sistema sócio ecológico, mas um sistema sócio energético, estes conceitos podem ser utilizados para destacar o quão fácil ou difícil pode ser para a sociedade mover o nexo energia e pobreza de um caminho indesejável para um desejável.

As trajetórias futuras resultantes expressas em cinco grupos de cenários (“S1-Conservador”, “S2-Migração”, “S3-Transição fracassada”, “S4-Transição através da educação contextualizada” e “S5-Superando a pobreza no Ceará rural”) apontam duas principais condições sociais e políticas - educação e governança – que, dependendo de seus estados, determinam se energias modernas e renováveis irão contribuir para o aumento ou redução da pobreza. Assim, os possíveis desenvolvimentos de longo prazo do nexo energia e pobreza no Ceará rural representados nos cinco cluster de cenários podem ser divididos em dois caminhos principais: um representando a continuidade da pobreza e o outro a redução da pobreza com o apoio de energias modernas e renováveis.

No primeiro caminho, composto pelos clusters “S1 Conservador”, “S2-Migração” e “S3-Transição fracassada”, espera-se que energias modernas e renováveis contribuam para manter ou aumentar a pobreza no meio rural cearense. As possíveis razões para isto são, em particular, capacitação e educação *limitada* e governança *inadequada*. Sob estas duas condições, grupos sociais que já estão em uma melhor posição econômica ou são politicamente bem representados podem se beneficiar mais de energias modernas e renováveis do que as pessoas pobres e marginalizadas, mantendo assim o status quo da pobreza e alta desigualdade. Os resultados desta pesquisa indicam que o Ceará rural está seguindo este primeiro caminho, pois há uma conjuntura antropogênica histórica que favorece uma educação *limitada* e uma governança *inadequada*, o que agrava a pobreza e alta desigualdade. Esta conjuntura histórica é resistente a mudanças e não se limita ao Ceará, mas se estende à sociedade brasileira em geral. Neste sentido, o Ceará rural parece estar preso neste primeiro caminho.

No segundo caminho de desenvolvimento, composto pelos clusters “S4-Transição através da educação contextualizada” e “S5-Superando a pobreza no Ceará rural”, espera-se que sistemas de energia descentralizados e renováveis e meios adequados de cocção de alimentos contribuam para a redução da pobreza no meio rural cearense. As principais condições para que isso ocorra referem-se a capacitação e educação *contextualizada* e uma governança *adequada*. Entre essas duas condições, a primeira é apontada como a mais proeminente para desencadear o valor social da energia como um mecanismo para a redução da pobreza. A capacitação e educação *contextualizada* busca encorajar e capacitar as

pessoas a refletirem e problematizarem criticamente um determinado contexto. Isto pode levar a um aumento de consciência do nexo energia e pobreza entre os membros da comunidade e planejadores e a melhores estratégias para lidar com o nexo. Governança *adequada*, em constante diálogo com as comunidades rurais, pode promover reformas de base para reduzir as elevadas desigualdades sociais e econômicas, enquanto maximizando o acesso e o uso da energia para a redução da pobreza. Quando combinadas, educação *contextualizada* e governança *adequada* abrem espaço para construir novas capacidades e oportunidades entre as pessoas pobres e podem levar a um caminho promissor para o uso de energias modernas e renováveis na redução da pobreza.

Embora este estudo sugira que as áreas rurais do Ceará estão seguindo o primeiro caminho de desenvolvimento descrito acima (ou parecem estar presas neste caminho), isso não significa que o Ceará rural não possa sair deste caminho que gera a pobreza e opressão de pessoas pobres e marginalizadas. O segundo caminho apresenta uma alternativa para trilhar um novo rumo com o auxílio de energias modernas e renováveis. Esse segundo caminho, porém, não é um caminho fácil de se seguir, pois vai em contradição à conjuntura histórica e o atual status quo que promovem a pobreza no Brasil em geral e no Ceará em particular. No entanto, é um caminho possível e promissor em direção a uma sociedade inclusiva, com menos desigualdade e sem pobreza.

Além disso, a abordagem integrativa desenvolvida neste estudo pode representar uma contribuição valiosa à futuros estudos de caso nas áreas de acesso à energia e desenvolvimento sustentável, pois permite uma melhor compreensão da dinâmica de áreas rurais em relação a energia e pobreza. A abordagem pode, portanto, contribuir na melhoria de políticas e estratégias destinadas a maximizar o uso da energia na redução da pobreza, minimizando os riscos de efeitos colaterais indesejáveis para as pessoas pobres. Por fim, esta abordagem pode contribuir para o acesso integrativo e inclusivo à energia em comunidades rurais pobres.

Chapter one

Introduction

Poverty in its different forms and dimensions denies 1.3 billion people around the world (from which 1.1 billion live in rural areas) to live a full and dignified life (OPHI and UNDP, 2020). Poor people are also the most vulnerable to shocks from different natures (e.g. economic and health crises and extreme weather events) and often have low levels of human assets like education, basic sanitation, health care, food security and access to clean water and modern energies. Poverty is also closely related to socioeconomic inequalities and does not only affect private life but also the collective life of individuals (e.g. it contributes to increasing political and social tensions and to limiting societies to growing prosperously and inclusively (UN, 2009)). Thus, poverty is morally and ethically unacceptable and its end is recognized as the greatest global challenge and essential for achieving sustainable development (UN, 2015).

In 2015, about 10 percent of the global population (734 million people) were living under extreme poverty (i.e. earning less than $1.90 a day). This percentage fell to an estimated 8.2 in 2019. Part of the Sustainable Development Goals (SDGs), SDG1 seeks to eradicate poverty around the world in all its forms by 2030. Without the COVID-19 pandemic, the world was already not on track to meet SDG1 and about 6 percent of the world's population was expected to live in extreme poverty by 2030 (UN, 2020). Now (early 2021), with the large impacts of COVID-19 on health systems and the economy, the situation is expected to get even worse and about 110 to 150 million people can be pushed back to extreme poverty in 2020-21 (World Bank, 2020). Consequently, poverty is expected to increase in the coming years (UN, 2020; World Bank, 2020).

Poverty can be conceptualized as deprivations that limit the capability of people to achieve elementary functions that individuals, upon reflection, may have reasons to value (cf. Sen, 1999). While such a concept can lead to subjectivity, it considers poverty as a multidimensional phenomenon of opportunity deprivations that cannot be measured only by income and Gross Domestic Product (GDP), though these aspects are also relevant for poverty reduction. In that concept, people's elementary functions can be being healthy, educated, well-nourished or having social and political participation in society, while capabilities represent the means that people have to achieve such functions. For example, agrarian policies that foster food security can contribute to avoid that a country suffers from collective hunger. In other words, the opportunity for food security can increase through adequate agrarian policies. Investments in water supply, basic sanitation and education are measures that can increase opportunities to foster people's health and education. Thus, such policies and investments are considered as means that can contribute to reduce poverty (Sen, 1999).

In the context of energy and poverty, the access to modern and affordable energy services (e.g. heating, lighting, refrigeration and electromechanical power) is also expected to be a mechanism that contributes to reduce poverty, especially in the rural areas of developing countries since these are the areas that lack access to modern energies nowadays the most (Karekezi et al., 2012; Practical Action, 2014).

Modern energies can be conceptualized as forms of energy that can be used in a more efficient and less polluting way than traditional forms (cf. Barnes et al., 2011). According to this concept, modern energies represent better forms of using energy and are not limited to the type of fuel used, although the substitution of more polluting, low quality and inefficient fuels to less polluting, high quality and more efficient fuels is also important. For example, the use of kerosene lamps can be considered a traditional form of energy, while the use of electricity for lighting a modern one. Kerosene lamps increase indoor air pollution and fire risks at home (Pode, 2010), are less efficient and more expensive than electric lighting in the medium term (Mills, 2003). The use of biomass in improved cookstoves that work with closed combustion chamber and chimney can be considered a modern form of cooking, while the use of biomass in three-stone fireplaces a traditional one. Three-stone fireplaces consume much more biomass and cause much more indoor air pollution than improved cookstoves (Practical Action, 2010).

The dominant discourse in the literature (e.g. Halff et al., 2014; IEA, 2020a-b, 2017; IEA et al., 2020; Karekezi et al., 2012) highlights the need to provide access to modern and affordable energy services for poor people, or to eradicate energy poverty, as a way to fight poverty. This is frequently justified because there is a general expectation that once poor people have access to better forms of energy, they have the opportunity to benefit from energy services to improve their quality of life, overcome deprivations and increase income generation while enabling them to gradually move out of poverty. For instance, with access to electricity, household chores can be accomplished in a better way using electric appliances like mixers, blenders and washing machines. The quality and range of services as education and medical assistance can be enhanced and enlarged using electricity. Also agrarian and non-agrarian economic activities can be boosted, increasing employment opportunities and income generation (more detail are presented in chapter two).

Such potential benefits of energy towards a better quality of life and less poverty inspire several initiatives and goals around the world to eradicate energy poverty, as the SDG7 that calls for universal access to modern and affordable energy by 2030. The SDG7 focuses on the access to electricity and clean means of cooking and is expected to contribute to the achievement of additional SDGs, including poverty eradication (SDG1), good health and well-being (SDG3), quality education (SDG4), gender equality (SDG5), clean water and sanitation (SDG6) and reducing inequalities (SDG10) (UN, 2017).

To increase electricity access in rural areas, strategies focusing on grid extension and centralized electricity supply are preferred, where possible, because of cost-benefit (Foley, 1992). To reach universal electricity access at the global level, however, decentralized power systems (e.g. mini-grids and standalone electricity systems) based on renewable energies will play an essential role because many rural communities in developing countries are located in remote regions with difficult ground access and low population density (Practical Action, 2019; Zerriffi, 2011). Where possible, decentralized power systems can be connected to the main grid, increasing system reliability, decreasing environmental impact caused by centralized electricity supply and postponing investments in large electrical infrastructure (ANEEL, 2016). To universalize the access to clean means of cooking, strategies focus on fuel switching from biomass to Liquefied Petroleum Gas (LPG), natural gas, biogas, electricity and solar and on the adoption of improved biomass cookstoves (IEA et al., 2020).

Although the strategies briefly presented above are important to reach universal access to modern energies, the world is not on track to reach SDG7 and 660 million people are expected to lack electricity access and 2.4 billion to clean cooking facilities by 2030 (these figures are currently around 770 million and 2.6 billion, respectively) (IEA, 2020c). The expected numbers for 2030 already consider some impacts of the COVID-19 crisis on energy access, but they may increase as the impacts of the current health crisis continue in 2021.

Once observing the potential benefits of energy access for a better life, as briefly described above (additional examples are presented in chapter two), one could expect that the arrival of energy in poor rural communities means a kind of “straight road” to the reduction of poverty. However, such an expectation may not always realize. The expectation mentioned above can be observed in the dominant literature in the energy access sector focusing on the potential benefits of energy access while paying less or no attention to possible neutral or negative impacts on poor rural communities. Although less explored in the literature, some studies (e.g. Aklin et al., 2017; Bensch et al., 2011; Salmon and Tanguy, 2016; Squires, 2015) have demonstrated that energy can have neutral or even cause negative impacts on poor people (more detail in chapter two).

There are several contextualized factors that can hamper energy to act as a means of poverty reduction. For instance, the argument widely used in the literature that energy increases the access to information by enabling people to use information technologies such as televisions, radios and mobile phones does not mean that poor people will have access to adequate information to help them overcome poverty. If the information content spread out in a society is one that reinforces social, economic and political patterns that reproduce poverty, one of the main impact that this information may have on people's lives, without a critical reflection, is the acceptance of poverty and social problems as something "normal" of modern societies (more detail in chapters five and seven). The same can be applied to education. With access to electricity, rural schools can offer lectures after sunset, which does not mean that the social and economic dynamics of communities will necessarily improve. As argued by Freire (2005), lectures and the school environment do not necessarily cause positive impacts on society and can be based in retrograde foundations that generate poverty and the oppression of poor people (more detail in chapter five).

In that sense, if modern energies are to be mechanisms to reduce poverty, it is not enough to eradicate energy poverty. All through this study, it is argued that the context in which modern energy services are provided is essential to foster positive benefits and avoid possible negative impacts on poverty reduction. It is inside a context that developments happen and people act, which may lead energy to contribute or not to reduce poverty (more detail in chapters two and five). Often, the dominant literature on energy access gives less or no attention to the context in which modern energies are provided in rural areas and treat community members as users or beneficiaries of energy but not as local transformation agents of the situation they face. Such a view contributes do the idealization that energy will result on positive impacts on poverty reduction disregarding neutral and negative impacts.

This study adds to the scientific knowledge by analysing the context in which modern and renewable energies can contribute to reduce poverty considering as case study rural areas in the semi-arid Brazilian state of Ceará, which is located on the north-eastern coast of Brazil and has a rural population of about 2.1 million people (IPECE, 2018). In the last years, Ceará has achieved important advances to reduce energy poverty as the universalization of electricity access in 2015. However, the State is still one of the poorest Brazilian states with high socioeconomic inequality (de Assis and Linhares, 2015; IPECE, 2020; Nogueira and Medeiros, 2016). The use of cookstoves based on LPG combined with cookstoves based on biomass is common in the region (IBGE, 2020a). In particular, this study aimed to answering the following research question: what are the conditions needed in long-term planning so that modern and renewable energies, in the forms of decentralized electricity generation and clean means of cooking, can contribute to reduce poverty in the rural areas of Ceará?

To answer the above question considering the multifaceted context in which energy is provided in rural Ceará, this study proposes to deal with the energy-poverty nexus, briefly introduced and conceptualized as the systematic interrelationships between energy and the causes of poverty. That way, the energy-poverty nexus includes the eradication of energy poverty and goes beyond it by creating a multifaceted problem between energy and poverty.

Ultimately, the energy-poverty nexus provides a comprehensive view of a complex problem involving SDG7 and SDG1 the most, contributing as well to overcome limitations of current views on energy poverty that generalize positive impacts of energy access on poverty reduction. Thus, as an additional scientific contribution, this study intends to contribute to moving the discourse on energy poverty to the energy-poverty nexus, applied to the energy access sector as a sector that intends to significantly contribute to reducing poverty in the rural areas of developing countries.

The fact that the energy-poverty nexus focuses on the reduction of poverty through the access to and use of modern energy services does not exempt it from addressing additional challenges, such as high socioeconomic inequality and gender inequality, that contribute to increase poverty and extreme disparities in society. Thus, such challenges are also considered in this study for the case of the energy-poverty nexus in the rural areas of Ceará. Also, although the reduction of monetary poverty is important in modern societies, this poverty does not reflect additional deprivations that people may have. Thus, this study considers poverty as a multidimensional phenomenon (cf. OPHI and UNDP, 2020), including among others the lack of access to adequate education, health care, basic sanitation and access to potable water, electricity and clean means of cooking.

To analyse the energy-poverty nexus, this study developed the Integrative Approach to the Energy-Poverty Nexus, which was partially applied to the case of rural Ceará to answer the research question presented above. The Integrative Approach represents a participatory and systematic approach to deal with energy and poverty in a community, region or country and is divided in six main steps. In the first and second steps, the energy-poverty nexus is characterized and problematized in a specific study object (i.e. community, region or country). In the third step, the analysis of the energy-poverty nexus is conducted and visions about how the nexus may unfold in the future are designed. Step four focuses on the analysis of system dynamics and on the conditions needed to change pathways of development in the future. Step five seeks to create and adopt strategies for action. The last step evaluates the results, readapts strategies and celebrates the outcomes achieved. For the case of rural Ceará, the Integrative Approach was performed until step four, which allowed to answer the research question. Steps five and six of the Integrative Approach can be performed in Ceará based on the findings of this research and would need the engagement of local actors and governmental authorities.

This study is divided in seven chapters, including this introduction. The second chapter presents the state of the art on the access to modern energies and possible positive, neutral and negative impacts on poor rural communities. The chapter also presents how different approaches around the globe have dealt with the concepts of energy poverty and the energy-poverty nexus. The definition of the energy-poverty nexus used in this research is also provided in chapter two. Finally, the chapter provides an outlook on the energy access sector at the global level and some reflections on the status quo of energy access.

Chapter three introduces the Integrative Approach to the Energy-Poverty Nexus and suggests methods that can be used to perform the steps of the Integrative Approach. One example of its application in a hypothetical rural community is also provided. In simple words, one can say that chapter three describes the theoretical approach and methodology developed and used in this research.

Chapter four starts with the application (steps one and two) of the Integrative Approach to the Energy-Poverty Nexus in rural Ceará aiming to answer the research question proposed in this study. In this chapter, the energy-poverty nexus in rural Ceará is contextualized and characterized as an interrelated, dynamic and multifaceted socio-energy system; that means an energy system in which society plays an essential role in determining how the system is composed of and used (Miller et al., 2015).

Chapter five applies step three of the Integrative Approach and uses Cross-Impact Balance Analysis (CIB) (Weimer-Jehle, 2006) for the analysis of the energy-poverty nexus in rural Ceará and the design of future perspectives for it. CIB also allowed for the identification of the main conditions that can promote modern and renewable energies in rural Ceará as a mechanism to reduce poverty in the region. In simple words, the research question proposed in this study is answered in this chapter.

Chapter six adapts and uses the concepts of resilience, adaptability and transformability of social-ecological systems (SESs) (Walker et al., 2004) to perform step four of the Integrative Approach. The use of these concepts adapted to the energy-poverty nexus in rural Ceará enabled to better understand how easy or difficult it is for society to change pathways in the future considering the main conditions identified in chapter five. Chapter six also presents a critical review on the Integrative Approach, discussing limitations and research gaps. Finally, chapter six presents the main conclusions of this study.

Chapter seven finalizes this dissertation by doing some additional reflections on the main findings and conclusions of this research and extending these reflections to the energy access sector at the global level. In that sense, chapter seven represents the outlook of this study towards integrative and inclusive energy access.

Finally, it is worth noting that, to the knowledge of the author of this study, it is the first time that interrelationships between energy and poverty are analysed in a systematic way for rural areas using CIB analysis and adapted concepts of resilience, adaptability and transformability in socio-energy systems, using rural areas in Ceará as case study. Also, the application of the Integrative Approach to the Energy-Poverty Nexus can be an interesting approach to be applied in similar regions around the globe seeking to maximize the use of modern and renewable energies as a means of poverty reduction in rural areas.

Chapter two

State of the art on energy access

2.1 Introduction

Worldwide it is estimated that about 2.6 billion people have no access to clean means of cooking and 770 million to electricity (IEA, 2020c). Most of them live in the rural areas of developing countries. Often, these numbers are understood and demonstrated as the world population living in energy poverty, or those living without access to modern energies, whose lives are severely impacted by energy deprivations (IEA, 2010; Karekezi et al., 2012; Practical Action, 2012).

Poor rural people often face several deprivations in their daily life due to the lack of access to adequate energy services. Such deprivations can manifest themselves in a wide range, from the impossibility to use a fan during summer nights for a better rest to the impossibility to run machinery to produce goods and raise income. Thus, once poor people have access to modern energy services and can afford electric equipment and bills, many benefits can arise as everyday activities can be facilitated through the use of energy (Karekezi et al., 2012; Practical Action, 2014). In the literature on energy access, many studies highlight positive effects of the access to and use of modern energy services (detail in section 2.2), while few scholars have investigated neutral and negative impacts of energy access in rural communities (detail in section 2.3).

Energy poverty is a broadly used concept in the energy access sector, but there is no consensus on what should be considered under its scope and how to measure it. In fact, a universal scope is difficult to be defined as countries, regions and people have different energy needs (Barnes et al., 2011; Pachauri and Spreng, 2004). A common understanding is that the lack of adequate energy is associated with poverty in multi-dimensions, such as monetary, educational, healthcare and self-esteem, and contributes to keep people in a vicious cycle of poverty. Also, energy poverty is often dealt by science as the lack of adequate energy services to satisfy basic human needs at the domestic level (e.g. cooking, heating, lighting, refrigeration, communication and entertainment). Under such understanding, the concept of energy poverty can be applicable to rural and urban areas as well as to developed and developing countries. Some studies have also included additional deprivations at the community and economic level in their concept of energy poverty, which are more applicable to the rural context of developing countries (detail in section 2.4). Other studies refer to the energy-poverty nexus, which in a broad sense refers to energy poverty and the interrelationships between energy and poverty (detail in section 2.5).

Overcoming energy poverty represents a global issue on public agendas such as the SDG7 that aims to ensure access to modern and affordable energy for all people around the world by 2030 (UN, 2017). Nonetheless, under current trends (before the COVID-19 pandemic), the world is not on track to achieve SDG7 (detail in section 2.6). In addition, it is already known that the COVID-19 crisis has negatively affected and will continue to affect progress towards SDG7, but to what extent it cannot yet be foreseen in total because the crisis is still ongoing (IEA, 2020c; IEA et al., 2020).

This chapter explores and provides reflections on the state of the art on energy access from a global perspective, with emphasis on the rural areas of developing countries. This includes a review on deprivations caused by the lack of modern energy services and possible benefits of energy access (section 2.2) followed by possible neutral and negative impacts of energy access (section 2.3). In section 2.4, worldwide approaches on energy poverty are explored while section 2.5 explores the energy-poverty nexus. Since the interrelationships between energy and poverty are at the core of this research, section 2.5 also defines the concept of the energy-poverty nexus used in this study. Section 2.6 explores approaches and trends to accelerate the access to modern energy services and current projections on the energy access sector. Finally, section 2.7 presents some reflections on the state of the art on energy access, followed by closing remarks (section 2.8).

It should be highlighted that although this study focuses on the rural areas of the Brazilian State of Ceará, this chapter does not present the state of the art on energy access in Ceará. The reason for that is because the methodology used in this study (presented in chapter three) requires a detailed description of the context of the study object. Thus, the state of the art on energy access in Ceará is presented and discussed in chapter four.

2.2 Deprivations related to the lack of energy and possible benefits of accessing it

In the literature, the dominant discourse in the energy access sector in developing countries explores deprivations related to the lack of energy access and possible benefits of having access to modern energy services (e.g. Barnes and Samad, 2018; Bates et al., 2009; Cabraal et al., 2005; Harmelink et al., 2018; IEA, 2017; Karekezi et al., 2012; Openshaw, 2010; Pode, 2010; Practical Action, 2012, 2010, 2014, 2013; Sattler, 2016; Sovacool and Drupady, 2012; Tarnawiecki et al., 2013). This section provides a review of deprivations and potential benefits of energy access related to electricity and means of cooking. The former is explored at the household, community and economic level, while the latter only at the household level. According to the studies reviewed, adequate energy services can significantly increase opportunities to improve the quality of life, foster economic growth and help people move out of poverty.

2.2.1 From deprivations to benefits of energy access at the household level

Deprivations at the domestic level due to the lack of access to adequate electricity and clean means of cooking can severely impact the quality of life and health of residents, contributing to keep them in poverty. For instance, under the light of wick lamps, people have inadequate lighting to read or conduct activities after sunset while being exposed to elevated number of particulate matter, increasing health risks. Therefore, modern energy services at home can considerably improve the quality of life (Barnes and Samad, 2018; IEA, 2017; Practical Action, 2014) and even small quantities of energy have been pointed out as being of high importance to human welfare (AGECC, 2010; Birol, 2007; Goldemberg et al., 1985).

Under suitable access to electricity and capacity to afford electric appliances and consumption, families may substitute inefficient and unsafe means of lighting such as candles and wick lamps, with light bulbs and profit from high-quality lighting. Among possible benefits of electric lighting, some are worth mentioning: (i) reduced risks of fire at home, (ii) reduced health hazards caused by particulate matter, typical of the incomplete combustion of biomass, candles, oil and kerosene, (iii) better learning conditions, since children (and also adults) can accomplish school work or read books at night under a better lit and healthier environment, (iv) improved light and healthier conditions to perform daily activities after daylight (Cabraal et al., 2005; Karekezi et al., 2012; Practical Action, 2010) and (v) reduced energy expenses, as electricity has been proved to be cheaper and more efficient than traditional fuels (Mills, 2003; Pode, 2010).

Benefits of modern energy services at home can be extended beyond proper lighting. Food can be preserved for a longer period under adequate refrigeration. Domestic activities such as food processing, washing and ironing can be carried out in an easier and faster way using electric facilities, benefiting primarily women and girls. Thus, the use of electric appliances can save time and human efforts that can be allocated to develop other activities such as education, childcare and farming. Communication, access to information and entertainment are promoted through information and communication technologies (ICTs), such as radios, televisions, telephones, projectors, computers and internet (Karekezi et al., 2012; Practical Action, 2010).

The use of clean means of cooking represents another milestone opportunity for a better and healthier life, especially for women, children and the elderly since these social groups frequently spend more time at home and are more active in cooking activities, including biomass gathering, than men. High indoor air pollution is responsible worldwide for about 4.3 million deaths a year. This means that this kind of pollution kills more people than malaria, tuberculosis and HIV/AIDS combined and is perhaps the most ignored and extensive health risk to humanity nowadays (WHO, 2016).

Clean cooking means can reduce health hazards and can be achieved through two main forms. The first, and more acceptable in the literature, refers to fuel substitution from biomass to LPG, natural gas, biogas, solar or electricity, for example (IEA, 2019a). The second corresponds to the adoption of improved cookstoves based on biomass and well-ventilated kitchens (Barnes and Samad, 2018; Openshaw, 2010). Such measures reduce indoor air pollution and health risks through inhalation of hazardous gases.

In summary, access to modern and affordable energy services at home in the forms of electricity and clean means of cooking can considerably improve the quality of life and health conditions of residents and, therefore, can also contribute to reduce poverty in rural communities (Karekezi et al., 2012; Practical Action, 2014).

2.2.2 From deprivations to benefits of energy access at the community level

Energy deprivations at the community level due to the lack of access to modern energies can be translated into services that cannot be performed or are performed under precarious conditions to the local population. Thus, once communities have adequate energy access, rural people can benefit from energy in many forms. For instance, medicines can be stored longer under adequate refrigeration and electric equipment can be used for small medical operations and treatments. Ground water can be electrically pumped to supply buildings. Security against criminality and animals' attacks can be enhanced by street lighting. Electricity also allows the use of ICTs that can connect rural clinics to health centres in cities and are useful for broadcast, increasing the impact of vaccination and awareness campaigns (Barnes and Samad, 2018; Cabraal et al., 2005; Karekezi et al., 2012; Practical Action, 2013). In addition, ICTs can be useful for warning messages (e.g. drought, storms and earthquakes), helping communities improve resilience to natural disasters and urgent situations. Simultaneously, aid can be claimed faster in case of urgent necessities (Smart Villages, 2016).

With electrified public centres, cultural and social activities can be offered after nightfall through celebrations and meetings. Health centres can offer medical assistance and school can operate beyond daylight hours. Teachers can use ICTs to provide better lectures and extend students' knowledge (Barnes and Samad, 2018; Karekezi et al., 2012; Practical Action, 2013). Adults can mostly benefit from educational programmes at night, because during the day they are involved in domestic and economic activities (Cabraal et al., 2005). Moreover, it has been demonstrated that families with educated adults, especially among those with a female head, pay more attention in ensuring the education of children (Lloyd and Blanc, 1996).

In summary, the lack of energy access at the community level contributes to limit people's lives in different forms such as health care, social, cultural and education. Thus, adequate energy access in rural communities can substantially increase the quality and range of public services and can, therefore, contribute to improve the quality of life and to reduce poverty (Barnes and Samad, 2018; Cabraal et al., 2005; Karekezi et al., 2012; Practical Action, 2013).

2.2.3 From deprivations to benefits of energy access at the economic level

The lack of energy access at the economic level inhibits people's capability to generate income and can manifest itself in a direct and indirect way. The direct one refers to, for example, the impossibility to run machinery for grain processing that limits farmers to increase revenues. Therefore, modern energy services can have direct benefits on economic performance through the provision of power to support agrarian and non-agrarian commercial activities. In respect to agrarian activities, once people have access to adequate energy services and can afford equipment and energy consumption, many practices previously performed by human or animal force can be powered by electricity. For example, through electromechanical power and availability of water, fields can be efficiently irrigated by using adequate water pumps, which can lead to increase yields, food security and income. Machineries such as fodder choppers, grinders and dryers can reduce production losses as well as time and efforts used in post-harvest processing (Bates et al., 2009; Karekezi et al., 2012; Practical Action, 2012).

The indirect way in which the lack of energy access impacts the economic level refers to the consequences that energy deprivations at the household and community levels (detail in sub-sections 2.2.1 and 2.2.2, respectively) can have on the economic situation of families. For instance, high indoor air pollution caused by the lack of clean means of cooking increases the risks of respiratory diseases. Consequently, unhealthy people spend more money on medicines and medical treatments than healthy ones (Holdren et al., 2000; Hutton et al., 2006). Moreover, unhealthy people have less capability to develop activities and generate income than healthy ones. Thus, the benefits of adopting clean cooking facilities can have an indirect effect on the economic level. Another example from the community level is the electrification of health clinics, which can decrease infant and maternal mortality, and thus, enhance people's health while indirectly affecting the financial situation of families (Cabraal et al., 2005; Karekezi et al., 2012).

Modern energy services are able not only to enhance rural economic activities already established and to reduce losses and working time, but they can also be used as a support to create new opportunities (Practical Action, 2012). In this sense, the use of ICTs can contribute to economic growth as well. With adequate information access, farmers may improve the quality and productivity of their produce by learning better agricultural practices. ICTs can also help to establish bridges between farmers and markets and increase farmers' awareness of current market values to negotiate better prices for the commercialization of their products (Cabraal et al., 2005; Karekezi et al., 2012; Practical Action, 2012).

In addition to agrarian activities, also non-agrarian economic practices can benefit from modern energy services. Indeed, under adequate energy supply, commerce can store perishable products longer. Small enterprises or industries such as sewing, textile and welding can be established, generating new employments. Under well-lit rooms, commerce, enterprises or even people at home can extend working hours or set new activities for earning their living after sunset. Additionally, the use of computers and telephones can boost non-agrarian activities by increasing efficiency and linking markets (Cabraal et al., 2005; Karekezi et al., 2012; Practical Action, 2012).

In summary, access to modern and affordable energy services in agrarian and non-agrarian economic activities can contribute to better working conditions, services and products with enhanced quality and market value, which can increase economic dynamics and foster economic growth in rural areas (Cabraal et al., 2005; Karekezi et al., 2012; Practical Action, 2010).

2.3 Possible neutral and negative effects of energy access

Although the mainstream in the literature highlights potential benefits of energy access, there are a few studies that have found that access to modern energies can lead to neutral and negative effects on rural communities and poor families (e.g. Aklin et al., 2017; Bensch et al., 2011; Clancy et al., 2003; Salmon and Tanguy, 2016; Squires, 2015). This section explores such studies, in which one can note that the potential benefits of energy access presented in section 2.2 may not always realise.

Squires (2015) found that access to electricity decreased educational attainment of children in rural Honduras because the advent of electricity increased employment opportunities for children and adults, especially in farming, changing the dynamics of households and leading children to drop out of school.

Bensch et al. (2011) investigated the impacts of electricity in rural households in Rwanda across four socioeconomic indicators: (i) hours of lighting, (ii) the time that children dedicate studying at home, (iii) energy expenditures and (iv) income generation. The authors found that electricity caused positive effects mainly on lighting usage. For the time that children spend studying at home and for energy expenditures, small to non-significant positive effects were found. The study also noted that electricity is rarely used at home to generate income in the region analysed.

Aklin et al. (2017) assessed the socioeconomic effects of off-grid solar energy on rural households in India and found no evidence that electricity has contributed to socioeconomic development such as increasing savings, income generation, women empowerment or study hours at home. According to the authors, one possible explanation for the lack of positive results can be attributed to the limited and low-quality energy provided for the families (lighting and mobile charging in partial time), which do not enable the families to take more advantage of energy to generate socioeconomic benefits.

A study conducted by Salmon and Tanguy (2016) investigated the effects of electricity on labour supply decisions of monogamous spouses in rural Nigeria. The authors found that electricity tends to enhance people's capability to participate in the labour market and has contributed to increase the time that husbands and wives devote to work. However, contradicting the expectations that electricity brings positive effects on women, especially regarding time availability, the authors found that electricity brought positive effects on husbands' working time in detriment of the wives' working time. The authors pointed that one reason for that is because the labour supply decisions among the spouse are dependent and influence each other. For example, when the husband decides to increase his working time after electrification, the wife needs to assume work activities previously carried out by the husband. One additional reason is because of the low quality of electricity in rural Nigeria, which does not allow female to reduce working time with domestic chores through the use of electric appliances. In this specific study, one might suggest that electricity contributed to increasing gender inequality.

Another study from a gender perspective can be found in Clancy et al. (2003). In this study, the authors present and discuss examples from the literature in which the arrival of electricity in rural communities has primarily benefited men because they often take the decisions at home, in particular regarding finance. In many of these cases, men have given priority to buying entertainment appliances (e.g. radio and television) or equipment that reduce their working time (e.g. electric pump for irrigation) instead of buying equipment that would improve domestic chores, which frequently are assumed as women's tasks.

Recently (2018-19), an applied-research project led by a research team from the Arizona State University and the Karlsruhe Institute of Technology (ITAS, 2018)[1] found out that social conflicts[2] inside and between communities have reduced the benefits of energy access in rural communities in Bolivia. In the Bolivian Amazon, for example, an off-grid solar energy system was installed in a community to refrigerate fish, aiming to increase food security and

[1] The author of this dissertation took part in the referred project.

[2] The term conflict is used here in a more general sense and does not mean or include violent or armed conflicts.

family income. The system was expected to benefit 12 families and would be primarily managed by women. However, circa two years after implementation, the system was benefiting five families, which have excluded the other seven as beneficiaries of the system due to internal conflicts inside the community. In another example, a micro-grid based on hydroelectricity was installed in an Andean rural community in Bolivia using external funding. The hydropower plant has enough power capacity to provide electricity for the local community and the neighbouring community that has no electricity access at all. However, due to the lack of trust between the communities and historical conflicts, neither the community in which the micro-grid was installed nor the community without electricity are willing to connect the latter to the micro-grid.

Finally, it is worth noting that the studies presented in this section do not argue in favour of stopping programmes to eradicate energy poverty, but they highlight that access to modern energy services can bring different results than those normally expected, which should be considered in energy planning.

2.4 Different views on energy poverty

Energy poverty is a broad concept that generally refers to the lack of access to adequate energy services. Its applicability can be found in different contexts across developed and developing countries and rural and urban areas. Often, it is inside these different contexts that scholars sharpen the concept of energy poverty and set its scope, which can vary significantly one from the other. In this section, three different scopes of energy poverty are presented. The first and the second refer to energy supply to meet basic energy needs at the household level in developed and developing countries, respectively. The third scope addresses primarily the rural areas of developing countries and considers energy supply to overcome deprivations at the household level and beyond it.

Although the focus of this research is on the rural areas of developing countries, this section extends the vision and explores how energy poverty has been tackled in developed countries. This is important because approaches adopted in developed countries are often used as reference for developing countries, which can result in inaccurate approaches because the realities of developed and developing countries diverge in many aspects, such as necessities, cultures, economies and politics.

2.4.1 Energy poverty at the household level in developed countries

In the last years, the number of scholars referring to energy poverty in developed countries has increased, in particular in Europe (e.g. Bouzarovski, 2014; Bouzarovski et al., 2012; Buzar, 2007; CEB, 2019; Chester and Morris, 2011; EPOV, 2020a; European Commission, 2019, 2010; European Parliament, 2017; Pye and Dobbins, 2015; Schuessler, 2014; Ürge-Vorsatz et al., 2012). In such contexts, energy poverty is considered as domestic energy deprivations and, despite the existence of particularities, they normally share issues related to the affordability and vulnerability of energy services, energy prices, energy efficiency, energy justice, household income and public health.

In fact, current approaches to energy poverty in developed countries derive from or are strongly influenced by the concept of fuel poverty proposed by Boardman (1991), which has a wide tradition in the United Kingdom and the Republic of Ireland (Bouzarovski, 2014). The initial approach to fuel poverty focused on the capability of households to afford adequate energy services for space heating and on the implications that fuel poverty has on public health, especially in the winter (Boardman, 1991; Li et al., 2014; Moore, 2012). As a threshold to define a fuel poverty line, Boardman (1991) suggested that costs of energy services should not exceed 10% of the total household income.

Since the work of Boardman (1991), the scope of fuel/energy poverty in developed countries has evolved and currently it contemplates the affordability of domestic energy services in general and safeguard energy supply (Boardman, 2010; Hills, 2011; Moore, 2012), being no longer focused only on space heating in winter but also on cooling in summer (EPOV, 2020b). The fuel/energy poverty line is still based on a certain amount of family income expended to meet desirable energy needs, while methods to measure it and to set a threshold line vary between scholars (e.g. Boardman, 2010; Chester and Morris, 2011; Hills, 2011; Schuessler, 2014). The definition of energy poverty presented by Grevisse and Brynart (2011) may perhaps synthesize and capture general aspects of the current view on the issue in developed countries:

> "Energy poverty is the impossibility (or the difficulty) for a household to gain access to the energy it needs to ensure dignified living conditions at an affordable price from the point of view of its income. In the restrictive context of heating, this means the impossibility of heating its home to an adequate level and at an affordable cost." (Grevisse and Brynart, 2011).

Finally, it is worth noting that the transition to low-carbon energy systems in European countries is drawing the attention of the European community to energy poverty, aiming to ensure that such an energy transition leaves no one behind (European Commission, 2019). Recently (2018), the European Commission has created the Energy Poverty Observatory (EPOV) as an effort to help the Member States on combating energy poverty (EPOV, 2020a).

2.4.2 Energy poverty at the household level in developing countries

Affordability of modern energy services also represents a central aspect of energy poverty in developing countries. Nonetheless, the mainstream refers to accessibility of modern and affordable energy services, since most of the global population lacking electricity and clean means of cooking live in developing countries (IEA et al., 2020). Thus, energy poverty in these nations is often tackled in the literature as the lack of access to modern energy services at the household level to sustain a decent life, though such a life is subjective (e.g. Barnes et al., 2011; Bhide and Monroy, 2011; Foster et al., 2000; Harmelink et al., 2018; IEA, 2019a, 2010; Khandker et al., 2012; Mirza and Szirmai, 2010; Nussbaumer et al., 2012; Pachauri et al., 2004; Pereira et al., 2011). Some of these studies recognize the importance of including deprivations from additional levels under the umbrella of energy poverty, as the lack of power for economic production and to improve community services (e.g. IEA, 2019a, 2010; Nussbaumer et al., 2012; Pachauri et al., 2004). However, due to different constraints, as the lack of reliable data and methods of quantification, most scholars are still considering energy poverty only at the household level.

At the domestic level, efforts have been made to estimate the amount of energy necessary for a person or family to satisfy basic human needs (e.g. Goldemberg et al., 1985; Krugmann and Goldemberg, 1983; Pachauri et al., 2004). Nonetheless, subjects as decent/normal life, minimum life standards and the satisfaction of basic human needs are arbitrary and sensitive, as they may vary according to culture, climate, region, age, gender and context. Thus, a frequent challenge on such estimations is how to define which kind of energy services are needed to overcome energy poverty as well as how to measure and monitor this poverty (Barnes et al., 2011; Day et al., 2016; Pachauri et al., 2004).

In that way, scholars often consider particularities of target groups and include in their analyses domestic energy services to meet adequate cooking facilities, lighting, refrigeration, communication and entertainment as basic human needs. Thus, one can say that there is a common understanding that energy poverty in developing countries is a two-dimensional problem, involving heating and lighting or cookstoves and electricity at home (Sovacool, 2014). Also, it is worth highlighting the multi-tiers approach for measuring household access to electricity and clean cooking (ESMAP, 2015), well known in the literature. Through multi-tiers, the availability, capacity, reliability, quality, affordability and additional parameters of energy services and technologies can be measured to determine different levels and potential benefits of energy access at home (Harmelink et al., 2018).

Finally, it should be noted that progress to achieve the SDG7 is measured using the definition of energy access provided by the International Energy Agency (IEA), as:

> “a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average” (IEA, 2020d).

In that sense, if a household has the minimal access to electricity to supply lighting, charge a phone and plug a radio or television and has access to clean cooking facilities, such a household is considered out of the crowd of those without access to modern energy services.

2.4.3 Energy poverty beyond the household level

A limited number of scholars have considered energy poverty beyond domestic energy deprivations, including deprivations at the community and economic levels (e.g. IEA, 2012; Practical Action, 2012, 2010; Reddy et al., 2000; Sovacool, 2014; Sovacool et al., 2012). Although these scholars in general focus on the rural areas of developing countries, their approaches can also be applied in other contexts such as urban areas in developed countries.

Reddy et al. (2000) conceptualized energy poverty as:

> "…the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development." (Reddy et al., 2000).

The concept above captures important aspects that when not satisfied can contribute to underdevelopment and to increase poverty. González-Eguino (2015) further explored the concept presented by Reddy et al. (2000). The author addressed the absence of sufficient choice, which goes back to the work of Sen (1999) and addresses the incapability of individuals to choose options they may value and that may increase their capabilities to live a desired life. For instance, lack of motive power on farming limits people's lives and freedom of choice, because farmers have to choose between not doing a certain activity or doing it using human or animal force, which can affect other functionalities, as being healthy.

González-Eguino (2015) also highlighted in the concept provided by Reddy et al. (2000) the importance of energy services rather than consumption, because services are what people demand from energy, such as light, comfortable rooms and mobility (cf. Lovins, 1977). Further aspects stressed by González-Eguino (2015) refer to important features that energy technologies/services should meet. For instance, people should have conditions to pay electricity bills (affordability), have uninterrupted electricity access (reliability), be able to use electricity to realize daily activities (high-quality), and in a safe environment (e.g. substituting candles that increase the risk of fire with electric bulbs). Additionally, technologies should be adequate for different realities, respecting local aspects such as local culture. Besides all these issues, energy services should be environmentally benign and be used to support economic and human development. Nevertheless, economic and human development does not mean equal development, as many countries with rich energy and natural resources are very poor and unequal in relation to social, economic and political aspects (González-Eguino, 2015).

Practical Action (2010) introduced the concept of Total Energy Access, which indicates minimum standards of energy services that people should have to enjoy a decent life and generate income. Sovacool et al. (2012) and Sovacool (2014) argued that cooking and lighting represent only two faces of a big picture of energy deprivations. People living in rural areas often lack motive power for economic production and adequate mobility. Thus, according to the authors, these energy deprivations should also be included under the scope of energy poverty. As motive power was already discussed in sub-section 2.2.3, the lack of mobility is here explored. Poor people often rely on non-motorized transport means (e.g. walking, bicycle and animal) and often do not have access to adequate infrastructure, fuel and transport options. Low mobility affects mainly women, reduces income generation and opportunities and increases isolation of communities in many aspects (e.g. social, economic, educational and public assistance). Furthermore, poor people often spend a considerable part of their limited income to meet mobility needs. Thus, the lack of access to modern and affordable energy to improve mobility and the lack of a better infrastructure are also deprivations that contribute to underdevelopment and to increase poverty in rural communities (Sovacool et al., 2012).

In summary, one can argue that energy poverty in the rural areas of developing countries is a matter that affects much more than household energy deprivations and should include energy deprivations at the community and economic levels at least (cf. discussed in sub-sections 2.2.2 and 2.2.3).

2.5 The energy-poverty nexus

Although not so widely used as the term energy poverty, the literature also presents studies referring to the energy-poverty nexus (e.g. Ali and Megento, 2017; Biswas, 2020; Bouzarovski, 2017, 2013; Casillas and Kammen, 2010; Clancy et al., 2003; Goozee, 2017; Karakara, 2018; Miller et al., 2018; Nussbaumer, 2012; Sattler, 2016; UNDP, 2012). There is no common understanding on the energy-poverty nexus but, in general, one can say that studies dealt with it as another way to discuss energy poverty and the interrelationships between energy and poverty. That way, the energy-poverty nexus can be found in the literature across different contexts, from developed to developing countries and from rural to urban areas, as energy poverty.

Some scholars use the term energy-poverty nexus interchangeably with energy poverty (that has also no common definition in the literature, as presented in the previous section) and discuss potential benefits of overcoming energy poverty, as those potential benefits presented in section 2.2, in particular at the household level. In that sense, studies on the energy-poverty nexus refer to the lack of access to electricity and clean means of cooking in developing countries and trace links with poverty (e.g. Ali and Megento, 2017; Karakara, 2018) and also climate change. Some studies that include climate change refer to the energy-poverty-climate nexus (e.g. Casillas and Kammen, 2010; Sattler, 2016). Other studies use the energy-poverty nexus as a way to discuss energy poverty and energy justice in developed countries, in particular in the European context (e.g. Bouzarovski, 2017, 2013).

There are also other scholars that when discussing the energy-poverty nexus seek to establish deep interrelationships between energy and poverty, discussing as well gender equality, climate change, health, welfare and development (e.g. Biswas, 2020; Clancy et al., 2003; Goozee, 2017; Miller et al., 2018; Nussbaumer, 2012; UNDP, 2012).

Since the energy-poverty nexus is at the core of this study to analyse the conditions in which modern and renewable energies, in the forms of decentralized energy systems and clean means of cooking, can contribute to reduce poverty in the rural areas of the Brazilian State of Ceará, this study conceptualizes the energy-poverty nexus as the systematic and dynamic interrelationships between energy and the societal and institutional causes of poverty. In that sense, the energy-poverty nexus encompasses the eradication of energy poverty and goes beyond it by systematically analysing energy access and use and the reasons for poverty aiming to overcome barriers and create opportunities for poor people to increase their capabilities to use energy services to overcome poverty. This concept is used throughout this study using rural Ceará as case study and is not limited to the household level.

In comparison to the different views on energy poverty (section 2.4), the concept of the energy-poverty nexus presented above aims to contribute to overcoming the limited view frequently used in science and in the energy access sector that the access to modern energy services will result on positive impacts on poor people. This is expected because the energy-poverty nexus should provide a comprehensive and multifaceted picture of energy access and use and the causes of poverty. This matter is discussed in detail in the next chapters of this dissertation through the case study of the energy-poverty nexus in rural Ceará.

2.6 Outlook on energy access at the global level

This section provides an outlook on the energy access sector considering current approaches, trends and future projections to advance progress on access to electricity and clean means of cooking at the global level. To increase access to electricity, current approaches have focused on the use of decentralized energy systems (off-grid solutions) or a mix of centralized and decentralized electricity supply in case that small power generators can be connected to the grid[3]. To increase access to clean cooking, approaches have mainly focused on fuel

[3] There is no consensus in the literature on what should be the up limit of power capacity to be considered as distributed generation or decentralized electricity supply. In Brazil, if a generator or a power plant is connected to the distribution grid, this kind of power supply is considered as distributed generation (cf. Presidência da República, 2004). But in Brazil there is an up limit of power capacity to *micro* (≤ 0.075 MW) and *mini* (0.075 ≤ 5 MW) distribution generation (ANEEL, 2015), discussed in detail in chapter four, sub-section 4.4.10.

substitution and improved biomass cookstoves. Projections on energy access indicate that under current trends, SDG7 is not expected to be achieved by 2030. To universalize access to modern energy services, especially clean cooking, additional efforts are needed.

2.6.1 Approaches and trends to promote energy access

Most of the progress achieved in the past to advance electricity access in rural areas followed a traditional on-grid approach on rural electrification, by extending transmission and distribution electricity grids and generating electricity in a centralized way (Foley, 1992). The preference for this approach lies primarily in cost-benefit since a large number of consumers can be electrified and the electricity is produced by large power plants, transmitted and distributed via interconnected grids to the end consumers, which frequently live close to each other.

In the last years, however, strategies focusing on decentralized electricity supply, in which the electricity is generated close to the consumption and using small generators, or combining centralized and decentralized electric systems have gained increased space to accelerate progress in the energy access sector (IEA et al., 2020; Practical Action, 2019).

For communities located in remote or isolated areas with a dispersed population, the adoption of decentralized electricity supply using off-grid solutions (e.g. mini-grids and standalone electricity systems not connected to the grid) frequently based on renewable energies (e.g. wind and solar) can prove the best cost-benefit because the extension of the grid, in several of these cases, can be unfeasible in economic and physical terms (Practical Action, 2019; Zerriffi, 2011).

For communities in which the extension of the grid is feasible, the integration of centralized and decentralized electricity generation is interesting in the sense that the latter can (i) improve the reliability and voltage level of the grid and the whole system; (ii) be produced by local consumers (so-called prosumers); (iii) contribute to postpone investments in large electrical infrastructure (e.g. large power plants and transmission grids) since the electricity is produced and consumed locally; (iv) contribute to diversify the electricity mix and (v) have less environmental impact than centralized generation. However, one should note that the complexity to operate an integrated system combining centralized and decentralized generation increases considerably in case many small generators are connected into the grid (ANEEL, 2016).

Using the approaches described above, access to electricity has reached about 90% of the global population in 2019. Nevertheless, under current trends, the gap of 10% is not expected to be closed by 2030 (detail in the next sub-section 2.6.2). Currently, the high deficits in terms of electricity access are concentrated in Sub-Saharan Africa, followed by Central and Southern Asia (IEA et al., 2020).

In terms of access to clean means of cooking, the high deficits are located in Sub-Saharan Africa and Central, Southern, Eastern and South-eastern Asia. Efforts in the last years to increase access to clean cooking took place at a slow tempo around the world. In Sub-Saharan Africa, the number of people without access to clean cooking has even increased from 750 million in 2010 to 890 million in 2018 due to stagnated efforts to increase access to clean means of cooking combined with population growth. If current trends remain, about 30% of the world population will rely on unhealthy means of cooking by 2030 (IEA et al., 2020) (detail in the next sub-section 2.6.2).

Currently, approaches to increase access to clean cooking have focused on fuel switching from biomass to LPG, natural gas, biogas, electricity and solar and on the adoption of improved biomass cookstoves. One should note that improved biomass cookstoves are used in the energy access sector as a strategy to reduce high indoor pollution and increase efficiency (cf. IEA et al., 2020) but they are frequently not considered as a clean means of cooking (cf. IEA, 2019a). In this dissertation, however, improved cookstoves based on biomass are considered clean means of cooking and unprocessed biomass (e.g. firewood and agricultural and forestry residues) is considered a modern fuel source under determined conditions, which are presented in detail in the next sub-section 2.7.1.

Finally, it is worth noting that the first estimations conducted by IEA (2020c) point out that the current COVID-19 crisis is expected to set back efforts to universalize access to modern energies worldwide and the number of people without energy access can increase, in particular in Sub-Saharan Africa. The extension of the damage to the energy access sector remains to be seen since the health crisis is still ongoing, which seems to anticipate a global economic recession.

2.6.2 Future views on energy access

Future views expressed in form of energy scenarios represent important orienting means for society aiming to explore possibilities to achieve a determined goal or avoid something happening in the future. For that, scenario techniques are used to analyse a situation and describe in a robust and scientific way how this situation may unfold in the future. Based on these scientific, yet imperfect, views of the future, stakeholders can design policies to give priority to a desired future view instead of an undesired one (Dieckhoff et al., 2011; Kosow and Gaßner, 2008).

In the energy access sector, scenarios are often built using model-based approaches and are used to explore future views or to design pathways to reach universal energy access worldwide or in a specific region (e.g. Bazilian et al., 2012; Gómez, 2014; IEA, 2019b, 2017; Ouedraogo, 2017; Welsch et al., 2013). In the following, two of the most recent scenarios (2020) on energy access developed by the IEA are reviewed, which already consider the first impact estimations of the COVID-19 crisis on energy access. The preference for reviewing the IEA scenarios in this research is given because these scenarios are often used as reference in the energy access sector.

The first scenario, Stated Policies Scenario, can be understood as a predictive scenario (cf. Börjeson et al., 2006) in the sense that it seeks to explore what can happen in the future considering current policies and announced policies intentions. The Stated Policies Scenario signalizes stakeholders the direction that today's policy ambitions can lead the energy sector achieving universal energy access at the global level. The second scenario, Sustainable Development Scenario, is a normative scenario (cf. Börjeson et al., 2006) that sets the achievement of SDG7 by 2030 as a target and explores what needs to be done to reach that goal. Both scenarios derive from the simulation model World Energy Model, which has been developed over the last 20 years by the IEA and intends to replicate how energy markets function (IEA, 2019b). In addition, both scenarios consider energy access as the domestic access to electricity and clean means of cooking, following the IEA definition of energy access presented in sub-section 2.4.2. That means that energy access at additional levels, such as the community and economic levels, is not in focus of the analyses.

According to the Stated Policies Scenario, under present and announced policies, 660 million people are expected to lack electricity access by 2030, living primarily in sub-Saharan Africa. In the clean cooking sector, the scenario demonstrates that current and expected policies are inefficient to significantly change the current trend, since from the present 2.6 billion people without access to clean means of cooking, 2.4 billion are expected to be in the same situation in 2030, living primarily in Developing Asia, Africa and India (IEA, 2020c).

In the Sustainable Development Scenario, universal access to electricity is to be achieved using mainly decentralized solutions (e.g. standalone energy systems and mini-grids as presented in sub-section 2.6.1) because most of the people lacking electricity live in rural and remote areas. To achieve the target of leaving no one behind, the current electrification rate per year needs to increase threefold (IEA et al., 2020). For that, current and announced investments in electricity access need also to increase three times and reach USD 35 billion per year (IEA, 2020c). In the clean cooking sector, universal access should be achieved mainly by fuel switching to LPG and natural gas and by the adoption of improved biomass cookstoves, which are assumed to reach adequate emissions performance by 2030 (cf. IEA, 2019a). To reach universal access, the annual rate of people that gain access to clean cooking has to increase from 0.8% (average from 2010 to 2018) to more than 3%. For that, current and announced investments need to increase five times and reach about USD 5 billion per year (IEA, 2020c). Also, it is worth noting that the cost per person to gain access to clean cooking is relatively low, estimated at USD 20 (IEA, 2017).

2.7 Reflections on the state of the art of energy access

When observing the deprivations caused or maximized by the lack of energy access and the potential benefits of modern energy services on reducing such deprivations, as explored in section 2.2, it becomes easier to understand why energy poverty is something morally unacceptable in the 21st century and why its eradication must be pursued. However, the eradication of energy poverty may not always lead to desired results, as discussed in section 2.3.

This section provides some reflections on the state of the art discussed in the previous sections. It covers a discussion about the acceptance of unprocessed biomass as modern cooking fuel (sub-section 2.7.1), possible desired and undesired consequences of energy access (sub-section 2.7.2) and the importance of the context when expanding energy access in rural areas (sub-section 2.7.3).

2.7.1 Unprocessed biomass as modern fuel

The acceptance of unprocessed biomass as a modern cooking fuel is frequently neglected by science and decision-makers, who often see it as an unsustainable and underdeveloped fuel that should be replaced by commercial ones (Openshaw, 2010). Examples of the non-acceptance of biomass as a modern fuel can be found in Bermann (2003), Harmelink et al. (2018), IAEA (2005) and IEA (2019a). In fact, the unsustainable, unsafe and inefficient use of biomass leads to health, social, environmental and economic risks (Birol, 2007).

There are two main arguments used in the literature to advocate fuel switching from biomass to commercial fuels to achieve clean cooking. The first argument refers to high indoor air pollution and the second to the time and human efforts (opportunity and physical costs) used to gather biomass. Both arguments can be understood as problems that predominantly affect women and children, as they are often at home and in charge of biomass collection (Clancy et al., 2003; Holdren et al., 2000; Karekezi et al., 2012).

The first argument constitutes a technical problem that can be minimized by the adoption of improved cookstoves based on biomass and well-ventilated kitchens, which significantly reduce indoor air pollution. If the burning process of biomass is adequate in terms of temperature and ventilation, the main emission is CO_2 that can be expelled outside the house if the stove works with a closed combustion chamber with chimney (Openshaw, 2010). In addition, improved biomass cookstoves are about 40% to 50% more efficient than traditional cookstoves or open-fire stoves, contributing in this way to reduce emissions and biomass consumption (Barnes and Samad, 2018).

The second argument (i.e. time expended and physical efforts to collect biomass) can be minimized if biomass is managed in a sustainable way and transported from the field to the houses using better transport means like tractors, carts (pulled by horses or oxen) or handcarts. If the harvest of biomass is not higher than its replacement in forest patches near households, its accessibility is enhanced and the time used for biomass collection can be significantly reduced. Additionally, improved cookstoves may help reducing pressure over natural systems as they consume less biomass (Barnes and Samad, 2018; Openshaw, 2010). Sustainable management of biomass also contributes to climate regulation, carbon sequestration, agriculture productivity and income generation (Faggin et al., 2017). Finally, one should note that biomass is a fuel that often belongs to the culture of rural communities.

Therefore, this study understands that unprocessed biomass represents a modern fuel under the conditions presented above; i.e. by using improved biomass cookstoves combined with well-ventilated kitchens and by adopting sustainable forest management practices and adequate transport of biomass. Nevertheless, it should be recognized that achieving these conditions can be extremely challenging for poor people in rural areas.

The use of biomass as a modern fuel under adequate management conditions can represent an important strategy to improve energy democracy and security in rural communities, since it is a fuel that can be fully managed (i.e. production, extraction and consumption) by the local families. Nevertheless, strategies that focus exclusively on fuel switching seem to disregard such potential use of biomass as a modern fuel.

The vision focusing on fuel switching seems to entail an idea that rural communities in developing countries need to follow the “development steps” adopted by developed countries (i.e. to use commercial fuels). This points to a paradox in the sense that if poor families need to switch from biomass to commercial fuels, perhaps also non-poor families should abdicate burning firewood in cosy fireplaces in the winter. Therefore, a narrow vision based exclusively on fuel switching does not seem to contribute to achieving clean cooking facilities for more than 2.6 billion people around the world, when the main problem of inadequate means of cooking resides in unsustainable, unsafe, unhealthy and inefficient use of biomass.

That way, meeting clean means of cooking worldwide seems to require an integrative approach that considers sociocultural, economic and environmental aspects of rural communities (i.e. the context in which communities exist). Such approach would focus on fuel switching and on sustainable management and adequate transport of biomass combined with improved biomass stoves and kitchens properly ventilated.

2.7.2 (Un)desired consequences of accessing modern energy services

In the literature, access to modern energies in the forms of electricity and clean cooking facilities is recognized as a means that can lead to positive socioeconomic results and contributes to mitigate climate change. Consequently, there is a general expectation that once poor people have access to modern energies, they will be able to take advantage of energy services to gradually move out of poverty through the many benefits presented in section 2.2.

One example of the above mentioned expectation can be found on the Special Report on Energy Access provided by IEA (2017). The report presents the scenarios that precede the ones from IEA (2020c) (discussed in sub-section 2.6.2) but the level of detail is richer in IEA (2017) than in IEA (2020c). All impacts of accessing energy access presented in IEA (2017) are described as positive impacts and refer to those already mentioned in section 2.2. Thus, once reading the report, the reader can have an optimistic perspective that the achievement of SGD7 will result in gains in many forms (e.g. health, well-being, environment and economic) and will not generate disadvantages for the families who benefited from energy access. In that sense, the report seems to idealize a kind of “happy end” for poor families with the arrival of modern energy services. Even the title of the study, *Energy Access Outlook 2017: From Poverty to Prosperity*, may suggest a kind of “straight road” towards poverty reduction and prosperity through energy access. In the real world, however, the construction of the pathway from poverty to prosperity seems to be much more complex than the provision of modern and affordable energy access for poor people.

Providing access to modern energies, although urgent and necessary, does not imply that the potential benefits discussed in section 2.2 will take place. If energy was a synonym of prosperity for all the people, poverty would not be a reality in many slums and poor communities that already enjoy access to electricity around the world.

The understanding that the energy access can have positive, neutral and negative impacts on the life of poor people suggests that additional factors are relevant to determine the resulting consequences of getting energy access (see next sub-section). Moreover, such understanding can suggest that if energy can be a driver of negative impacts on a given social group, another group can profit from the same impacts. For example, in the study conducted by Squires (2015) (presented in section 2.3), while electricity access contributed to generate negative impacts on the educational level of poor children, it is possible that the employers of those children took advantage of it because electricity allowed them to expand their businesses. In addition, one may say that the overall context in rural Honduras (e.g. sociocultural, economic and political conditions) allowed employers to hire a cheaper labour force. If the families of the children that dropped out of school after electrification had adequate opportunities and conditions to earn a living, one can imagine that the children would not have to work to help their parents because of the financial situation of the households. Thus, it is possible that for the children and their parents, an employment opportunity in the agrarian sector fostered by electricity access was one of the “best” and immediate option among those options available to earn a living. In this example, through additional research, it would not be a surprise to come out with the conclusion that electricity contributed to increasing poverty and inequalities in the rural areas studied by Squires (2015).

Similar cases as the one presented above are analysed in detail in the further chapters of this study, especially in chapters four and five. For now, such reflections may suggest that energy planning and scenarios focusing on the normative goal of eradicating energy poverty can be wrong in overestimating that energy access will bring solely benefits to rural communities, since it can also lead to undesirable results as discussed in this sub-section and in section 2.3. This naive expectation based on energy benefits, or the intentionally indisposition to consider possible neutral and negative impacts of energy access on poor rural communities, is similar to believing that fire only produces heat for cooking, disregarding the possibility that it can also destroy a house if not properly managed.

2.7.3 The context in which modern energies are provided

The discussion presented above raises an important question in the energy access sector: what makes that some people are able to take advantage of energy to leverage the benefits presented in section 2.2 and others are not able to do the same? The studies presented in section 2.3 provide some indication to answer this question, that can be related to the context (e.g. socio-political, cultural, economic and environment) in which people live. This context will determine the conditions and the range of opportunities available for people to benefit or not from energy services to reduce poverty. Since the context in which energy is provided is of great importance in this study, this matter is discussed in detail in the next chapters of this dissertation.

The reflections presented in this section start to shed some light to understand why the end of energy poverty by itself does not mean that poor people will have adequate conditions to take advantage of energy to move out of poverty. Access to energy is a mechanism that can facilitate the achievement of determined goals, but it does not imply that benefits will occur (although they are expected). To maximize benefits and reduce the risk of negative impacts on people’s life, the context in which people live and communities exist should be considered when planning energy access in rural areas. Some authors discussed in this chapter already noted the importance of considering the context once providing energy access (e.g. Clancy et al., 2003; Goozee, 2017; Miller et al., 2018).

Finally, it is worth highlighting that the reflections exposed in this section are often ignored by energy planning and scenarios, which frequently assume that the access to energy will be translated into benefits for poor families without considering the overall context involving these families and communities.

2.8 Closing remarks

This chapter presented the state of the art on energy access focusing on the rural areas of developing countries. It included a review on deprivations caused by the lack of access to energy services and potential benefits of accessing energy at the domestic, community and economic level (section 2.2); potential neutral and negative impacts of energy access on rural communities (section 2.3); different views on energy poverty and the energy-poverty nexus (sections 2.4 and 2.5); and current approaches, trends and projections on the energy access sector at the global level (section 2.6).

This chapter also presented some reflection on the state of the art of energy access (section 2.7), in which one can argue that the current literature on energy access lacks reflections on and approaches that deal with the context and dynamics of rural areas in relation to energy and poverty. This contributes to the idealization of positive impacts of energy access on rural communities, which may not always occur. Thus, one can argue that current approaches explored in the energy access sector are not enough to maximize energy as a mechanism for the reduction of poverty in the rural areas of developing countries.

Instead, a much deeper and systematic approach is needed that considers the context and the dynamics of rural areas in relation to energy and poverty. This can be achieved by analysing the energy-poverty nexus, conceptualized for this study in section 2.5 as the systematic and dynamic interrelationships between energy and the societal and institutional causes of poverty. In such an approach, the eradication of energy poverty is seen as essential to eradicate poverty but not enough for that. In other words, solving the problem of energy poverty is an important piece to solve a more complex puzzle related to the energy-poverty nexus.

Chapter three

The Integrative Approach to the Energy-Poverty Nexus – Methodological Outline

3.1 Introduction

Understanding energy as a mechanism to reduce poverty raises concerns that transcend a narrow view on the eradication of energy poverty and requires an approach that integrates energy and poverty as a complex and multifaceted system. In such an approach, the context in which people live and communities exist is of high importance to analyse the conditions in which modern energies can contribute to help people moving out of poverty.

This chapter presents the methodology used in this study by introducing the Integrative Approach to the Energy-Poverty Nexus, which was developed and partially applied in this research in the case of rural Ceará. The approach focuses primarily on the rural areas of developing countries. However, its applicability may also be useful for the urban context and developed countries. A critical reflection on the Integrative Approach applied in this study is provided in chapter six, section 6.4.

In simple words, the Integrative Approach to the Energy-Poverty Nexus seeks to analyse in a participatory and systematic way the multifaceted context of energy and poverty in a community, region or country, design visions, take action, evaluate results and celebrate the outcomes achieved. The main functions of the approach are to create future and systematic views related to energy and poverty, identify conditions and design strategies that enable society to change pathways in the future (if desired) and evaluate how the energy-poverty nexus may unfold under the adoption of the strategies designed. The approach can be executed in six main steps that work as a loop (detail in section 3.2).

For the specific context of this study, the Integrative Approach to the Energy-Poverty Nexus is essential to answer the research question aiming to analyse the conditions in which modern and renewable energies, in the forms of decentralized electricity supply and clean means of cooking, can contribute to reduce poverty in the long term in rural Ceará.

The Integrative Approach is based on methods that allow for the analysis of socio-energy systems in a participatory and systematic way (e.g. Chambers, 2007; Haraldsson, 2004). In that sense, the approach requires the participation of stakeholders to contextualize, problematize, systematize and analyse the energy-poverty nexus considering multidimensional factors.

In this study, the words stakeholders and actors are used interchangeably. If not otherwise stated, in the following the words stakeholders and actors refer to anyone who is interested or engaged in a determined topic; in this particular case, the energy-poverty nexus (e.g. community members and leaderships, non-governmental organizations (NGOs), policy- and decision-makers, the scientific community and civil society).

In the following, at first the Integrative Approach to the Energy-Poverty Nexus is presented in detail, including some suggested methods that can be used to perform the Integrative Approach (section 3.2). Section 3.3 reflects about uncertainties inherent to the system to be composed by the Integrative Approach. Then, in section 3.4, the Integrative Approach is applied to the hypothetical case of a rural community, focusing on cooking means. Finally, section 3.5 offers some closing remarks.

3.2 Steps of the Integrative Approach to the Energy-Poverty Nexus

The Integrative Approach to the Energy-Poverty Nexus is designed to be conducted together with local actors and benefits from participatory and system thinking methods. Participatory methods, if reflected as instruments for development, can (i) promote cooperation among different actors with different opinions and perspectives about a common issue, challenge or problem, (ii) increase efficiency, effectiveness and transparency of development programmes, strategies and actions by involving different actors in decision-making processes, (iii) give voice to marginalized social groups and (iv) empower people with confidence, new knowledge and capabilities through the exchange of knowledge and ideas (Chambers, 2007; Clayton et al., 1997; WFP, 2001).

System thinking can be used for the systematization and analysis of a given problem and considers three important aspects. First, it addresses elements that compose a system in relation to a problem. Second, it addresses interrelationships among system elements. And third, it enables to understand the behaviour of the system in response to a change in one element (Haraldsson, 2004).

Thus, the combination of participatory and system thinking methods provides a valuable approach to contextualize, problematize, systematize and analyse the energy-poverty nexus. The adoption of specific methods to be used can vary according to different realities (e.g. from the community to the national level; see detail in the steps discussed below).

The actors that will participate in the Integrative Approach are expected to vary according to the context of the study object. For instance, if the study object refers to a community, it makes sense to involve as many community members as possible, since they are the main actors of the energy-poverty nexus in their community, and some external actors, like energy and development planners, NGOs and local policymakers. When dealing with the energy-poverty nexus in a region or a country, it makes sense to involve stakeholders from the social, energy and rural development sectors, policymakers as well as communities' leaderships and NGOs that are in direct contact with local communities and know their realities quite well. The central point once deciding the actors that will participate in is to enrich participation, increase inclusivity (especially of marginalized social groups), increase transparency and ensure that all relevant elements of the energy-poverty nexus will be addressed and discussed with the actors involved.

The Integrative Approach is divided in six main steps that work as a loop, as shown in the following Figure 3.1. In summary, steps one, two and three seek to contextualize, problematize, systematize and analyse the energy-poverty nexus considering the knowledge and perceptions of actors involved in the nexus, leading to better understand the current situation and creating systematic future views of the nexus. In step four, the analysis of future views enables to better understand the conditions that need to change to lead the energy-poverty nexus from the current situation to a desired pathway of development. This will lead in step five for the design of better strategies aiming to change the conditions previously identified. Finally, the Integrative Approach allows in step six for the evaluation of the results achieved by the strategies adopted aiming to refine strategies (if necessary) to achieve better results or keep the nexus following an achieved and desired pathway. In the following, the six steps of the Integrative Approach are discussed in detail and specific methods that can be used to perform the steps are suggested.

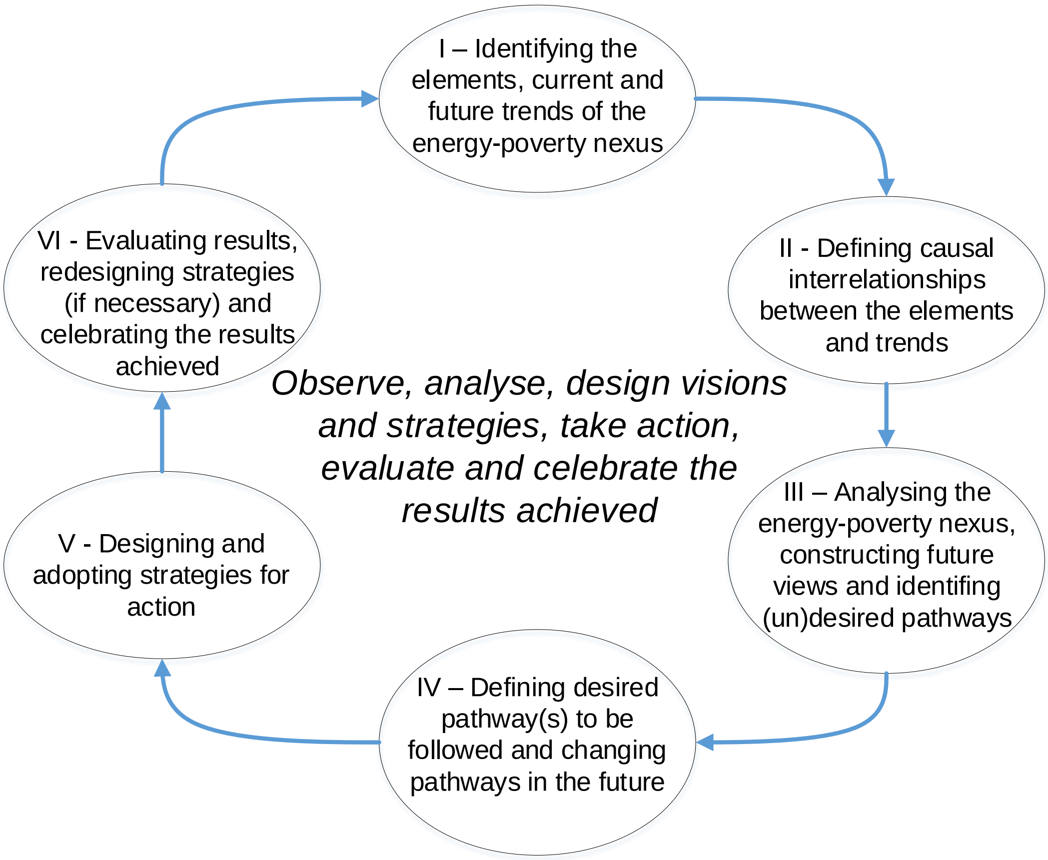


Figure 3.1: The six steps of the Integrative Approach to the Energy-Poverty Nexus

3.2.1 Step one - Identifying elements of the energy-poverty nexus and their trends

The first step of the Integrative Approach seeks to identify and characterize the elements (i.e. factors) that contextualize the energy-poverty nexus in a specific community, region or country considering the knowledge and perceptions of local actors, supplemented by literature research. These elements can be of different natures, such as socio-cultural, political, economic, environmental and technological. Also, the elements are context-specific and are expected to change according to different realities (e.g. socio-cultural and geography). For each one of the elements identified, step one seeks to identify possible future trends that explore how the elements may unfold in the future (detail below).

In this first step, two general questions for the contextualization of the energy-poverty nexus are: how is the current situation regarding access to modern energy services in the study object? How are the current situation regarding poverty, socioeconomic inequalities, living and environmental conditions and economic and social opportunities and activities in the study object? If the study object refers to a community, it is useful to gather information for the above questions not only at the local level but also regional and national. This can raise attention to external factors (e.g. national policies and climate change) that can influence the local level and are important to characterise the energy-poverty nexus in multi-dimensions.

These two general questions open space and increase reflections to answer more specific questions related to energy and poverty, such as: which multidimensional elements are important to contextualize and how do they contextualize energy and poverty in the study object? Which are the current situation of these elements? How may they unfold in the future?

By answering the questions above, the multifaceted context of energy (or the lack of energy) and poverty in a community, region or country can be identified, as well as future trends (often non-linear trends). It should be noted that additional questions may be formulated, aiming to contextualize the energy-poverty nexus as well as possible.

The first step can be accomplished by using participatory methods, such as focus group discussions, educational circles, brainstorming, round tables, community mapping and diagramming, transect walks, debates and semi-structured interviews with relevant actors (detail about these methods can be found in Chambers, 2007; Clayton et al., 1997; Freire, 1994 and WFP, 2001). The use of participatory methods are highly recommended in step one because they can provide sound qualitative data and capture local perceptions of actors regarding a given subject or study object (Clayton et al., 1997; WFP, 2001). Also, the qualitative data collected via participatory methods should be complemented by desk research.

In the case of rural Ceará, this study opted to conduct semi-structured interviews, transect walks in rural communities, one workshop and literature research to identify the system elements that compose the energy-poverty nexus in rural Ceará as well as future trends. An analytical description of these methods is provided in chapter four, section 4.2.

3.2.2 Step two - Defining causal interrelationships between the elements and trends

The second step of the Integrative Approach aims to interrelate the elements of the energy-poverty nexus in a systematic way, composing a comprehensive and multifaceted socio-energy system. Such systematization enables a better understanding of how the energy-poverty nexus works as a complex and dynamic system.

In this step, two main questions are important to be discussed with local actors. First, how do the elements identified in the first step interact with each other? This question aims at creating linkages between the elements that compose the energy-poverty nexus in the study object. Second, how do the current situation and future trends of the interrelated elements may influence each other? One can register the influences in a descriptive way or using quantitative scales for hindering to promoting, for example.

The result of step two is a systematic view of the energy-poverty nexus considering all interrelationships between the elements that compose the nexus as well as their trends. To perform step two, participatory approaches and methods as those suggested in step one can be used.

3.2.3 Step three - Analysing the energy-poverty nexus, constructing future views and identifying (un)desired pathways

The third step intends to analyse how the energy-poverty nexus as a multifaceted system may unfold in the future. For that, future views on the nexus are created considering the interrelationships identified in step two. These images of the future should be discussed and analysed together with local actors aiming to identify the pathway in which the nexus is currently unfolding as well as desired and undesired pathways in which the energy-poverty nexus may unfold in the future. Thus, another function of step three is to identify the system drivers and the main conditions that need to change to move the energy-poverty nexus from an undesired to a desired future view.

For the creation of future views and identification of main system drivers, scenario techniques that deal with complex systems in multi-dimensions can be used, like Cross-Impact Balance Analysis (CIB) (Weimer-Jehle, 2006), Intuitive Logics (Huss and Honton, 1987) and Causal Loop Diagrams (Haraldsson, 2004). This study opted to use CIB for the case of rural Ceará for two reasons: first, CIB improves transparency, traceability and objectivity on scenario construction dealing with socio-technical systems and non-linear trends (Lloyd and Schweizer, 2014; Weimer-Jehle et al., 2020, 2016). Second, the system boundaries and actors involved in this research allowed for the use of this scenario technique. An analytical description of the CIB analysis is provided in chapter five, section 5.2.

It should be noted, however, that if the study object to be analysed refers to a community and the community members should design future views, CIB may be too academic for that and not the best technique to be applied. Section 3.4 in this chapter presents one hypothetical example considering the case of one community in which future views are created only discussing with local families the influences between the future trends of the system.

3.2.4 Step four - Defining desired pathway(s) to be followed and changing pathways in the future

The step four of the Integrative Approach focuses on the main drivers and conditions identified in step three to define the desired pathway(s) to be followed and change pathways in the future (in case that the energy-poverty nexus is following an undesired pathway). That way, the main function of step four is to analyse the system seeking to better understand how easy or hard it is for society to change the conditions necessary to move the energy-poverty nexus from one pathway of development to another. Such analysis should also lay the foundation for local actors to determine which pathway(s) should be followed, since multiple desired pathways may be identified in the previous step of the Integrative Approach. In that sense, local actors can opt to define one desired pathway or opt to define multiple desired pathways which can be ordered in stages of development (e.g. pathway A should be first achieved as a prerequisite to achieve pathway B). In case the energy-poverty nexus is already following a desired pathway, step four is important to keep the nexus in the current pathway.

To perform step four, a deep understanding of the dynamics of the system is required, similar to step three. Therefore, this step suggests the use of methods that allow for the analysis of system dynamics. In this research, concepts related to the dynamics of social-ecological systems (Walker et al., 2004) were adapted and used for the case of rural Ceará because they allow for better understanding how easy or difficult it is for the system to adapt itself to a new condition without losing its main functionalities or be transformed to a new system and follow a new pathway of development (detail in chapter six). One should note, however, that step four may not require specific techniques in case of not so complex systems (one hypothetical example is provided in section 3.4).

3.2.5 Step five - Designing and adopting strategies for action

In the core of step five is the design and adoption of strategies to move the energy-poverty nexus to a desired pathway. If the nexus is already unfolding a desired pathway, strategies can be designed and adopted to strengthen the conditions to keep the nexus on track of the current pathway.

It should be noted that the definition of strategies is based on the present knowledge about the function and behaviour of the system. The present knowledge is, in turn, based on real experiences (past and present) or assumptions (due to lack of knowledge) about how the system works under determined conditions (Grunwald, 2011), as those designed in the future views created in step three. That way, strategies adopted can be redesigned to achieve better outcomes (see next step).

For the case of rural Ceará, strategies to achieve future views are suggested during the description of the future views (detail in chapter five, section 5.4). Nevertheless, it should be noted that this step (and also the next one) were not performed in this study. The execution of some strategies suggested in this study would require the participation of local actors involving the national and state government. It is worth noting, however, that some strategies suggested are already being implemented by NOGs in single communities, resulting in positive outcomes towards poverty reduction and human welfare. Details are provided in chapter five and six.

3.2.6 Step six - Evaluating results, redesigning strategies (if necessary) and celebrating the outcomes achieved

In the core of step six is the evaluation of the results achieved by the adoption of the strategies designed in step five. In that way, one can analyse whether the system conditions identified in step three have changed according to expectations.

Also, indicators and targets can be created based on the future views created in step three to monitor how far or close the energy-poverty nexus is from a desired future view. Indicators can also be constructed considering sustainable norms, rules and goals. To this end, the Integrative Concept of Sustainable Development can be useful since it presents a theoretical well-funded approach on sustainable development that is translated into a set of 15 rules aiming at securing human existence, maintaining society's productive potential and preserving society's options for development and action (cf. Kopfmüller et al., 2001) .

Step six of the Integrative Approach is also the place to redesign strategies in case the results achieved do not express those expected. But if the outcomes correspond to the expectations, step six is also the place to celebrate the outcomes achieved.

3.3 Uncertainties

The Integrative Approach tells future stories of the energy-poverty nexus but not a unique story because, in fact, such a story does not exist. Since the pool of stakeholders to be engaged in the approach is expected to change from case to case, the elements of the energy-poverty nexus as well as their descriptions, trends and interrelationships will also differ because other or additional knowledge and perceptions will be discussed with the stakeholders. This is a characteristic of participatory approaches (Clayton et al., 1997; WFP, 2000). Also, different actors may have different views on a specific matter.

Thus, there is a degree of uncertainty - know unknowns (Hanger- Kopp et al., 2019) - intrinsic to the system that for one reason or other cannot be eliminated. Often, such reasons are related to a lack of knowledge or lack of adequate conditions to make statements and observations, in particular related to the future because it is not possible to anticipate it (Kosow and Gaßner, 2008).

In that way, future-oriented approaches as the Integrative Approach to the Energy-Poverty Nexus should be interpreted as human-made constructions representing today's images of the future (Grunwald, 2011). On the one hand, this leads to understand that such images should not be classified as right or wrong but as plausible based on the set of knowledge considered in the study. On the other hand, the images can lead to arbitrariness since no accurate statement can possible be made about the future.

Nevertheless, the level of arbitrariness can be reduced as soon as the content of today's images of the future follow determined quality criteria, such as transparency, plausibility, traceability and consistency (Grunwald, 2002; Kosow and Gaßner, 2008). Thus, it is highly recommended in the Integrative Approach to the Energy-Poverty Nexus that the data collected through the participatory methods used, in particular in the three first steps of the approach, should be confronted and complemented by desk research and documented in as much detail as possible to describe the system as well as possible and avoid missing any important information.

The contextualization of the energy-poverty nexus may also suffer from unexpected future shocks or "black swans" events - unknown unknowns (Hanger- Kopp et al., 2019) - which are more challenging to be included and analysed in the nexus. For the particular case of the energy-poverty nexus in rural Ceará, the matter of uncertainties is discussed in detail in chapter six, sub-section 6.4.2.

3.4 Applying the Integrative Approach in a hypothetical case study

Since in the case of rural Ceará the Integrative Approach to the Energy-Poverty Nexus was partially applied until step four in this research, this section describes the full application of the Integrative Approach in the hypothetical rural community "Sunset". Although this is a community invented by the author of this dissertation to provide a simple example of the full application of the Integrative Approach, its general context may reflect the situation of many poor rural communities around the world.

Also, the system described for the community "Sunset" is not so complex as the one described for rural Ceará (chapter four) and its contextualization and analysis uses some of the methods used for the case of rural Ceará, but also additional ones (see below). This is important to highlight how the Integrative Approach to the Energy-Poverty Nexus is context-specific, as described in the previous section, while the methods to be used may vary from case to case.

3.4.1 The general context of the hypothetical community "Sunset"

In the community "Sunset" live 40 families that are in general small farmers but some are artisans and bricklayers. The families also fish in the local river for their own consumption and to generate additional income, as fish can be traded once a week in an informal market in the city that is 20 kilometres from the community. There is no connection to the electricity grid and the families rely on diesel generators that work about three hours a day and provide electricity for lighting, to plug domestic devices such as mixers, radios and televisions and to charge cell phones. Diesel is commercialized by middlemen in the community at a price 50% higher than the price paid in the city. When the generators are not working or the community has no diesel available, the families use wick lamps and candles for lighting. For cooking, the families rely on traditional cookstoves based on biomass. There is a community centre and a school that offers basic education. About half of the adult population is illiterate.

Recently, the regional government launched an energy programme to increase access to clean means of cooking and delegated the implementation task to NGOs that work with rural communities in the region. Basically, the programme would subsidise up to 60% of energy projects in rural communities for the implementation of clean cooking facilities based on solar, improved biomass cookstoves and biogas. The remaining 40% could be financed and the families would have four years to pay it back without interest rates.

Instead of following traditional approaches to increase energy access (or to eradicate energy poverty) in rural areas as discussed in chapter two, section 2.4, the NGO that works with the community "Sunset" is willing to apply the Integrative Approach to the Energy-Poverty Nexus to benefit as much as possible from the energy programme to improve living conditions and reduce poverty in the community. It should be noted that traditional approaches to increase energy access in this case would, in general, focus on technology transfer and would treat community members as users or beneficiaries of energy technologies. Different from traditional approaches, the Integrative Approach to the Energy-Poverty nexus aims to systematically create a problem between energy and poverty. Also, in the Integrative Approach the community members are treated as the main actors of local interventions and, therefore, local transformation agents of the situation they face. In the following, the application of the Integrative Approach in the community "Sunset" and the use of specific methods are described.

3.4.2 Problematizing and contextualizing means of cooking

In the first step of the Integrative Approach, the NGO can use transect walks (cf. ParCitypatory, 2017) in which families visit each other to observe and discuss in small groups how do they prepare their food and how do they gather biomass in the local forest. Transect walks give also the opportunity to observe and discuss general aspects of the daily life of the community, including health and environmental issues, basic sanitation and education. After that, an educational circle (cf. Freire, 1994) can be organized by the NGO involving all community members to discuss the observations made in the transect walks as well as the questions suggested in sub-section 3.2.1. Educational circles aim to problematize and increase the awareness of a given situation starting from the perspective of the local actors (i.e. in this case, the families of the community "Sunset").

During the discussions in the small groups and in the educational circle, the families can identify that current means of cooking used in the community cause high indoor air pollution and increase health problems, in particular among women, children and the elderly. It can also happen that the families do not see indoor air pollution as a matter of concern. This can happen in cases where families are so used to indoor air pollution that they do not perceive it as a problem, assuming it as something normal in their lives. In such cases, the organizers of the educational circle can further discuss indoor air pollution and provide additional information about its hazards to human health. This can encourage the families to problematize indoor air pollution relating it to health risks, medical expenses and less capacity to generate income and save money. That way, cooking technologies, respiratory diseases and income generation can be identified as elements of the energy-poverty nexus in the community. The current states of these elements can be written down by the organizers following the description provided by the families.

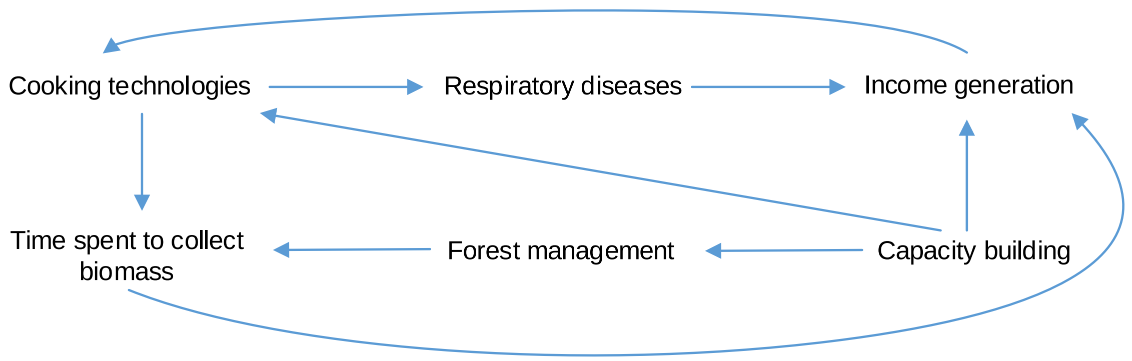
The organizers of the educational circle can also ask the families to draw (community mapping and diagramming, cf. Chambers, 2007) the local forest in which they are used to gathering biomass. Diagrams comparing past and present are also useful in such an activity. Once discussing the diagrams created, the families can raise concerns about forest management and the capacity of the community to adequately manage the local forest. In that way, three additional elements of the energy-poverty nexus can be identified: forest management, capacity building and time spent to gather biomass.

For each one of the elements identified by the families, the organizers of the educational circle can incite the families to visualize how these elements may unfold in the future. This incitation process can require inputs from the organizers to increase knowledge (e.g. about clean cooking technologies and sustainable forest management) among community members in order to *together* with (and not *for*) the families visualize future trends. These future trends could be, for example:

- Element “cooking technologies” - trend 1: traditional cookstoves based on biomass; trend 2: improved cookstoves based on biomass; trend 3: solar cookstoves; and trend 4: cookstoves based on biogas.
- Element “respiratory diseases” - trend 1: increased possibilities for respiratory diseases due to high indoor air pollution; trend 2: reduced possibilities for respiratory diseases due to low indoor air pollution.
- Element “income generation” - trend 1: better conditions to generate income; trend 2: worst conditions to generate income.
- Element “forest management” - trend 1: no management at all; trend 2: sustainable forest management.
- Element “capacity building” - trend 1: lack of knowledge; trend 2: improved knowledge.
- Element “time spent to collect biomass” - trend 1: zero hours per day (no biomass needs to be collected because the families use other fuels for cooking); trend 2: one hour a day; trend 3: more than two hours a day.

3.4.3 Means of cooking as a multifaceted and dynamic system

In the second step of the Integrative Approach, the families would be encouraged to create linkages between the elements identified in step one. The following map of interrelationships (Figure 3.2) could be created.



Note: The arrows connecting the system elements indicate direct relationship and respective direction of influence between the elements interconnected.

Figure 3.2: Map of interrelationships of the elements identified in the community "Sunset"

That way, one can note that the kind of technology used have an impact on the risk to develop respiratory diseases, which have an impact on income generation. Income generation will influence the kind of technologies adopted for cooking. Capacity building will also influence the technologies adopted because the community members can be trained to construct solar cookstoves, improved cookstoves based on biomass and biodigesters. Capacity can also be built to manage the local forest in a sustainable way, in the sense that the amount of biomass that the families remove from the forest is not bigger than its replacement. The kind of cooking technologies used as well as how the families manage the local forest will have an impact on the time that families need to collect biomass, which will have an impact on the opportunity to generate income (see Figure 3.2).

3.4.4 Creating and analysing future views

Once analysing the interconnections described in step two, the organizers of the educational circle can ask the families to indicate whether the trends of the elements identified in step one could promote, hinder or have no influence on the other trends. This information could be used to fulfil a cross-impact matrix (cf. Weimer-Jehle, 2006) indicating all influences between the trends of the system elements. However, since the number of elements is still small in this hypothetical example (additional elements can be incorporated later on since the Integrative Approach works as a loop), the organizers and the families can create future views in form of storylines following an analytical description of the level of influence between the future trends.

The first vision (i.e. storyline) could represent the continuance of the status quo. This would mean that families would continue using traditional cookstoves based on biomass. As a consequence, such cookstoves will continue causing high indoor air pollution that will increase the possibilities for respiratory diseases. Unhealthy people are more limited to generate income or save money than healthy ones. Since there is no local knowledge to manage the local forest in an adequate and sustainable way, the families will continue extracting more biomass from the forest than it can replace. In addition, since the efficiency of traditional cookstoves based on biomass is low, such stoves consume more biomass to produce the same amount of heat than improved cookstoves, increasing the removal of biomass from the forest. Since the capacity of the forest to provide biomass will reduce over time, the families will need more time to collect biomass that can take more than two hours a day. This time consumption will affect primarily women that are already in charge of gathering biomass in the community. Also, this time consumption will reduce the possibility for women to do other activities, which could include education and income generation. In this vision, the overall conditions of the families in terms of means of cooking is not expected to change, contributing to keeping poverty in the community.

Once discussing this first vision with the community members, they will have a systematic view of cooking means in the community and are expected to become aware of factors that were not clear for them before. The families can then draw another vision based on the level of interrelationships created above and on the discussion of the status quo presented in the first vision.

The second vision explores the adoption of clean means of cooking by the families in the community. Since most of the families prefer to prepare food in biomass cookstoves, it is expected that they will adopt improved cookstoves based on biomass combined with solar or biogas technologies for cooking. The preference for cooking using biomass may reduce over time as the families incorporate the use of solar and biogas technologies in their daily life. The adoption of clean cooking facilities will significantly reduce indoor air pollution that will reduce the risks of respiratory diseases. Healthy people will have better possibilities to generate income and to avoid expenses with medicine. The money saved by the families can be used for the adoption of clean cooking technologies among other family priorities. The use of clean cooking facilities will also reduce pressure over the local forest that can be better managed through the adoption of sustainable forest management. Since there is a lack of local knowledge on sustainable forest management, the NGO will promote this knowledge in the community through seminars and educational circles. Sustainable forest management companioned with improved cookstoves based on biomass that consume less biomass than traditional cookstoves will have positive impacts on the time that families need to collect biomass. This time can be used to develop other social and economic activities. In addition, the gender and transport issue of getting biomass will be discussed in the community and men will engage in biomass collection as well as better ways to transport the biomass from the forest to the houses will be adopted. Over time, in case the families opt to use only solar or biogas technologies for cooking, the time used to gather biomass would be eliminated or reduced to a minimum.

The visions presented above can be constructed only discussing and analysing with the families the level of influence of system elements and trends. Additional views can be created and for that the scenario techniques suggested in sub-section 3.2.3 can be useful.

As a further task of step three, families would identify necessary conditions to move the community from the status quo of the first vision to the second one, since the families acknowledge that the later vision is better than the first one and can improve living and health conditions and, consequently, contribute to reducing poverty in the community. Once analysing the two visions in detail, the families can identify that gender issues, the adoption of clean cooking technologies and capacity building to construct such technologies and to adequate manage the local forest are key to change pathways in the future in terms of clean cooking.

3.4.5 Changing pathways

In the fourth step of the Integrative Approach, the NGO and local families would work to understand how easy or hard it is for the community to change the conditions identified in the previous step to move the energy-poverty nexus (focusing on clean means of cooking in this example) from the first to the second pathway of development. In that sense, the second pathway of development is defined by the families as the desired pathway to be followed by the community.

Among the conditions identified in step three, gender equality may require significant efforts from the community members because it would mean re-education on the matter and a change on socio-cultural behaviour in the community, which may require considerable efforts from community members, especially men. The other conditions related to the adoption of clean cooking facilities and adequate forest management may not be so hard to be surpassed, because community members can be trained to build the cooking facilities and to adequately manage the local forest. The strategies to be adopted are defined in the next step of the Integrative Approach.

3.4.6 Defining and adopting strategies to change pathways

Since the families have limited resources to buy and install clean cooking facilities in the community, the energy programme launched by the regional government (detail in sub-section 3.4.1) represents an interesting opportunity for them. The following strategies could be created in step five of the Integrative Approach following up the discussions between the NGO and the local families.

In order to reduce costs with the installation of clean cooking facilities, the knowledge to construct improved cookstoves based on biomass, solar technologies for cooking and biodigesters will be promoted by the NGO. The local artisans and bricklayers will play an important role in this phase both to install the facilities and to replicate knowledge to other community members.

Since the regional government will subsidise 60% of the projects, the families could opt to create a local fund to save a small amount of their income. The objective of the fund is to have enough money after the four years period given by the government to pay back the 40% of the energy projects that will be funded by the government.

Gender issues will be discussed in the community in order to increase gender equality and increase opportunities for women to generate income. Capacity building on sustainable forest managed will also be promoted by the NGO. Considering that half of the adult population in the community is illiterate, capacity building will also focus on literacy.

The adoption of the strategies described above is expected to lead the families to install improved cookstoves based on biomass plus solar or biogas cooking technologies in their homes. The capacity building promoted by the NGO can increase opportunities to generate income. When combined, the strategies above are expected to increase quality of life and contribute to reduce poverty in the community.

3.4.7 Evaluating results, improving strategies and celebrating the outcomes achieved

In step six of the Integrative Approach, the evaluation of the results achieved can be done in additional educational circles in which the families discuss the advances and improvements achieved by the adoption of the strategies designed in the previous step. This can include but is not limited to the time spent to gather biomass, the level of indoor air pollution, respiratory disease in the community, improved opportunities and capabilities to generate income and the recovery of the local forest. All advances achieved can be celebrated by the families as forms to improve quality of life and reduce poverty in the community.

In this last step of the Integrative Approach, strategies designed in the previous step can also be reviewed aiming to achieve additional or better results. In that sense, the families can reflect on how to reduce even more indoor air pollution. The construction of well-ventilated kitchens can be an additional strategy to be adopted. Another strategy is the possibility to create a local cooperative to join efforts aiming to overcome additional challenges in the community.

Such a cooperative could further develop the idea of a local fund to raise funds for the installation of a solar facility to refrigerate fish, since fishing is an important activity in the community (see detail in sub-section 3.4.1). Such a measure can contribute to increase food security in the community, reduce losses and costs with diesel and add value to fish that is commercialized in the city. In addition, a local cooperative can increase opportunities for the community to access formal markets. Another target that can be pursued by the families (maybe through the cooperative) is the gradual substitution of diesel generators by solar home systems or a mini-grid in the community, including also the electrification of the community centre and the school that could offer socio-educational activities after sunset. In the meanwhile, the families can also reflect on strategies to reduce costs with diesel.

It should be noted that once after reflecting on the strategies adopted and additional challenges, the families could start to reflect on the energy-poverty nexus in the community once again, identifying new elements of the nexus. Following the discussion presented above, additional elements could be but are not limited to: the organization of the families (i.e. cooperative); diesel costs, solar electrification; fish refrigeration; food security and (in)formal markets. In that way, the steps of the Integrative Approach to the Energy-Poverty Nexus can be executed once again aiming to incorporate new elements and trends, design new visions and strategies, take action, evaluate the results achieved, redesign strategies (if necessary) and celebrate outcomes.

3.5 Closing remarks

This chapter introduced the Integrative Approach to the Energy-Poverty Nexus that is planned to be executed in six main steps and requires the participation of local actors to contextualize, problematize, systematize and analyse energy and poverty in a community, region or country. The Integrative Approach understands the energy-poverty nexus as a complex system composed of multifaceted elements that interact with each other and can contribute to increase or reduce poverty. For example, the impossibility of a family to pay for clean cooking fuels can represent one element of the energy-poverty nexus that contributes to keeping people in poverty. This deprivation can force families to use unhealthy means of cooking, which increases indoor air pollution and the risk of respiratory diseases.

The elements of the energy-poverty nexus are expected to vary when applying the Integrative Approach to different realities. In off-grid electrification, for instance, the training of community members to perform small repairs on electric generators can be decisive to maintain energy systems working properly. Such a training, however, may not be of relevance in communities already connected to the grid. The actors to be involved in the Integrative Approach are also expected to change according to different realities (e.g. from the community to the national level).

Finally, one can say that the Integrative Approach provides a comprehensive view on energy and poverty and on how the energy-poverty nexus in a specific context may unfold in the future. This should allow for the design of better strategies aiming to maximize energy access and use towards the reduction of poverty. That way, the Integrative Approach to the Energy-Poverty Nexus can represent an advance in science and the energy access sector if compared to typical approaches focusing on the eradication of energy poverty in rural areas.

Chapter four

Contextualizing energy and poverty in rural Ceará

4.1 Introduction

Rural areas of the Brazilian state of Ceará represent an interesting case study to analyse the energy-poverty nexus because the State has universal electricity access (MME, 2019), presents one of the biggest Brazilian potentials for wind and solar energy (Governo do Estado do Ceará, 2010a, 2009) and poverty is one main concern, in particular in rural areas (IPECE, 2020). Ceará is located on the north-eastern coast of Brazil in a climate predominantly semi-arid and has a rural population of about 2.1 million people, which represents about 25% of the total population of the State (IPECE, 2018).

In the last years, Ceará has made important progress in increasing the access to modern energy services (or to reduce energy poverty) in rural areas. Electricity access was universalized in 2015, mainly through grid extension. In general, poor families use electricity to meet basic human needs such as lighting, food refrigeration and communication. Regarding cooking fuels, the use of LPG is common, combined with biomass (IBGE, 2020a).

In terms of poverty reduction, advances can also be observed, in particular in the last two decades. The monetary stabilization in 1994 and increased social policies from 2003 were essential for that (Cardoso, 2013). Nevertheless, even considering the advances achieved, Ceará is still one of the poorest Brazilian states with a high level of socioeconomic inequality (de Assis and Linhares, 2015; IPECE, 2020; Nogueira and Medeiros, 2016). Also, since the Brazilian economic recession in 2015, poverty and inequalities started to increase again in Ceará, being more accentuated in rural areas (IPECE, 2020).

Considering the high potential for wind and solar power generation, the advances achieved towards the reduction of energy poverty (especially in terms of rural electrification) as well as the fact that poverty is still a matter of concern in the rural areas of Ceará, this study proposes to analyse the dynamics of the energy-poverty nexus in these areas to identify possible conditions in which modern and renewable energies, in the forms of decentralized power supply and clean means of cooking, can contribute to reducing poverty in the long term.

For that, the Integrative Approach to the Energy-Poverty Nexus proposed in the previous chapter was used.

This chapter follows the application of the steps one and two of the Integrative Approach (i.e. identification of the elements and trends of the energy-poverty nexus and causal interrelationships – detail in chapter three, section 3.2) and have three main objectives. The first is to characterize the current situation of energy and poverty in rural Ceará. This characterization lays the foundation for the second objective to present the elements and trends of the energy-poverty nexus identified following a fieldwork campaign in Ceará and supplemented by literature research. The third objective is to stablish interrelationships between the elements of the energy-poverty nexus, providing a systematic view of energy and poverty in rural Ceará, which is analysed in detail in the next chapter of this dissertation.

This chapter is organized as follows: section 4.2 presents an analytical description of the participatory methods used to gather data for the contextualization of energy and poverty in rural Ceará, supplemented by desk research. Then, section 4.3 presents the status quo of energy and poverty in rural Ceará. This status quo is also discussed in view of the national context, since it is not possible to characterize the energy-poverty nexus in rural Ceará considering only local factors. Section 4.4 describes the elements and future trends identified for the energy-poverty nexus. Section 4.5 focuses on the causal relationships between the elements of the energy-poverty nexus in rural Ceará, composing a complex and multifaceted socio-energy system. Finally, section 4.6 offers some reflections on the status quo of energy and poverty as well as on the elements that compose the energy-poverty nexus in rural Ceará.

4.2 Analytical description of the methods used to gather data

This study used some of the participatory methods suggested in the first step of the Integrative Approach (chapter three, sub-section 3.2.1) to gather material for the contextualization of the energy-poverty nexus in rural Ceará. This included semi-structured interviews with local actors (cf. Drever, 1995), transect walks in four rural communities (cf. ParCitypatory, 2017) and one workshop with some of the local actors interviewed. The participatory research took place in Ceará from March to April 2015 and was supplemented by desk research.

The use of semi-structured interviews is justified for two reasons. The first is because this study contemplates a small-scale research in the sense that its intention was to interview a small number of key people (exploratory research). The second reason is because semi-structured interviews give the possibility for the interviewees to express their thoughts with a certain degree of freedom, without the necessity to answer closed questions (Drever, 1995).

For the interviews, a guideline with main questions was created (appendix). The guideline was based on literature research and presents four topics of questions, namely: (i) electricity access and use, (ii) electricity production, (iii) means of cooking and (iv) poverty, socioeconomic inequalities and quality of life. The selected interviewees were communities' representatives and stakeholders involved in the energy, social and rural development sectors of Ceará that could provide answers and additional information to the main questions of the guideline. The local actors were asked to answer the questions related to their field of expertize or interest. In total, 28 people were interviewed. Most of the local actors interviewed were representatives of governmental agencies followed by academics. Representatives of rural communities, NGOs and electricity utilities, one private company and one economic consultant also participated in the interviews (Table 4.1).

Table 4.1: Representativeness and affiliation of the interviewees in Ceará

Representative	Affiliation	Nº of interviewees	Percentage (%)
Governmental Agencies	Secretaria do Desenvolvimento Agrário (SDA)	3	39.3
	Embrapa Agroindústria Tropical (Embrapa)	1	
	Instituto Agropolos do Ceará	1	
	Secretaria da Ciência, Tecnologia e Educação Superior	1	
	Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE)	1	
	Conselho Estadual de Educação (CEE)	1	
	Federação das Indústrias do Estado do Ceará (FIEC)	1	
	Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE)	1	
	Governo do Estado do Ceará - Chefia de Gabinete	1	
Academia	Universidade Estadual do Ceará (UECE)	2	25.0
	Universidade Federal do Ceará (UFC)	4	
	Universidade de Fortaleza (UNIFOR)	1	
Non-governmental Organizations	Centro de Estudos do Trabalho e Assessoria ao Trabalhador (CETRA)	1	10.7
	Centro de Desenvolvimento Agroecológico Sabiá	1	
	Instituto Joazeiro	1	
Electricity Utilities	Companhia Energética do Ceará (COELCE)	1	10.7
	Companhia Hidrelétrica do São Francisco (Chesf)	2	
Community leaderships	Community of São Pedro	1	7.1
	Cooperativa Agroecológica da Agricultura Familiar do Caminho de Assis (Cooperfam)	1	
Private Company (wind energy)	Braselco	1	3.6
Economic consultant	No affiliation	1	3.6
Total		**28**	**100**

All the 28 local actors interviewed were invited to participate in a workshop to discuss the energy and poverty situation in rural communities in Ceará. In total, 12 actors of those interviewed participated in the workshop. The semi-structured interviews and workshop were audio recorded and their content critically analysed and categorized (cf. Guerra, 2006). Alongside the interviews and workshop, four rural communities were visited and transect walks were conducted. The transect walks allowed for visual observation, photographic register and informal talks with communities' members to discuss their perceptions on energy and poverty in their communities.

The information collected during the participatory research was supplemented by desk research. Also, this research analysed data from the National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios* - PNAD). PNAD is a sample survey conducted every year (except in census years that occur every 10 years) by the Brazilian Institute of Geography and Statistics (IBGE) and investigates general characteristics (e.g. education, age, sex and income) and living conditions (e.g. household infrastructure and access to basic services) of the Brazilian population (IBGE, 2020b). The PNAD data for the years 2001 to 2019 were analysed using the computational programme R version 4.0.2 (R-Project, 2020). All the data collected from desk research aimed to provide complementary information and to reduce uncertainties to the findings of the participatory research conducted in Ceará.

4.3 The status quo of energy and poverty in Ceará

This section presents the general context of energy and poverty in rural Ceará. This context lays the foundation to present and discuss the elements of the energy-poverty nexus identified for the rural areas of Ceará in the next section 4.4. This section is organized as follows: sub-section 4.3.1 focuses on quality of life, poverty and inequalities in rural Ceará. Then, sub-section 4.3.2 explores the role of agribusiness and land concentration in the Brazilian agrarian sector, which has an influence on rural Ceará. The electricity mix, production and consumption of electricity in Ceará are presented in sub-section 4.3.3. Considering that wind energy is widely used in the State, sub-section 4.3.4 explores social and environmental impacts of wind energy on local communities presented in the literature. Finally, sub-section 4.3.5 offers some reflections on development models, in particular related to agribusiness and the wind energy sector, and their implications on poverty.

It should be noted that for some aspects discussed in this section (e.g. sociocultural, economic and political), the current situation in Ceará cannot be separated from the Brazilian context, since the national level influences the regional level. Therefore, this section discusses Ceará also considering the national context.

4.3.1 Quality of life, poverty and inequalities

In the 1990s and years before, rural Ceará was strongly marked by poverty and hunger. This situation was strengthened by adverse climate conditions (i.e. semi-arid environment with a natural and seasonal drought period) and often led to migration flows to southern Brazil (de Castro, 1984; Farias, 2007; JN, 2001). In the last two decades and until 2015, however, the situation has changed and progress has been made to reduce poverty and social vulnerability (de Assis and Linhares, 2015; de Castro et al., 2012; IPECE, 2020). Since 2015, poverty and inequalities started to increase again driven by the economic recession (IPECE, 2020).

The following Table 4.2 provides general socio-demographic and living conditions data for Ceará and Brazil. Data from Brazil are presented to trace simple comparisons between the national and state level regarding socio indicators and living conditions in rural households.

Table 4.2: General socio-demographic and living conditions data for Ceará and Brazil

Socio-demographic and living conditions data	Unit	Ceará	Brazil
Socio-demographic			
Area	1,000 km²	148.89	8,510.25
Population (estimation, year 2019)	Million	9.1	210.1
Population (last census, year 2010)	Million	8.4	190.8
Rural population (last census, year 2010)	Million	2.1	29.3
Population density (last census, year 2010)	Persons per km²	56.7	22.4
Life expectancy	Years	74.7	76.7
GINI index (year 2018)	(0 to 1)	0.548	0.545
Urbanization rate (last census, year 2010)	%	75.1	84.4
Population living in extreme poverty[1] (year 2018)	%	12.5	6.5
Population living in poverty[2] (year 2018)	%	46.9	29.4
Illiterate population (year 2018)	%	13.3	6.8
Living conditions in rural households[3]			
Access to electricity	% of households	99.8	98.5
Access to water – pipeline	% of households	34.8	29.9
Access to water – well or spring	% of households	46.0	58.7
Access to water – raining water stored in cistern	% of households	9.3	4.2
Waste collection	% of households	32.8	35.4
Waste is burnt in the property	% of households	60.2	57.3
Waste is buried in the property or thrown away in the surroundings	% of households	6.9	3.4
Connected to sewage pipes	% of households	6.3	8.4
Use of sewage pits	% of households	43.4	42.8
Use of rudimentary pits	% of households	37.5	33.2
Use of LPG for cooking	% of households	89.6	91.8
Use of biomass or coal for cooking	% of households	70.8	69.0
Use of electricity for cooking	% of households	33.7	38.1
Have refrigerator	% of households	97.5	93.3
Have television	% of households	94.6	92.3
Have washing machine	% of households	17.8	34.6
Access to the internet (via cell phone, computer or other device)	% of households	51.9	52.8

Notes: [1] Monetary poverty based on the World Bank's international poverty line of $1.90 2011 PPP per day.

[2] Monetary poverty close to World Bank's international poverty line of $5.50 2011 PPP per day.

[3] All data provided for living conditions in rural households refer to the year 2019. Own calculation (unweighted) based on data from the PNAD sample survey.

Sources: IBGE, 2020a-e; IPECE, 2020

The life expectancy in Ceará is lower than the Brazilian average and the State has almost the double illiteracy rate than the national average (see Table 4.2). In terms of economic inequality, although progress has been observed in the last years, Brazil is still one of the most unequal countries in the world (Neri, 2019; OXFAM, 2017) and the GINI index shows that economic inequality is slightly higher in Ceará than in Brazil (see Table 4.2). Also, it is worth noting that in Brazil, the six richest people concentrate the same wealth amount as the poorest 100 million people (OXFAM, 2017). In terms of monetary poverty, this is much more pronounced in Ceará than in Brazil (see Table 4.2), giving the State the fourth rank among the Brazilian states with the largest numbers of people living in extreme poverty (G1, 2019a).

Regarding living conditions in rural households, electricity access is universalized in Ceará and almost universalized in Brazil. Currently, there are about 95.000 families living in 11 north and north-eastern Brazilian states that have no access to electricity and the country expects to reach universalization in 2022 (MME, 2019). In terms of access to water, waste collection and basic sanitation, the situation in rural Ceará is similar to rural Brazil and much has to be done to universalize the access to these basic services. This lack of basic services negatively impacts the quality of life and contributes to increase diseases (Medeiros and Neto, 2011). In Ceará, the situation gets worse in periods of extensive droughts. Regarding means of cooking, most of the rural households in Ceará and Brazil use LPG combined with biomass cookstoves and, to some extent, electricity. In addition, most of the rural households have refrigerators and televisions, contrasting with the low percentage of households that have washing machines. The diffusion of the internet in rural Ceará and Brazil is also worth noting and more than a half of the households have internet access via cell phones, computers, tablets or other electronic devices (see Table 4.2).

Thus, in summary, one can say that the overall socioeconomic situation in rural Ceará presents worse indicators compared to the Brazilian average (even considering simple comparisons). In terms of water access, waste collection and basic sanitation, rural Ceará and rural Brazil present similar scores and are far from universalization. Regarding energy poverty, except the work from Obermaier et al. (2012), the author of this dissertation did not find any additional and specific study about the matter applied to rural Ceará. Obermaier et al. (2012) analysed the electricity consumption patter of 131 rural households in Ceará following electrification and found out that rural electrification increased social benefits because the families increased their electricity consumption after electrification. However, the authors could not infer whether the use of electricity has contributed or not to increase income generation. Based on the data collected and analysed in this study (i.e. fieldwork campaign and desk research) one can say that poor rural families use electricity to meet basic human needs at least and most of them use LPG and biomass for cooking.

The overall socioeconomic context presented above (including aspects related to energy access and use) is additionally discussed in the elements of the energy-poverty nexus identified for rural Ceará through the participatory research conducted in the State (detail in section 4.4).

4.3.2 Agribusiness and land concentration

The Brazilian agrarian sector is oriented to agribusiness and global commodities. This orientation began in the colonial period (1530 - 1822) through the production of monocultures such as sugar cane and coffee (de Castro, 1984) and was strengthened in the 1960s by the so-called “green revolution”, which intensified and increased the efficiency of agrarian activities through mechanization and use of chemicals while causing the rural exodus of many smallholder farmers who could not compete in a market focused on the large production of monocultures (Ipea, 2016a; Maluf et al., 2011).

Currently, agribusiness focusing on global commodity markets plays an essential role in the national economy (CNA, 2020). The focus on international markets is not only pushed by large farmers that are politically well represented but also by global demand for staple food, such as soybeans, meat, sugar cane, alcohol and coffee. In 2019, the agrarian sector was responsible for 21.4% of the Brazilian GDP (CNA, 2020) and corresponded to 43,2% of the total exports of the country (Governo do Brasil, 2020). To satisfy the demand in a competitive way, agricultural commodities are produced on a large scale and with high efficiency through monocultures that require a high investment of energy, capital and chemicals (Rural 21, 2018).

Although agribusiness represents an economic pivot in Brazil, it also contributes to environmental degradation and to increase socioeconomic disparities. Environmental degradation can be observed, for example, through the extensive forest lands converted in field crops and pastures, especially in the Amazon region (Pokorny et al., 2013), and through the negative impacts caused on soils, rivers, ground water and insects by the intensive use of chemicals in monocultures. Brazil is the largest world consumer of pesticides (G1, 2019b). Regarding socioeconomic inequalities, the land concentration required by the agribusiness model is one of the key factors for rural exodus and for the continuance of poverty in the country (de Castro, 1984; Helfand et al., 2014; Ipea, 2016a; MDA, 2003). This is so because many poor families (mostly smallholder farmers) that migrate to urban areas (frequently to suburbs and slums) lack qualifications besides agrarian activities, making it difficult for them to find jobs in the cities. Those poor families that remain in rural areas, in general, are not able to compete in the agribusiness model. Also, agribusiness in Brazil is associated with land conflicts, which in 2019 achieved the record amount of 1,254 conflicts in which 28 people died (CPT, 2020).

Land concentration in Brazil is an issue that goes back to the colonial period since it was in 1534 that the Portuguese Imperium first divided the Brazilian territory in 12 hereditary captaincies (Ipea, 2010a). Later on, in 1850, the promulgation of Law number 601, known as *Lei das Terras* (Land Law), defined that the only way to acquire land is by buying it (Presidência da República, 1850). Consequently, the law inhibited the access to land for poor people. The *Lei das Terras* was decreed in the period of immigration and 38 years before the abolition of slavery. Without conditions to pay for the land, the alternative for many immigrants, indigenous people and ex-slaves was to work for those who could afford land acquisition (Reis, 2015). Over time, the characteristic of vast extensions of land belonging to a few owners is still a reality in the country (de Castro, 1984; Filho and Fontes, 2009; Freire, 1994; Hoffmann and Ney, 2010; Ipea, 2016a; Leal, 2012).

In rural Ceará, the high concentration of lands is also a reality. In the State, 83% (or 281,785 units) of the rural proprieties are smallholders up to 20 hectares and hold 11% of the total agricultural land. In contrast, 7,410 farm units (equivalent to 2.17% of the total rural properties) have more than 200 hectares per unit and hold together about 51% of the agricultural land (Medeiros, 2016). Also, it should be noted that agrarian production in small properties is diversified, of low efficiency, uses family labour and is fundamental for local food sovereignty and for the food production that is consumed in the city, going in contrast to the agribusiness model found in large farming (Marques, 2016). Additional detail about small farming, its context and supportive policies are presented in the elements that contextualize the energy-poverty nexus in rural Ceará (section 4.4).

The disparity of land distribution reinforces the existence of the so-called *coronéis* (colonels) or *senhores da terra* (landlords) in rural areas, which was already reported by scholars in Brazil (e.g. Dowbor, 2016; Ipea, 2016a; Vigna, 2007) and mentioned by local actors interviewed in this study. The *coronelismo* was a phenomenon that occurred in the country from 1889 to 1930 in which the social, economic and political power of municipalities and regions were concentrated in the hands of local big landowners. In exchange for this power, the *coronéis* manipulated the votes of those people under their domains to support politicians at the state and national levels (Leal, 2012).

Currently, big landowners are politically organized in the so-called Rural bloc that concentrates the political and economic power in the Brazilian agrarian sector and is present at the main governmental spheres by politicians pushing forward the agribusiness model in the country (Vigna, 2007). The current Minister of agriculture, livestock and food supply is representative of the Rural bloc.

4.3.3 Capacity installed, production and consumption of electricity

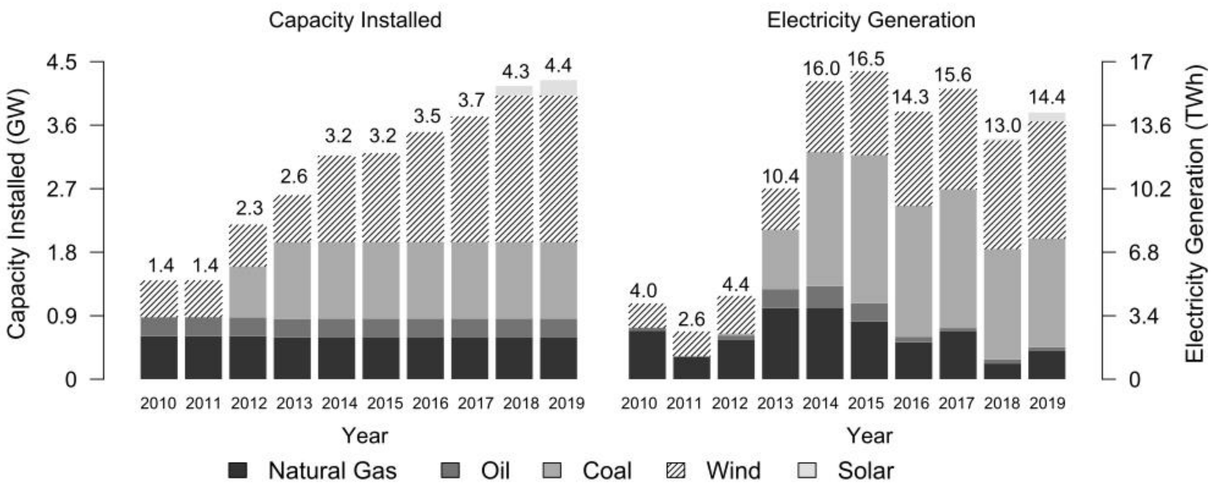
Due to its geographical features and location, Ceará has one of the biggest Brazilian potentials for wind and solar power generation (Governo do Estado do Ceará, 2010a, 2009), though the use of solar energy is still at an incipient stage with 218 MW of power capacity installed but with 2.2 GW of power planned to be installed in the coming years (ANEEL, 2021). The electricity demand is met by centralized power plants and the current (February 2021) installed capacity of electricity generation corresponds to 4.6 GW (Table 4.3). Ceará is integrated into the Brazilian electricity system that facilitates operation and management of intermittent renewable energies. The installed capacity of electricity generation in the State represents 2.6% of the total capacity installed in the Brazilian electricity system, which is characterized as a hydro-thermal power system (ANEEL, 2021).

Table 4.3: Current and planned power capacities in Ceará

Energy source	Capacity (MW)	Percentage (%)	Power plants (units)
Operating			
Wind	2,306	49.2	91
Coal	1,303	27.8	3
Natural Gas	565	12.1	6
Oil	291	6.2	28
Solar	218	4.7	8
Hydro	1.2	0.0	2
Tide	0.05	0.0	1
Total	4,684	100	139
Planned and under construction			
Wind	326	12.8	12
Solar	2,221	87.2	61
Hydro	1.3	0.05	1
Total	2,548	100	74
Total (operating, planned and under construction	**7232**	**-**	**213**

Sources: ANEEL, 2021

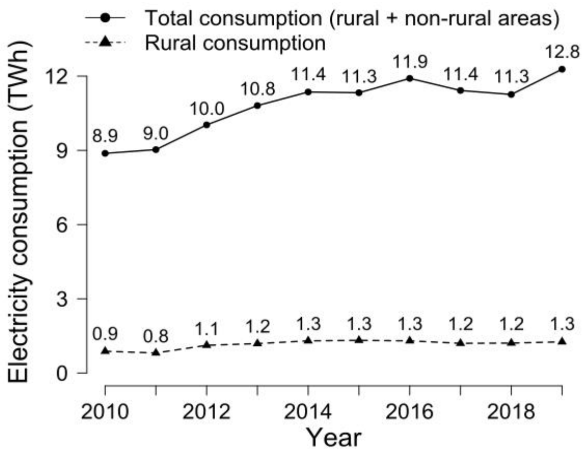
In the last years, wind energy has been the most growing energy source in terms of capacity installed in Ceará (Figure 4.1). Coal energy was introduced in 2012 with the installation of three power plants. Together with natural gas and oil, wind and coal energy represent the base of electricity generation in the State and produced 14.4 TWh of electricity in 2019. Since 2014, more electricity is produced than is consumed in Ceará.



Sources: EPE, 2020a-b, 2019, 2018, 2017a-b, 2016a-b, 2015a-b, 2014, 2013, 2012; MME, 2015a

Figure 4.1: Installed capacity and electricity generation in Ceará from 2010 to 2019

Rural areas in Ceará are responsible for about 10% of the total electricity consumption in the State and consumed 1.26 TWh of electricity in 2019 (Figure 4.2). This consumption pattern has been stable in the last years. Also, it is below the average of electricity consumption of almost all rural areas located in the southern and south-eastern regions of Brazil (EPE, 2020a), which are considered the most developed and richest Brazilian regions (Ipea, 2011). For instance, the rural areas of the state of Santa Catarina (Brazilian southern), that have about the half of the rural population of Ceará (PNUD et al., 2013), consumed 3.49 TWh of electricity in 2019 (EPE, 2020a). That means that rural Santa Catarina consumes around six times more electricity per capita than rural Ceará.



Sources: EPE 2020a, 2018, 2017b, 2016a-b, 2015a-b, 2014, 2013, 2012; MME, 2015a

Figure 4.2: Electricity consumption in Ceará from 2010 to 2019

Considering the electricity consumption in rural Ceará in the last years, it is possible to estimate a consumption of about 600 kWh per capita per year in average from 2013 to 2019 considering a rural population of about 2.1 million people. This may suggest that rural people are benefiting from electricity not only to meet basic human needs but also for production, following the levels of access to energy services presented in AGECC (2010). According to the authors, the electricity consumption of up to 100 kWh per capita per year is mainly used to meet basic human needs. Above 100 kWh, electricity starts to be additionally used for production (AGECC, 2010). Among poor people in rural Ceará, however, this is not the case because, in general, they use electricity to cover basic human needs (this matter is further discussed in sub-section 4.4.9).

4.3.4 Social and environmental impacts of wind energy on rural communities

Due to its capacity to attract external investments, the wind energy sector is often associated with development in Ceará (Governo do Estado do Ceará, 2010b). However, the advance of wind energy also brought negative impacts on rural communities, mainly related to frustrated development expectations, land degradation and land-use rights (Alencar, 2019; Brannstrom et al., 2017; Gorayeb et al., 2019; Lima, 2008; Sales, 2018).

That way, scholars have reported the frustrated expectation of community residents that wind parks would create local jobs and promote local development (Brannstrom et al., 2017; Sales, 2018). During the construction phase of the wind parks, local workers are frequently hired. However, once the parks are operating, the number of employees decreases substantially. Also, the operation of wind parks requires skilled labour that is not found in the local communities (Alencar, 2019; Brannstrom et al., 2017). The implementation of wind parks have also caused land degradation because the terrain needs to be prepared for the installation of the wind turbines, changing the landscape of dunes (Meireles, 2019), grounding local lakes, clearing native vegetation and changing the natural dynamics of coastal flows (Brannstrom et al., 2018).

Scholars have also reported the cases of the “sons of the wind”, a term commonly used in rural Ceará in reference to the children born from relationships between young women of the communities and temporary workers at the wind parks that do not assume paternity and leave the communities after the construction of the parks (Araújo and Meireles, 2019). Also, scholars have reported that the sociocultural identity of the communities have changed with the implementation of the wind parks (Gorayeb et al., 2019).

In relation to land-use rights, scholars and NGOs (e.g. Alencar, 2019; Araújo and Meireles, 2019; ASA, 2014a-b; Brannstrom et al., 2017; Lima, 2008; Meireles, 2019) have reported cases that occurred in Ceará and nearby states where wind farms were installed and the access to land, lakes and the sea previously used by the community residents were blocked by wind companies, affecting the social and economic dynamics of the local population (including family subsistence and food sovereignty). There are also reports of community residents that were threatened by the security guards of the wind parks. One cause of land conflicts occurs because it is not difficult to find local communities that have been living for generations in a region and do not have the official right over the land (Brannstrom et al., 2017; Lima, 2008).

Finally, Brannstrom et al. (2019) have reported weak economic and political institutions in Ceará that facilitate legal regulation, including environmental license, for the implementation of wind parks that benefit private investors (frequently external investors) and local high-income social groups but not local communities affected by the wind parks, which are kept “invisible” in reports to obtain the licence for project implementation. In that sense and in general, the authors have argued wind parks have been imposed on local communities, contributing to marginalize local people and interfering with their sociocultural and economic way of living. Since the communities in many cases do not have the official right over the land, they are also not able to receive revenues from the wind parks. According to the authors, strong political and economic institutions could reduce local conflicts and better distribute benefits of wind energy in the State. In that sense, Brannstrom et al. (2018) have reported the case of one community in Ceará in which land-tenure issues were not a problem and the community members have received revenues and benefits from the wind park installed on their lands.

4.3.5 Reflections on development models adopted

Considering the status quo of energy and poverty presented above, one can wonder whether current development models are reaching rural Ceará in a way to promote adequate opportunities among different social groups, seeking the reduction of extreme inequalities and poverty. This question is important because development models (frequently of economic development) are expected to have positive impacts on societies toward the reduction of poverty and inequalities and the increment of the quality of life among all their members (Collier, 2007; Ferreira et al., 2013; Ipea, 2015, 2010b; Sen, 1999). In the rural areas of Ceará, this expectation may not be realized if the situation and needs of poor people are not considered in a broad sense in development plans.

According to the literature analysed and some of the local actors interviewed in Ceará, this seems to be the case for the agribusiness model and the wind energy sector, at least. Regarding agribusiness, one can say that the centralized structure of big farmers and their representatives taking the decisions in the agrarian sector benefits primarily large farming while undermining small farming in Brazil in general and in Ceará in particular (detail in sub-section 4.3.2).

In relation to the wind energy sector, one can observe a lack of dialogue between private companies, the government of Ceará and local communities, which are not represented (or at least under-represented) in the implementation process of wind parks (Gorayeb et al., 2019; Sales, 2018). As a result, local communities have been more negatively than positively impacted by the wind energy sector in the State (detail in sub-section 4.3.4). That way, Brannstrom et al. (2019) have argued that wind energy in Ceará benefits the local elite and outside investors the most while marginalizing local communities, which is supported by a legal framework designed by weak economic and political institutions in the State.

It is worth noting that the lack of representativeness of local communities in decision processes is not restricted to the wind energy sector in Ceará, but it is an issue present in many energy projects in Brazil, especially in the Amazon region, which bring the stereotype of promoting development and energy security. Perhaps the most current example refers to the construction of the hydropower plant of Belo Monte in the municipality of Altamira, Pará, in the north of Brazil. Belo Monte is the fourth largest hydropower plant in the world with a power capacity of 11 GW (Presidência da República, 2019). The project of Belo Monte is tainted with corruption on a large scale (Mongabay, 2016a; Reuters, 2016; The Guardian, 2016a) and has caused severe socio and environmental impacts on traditional communities (G1, 2016a;

Southgate, 2016; The Guardian, 2016b). The impacts are of such magnitude that the Federal Public Ministry, an independent state institution in Brazil, launched a lawsuit charging the National government and the dam's builder Norte Energia with the crime of ethnocide against indigenous communities (Mongabay, 2016b, 2015; MPF, 2015).

In Ceará, there are examples of development models adopted that are inclusive and seek to reduce poverty and improve the quality of life in rural areas. These examples are presented and discussed in detail in the elements of the energy-poverty nexus in the next section 4.4. However, considering the development models presented above, one can say that poor people and communities are excluded from such development models (or at least under-represented in) since these models do not take the situation and needs of disadvantaged social groups into consideration and contribute to increase poverty and social inequality in Brazil in general and in Ceará in particular. This matter is further discussed in the next section 4.4 and in particular in the closing remarks of this chapter (section 4.6).

4.4 Elements and trends of the energy-poverty nexus in rural Ceará

The analysis of the data collected during the fieldwork campaign in Ceará supplemented by desk research (detail in section 4.2) allowed for the identification of a set of elements that seek to characterize the energy-poverty nexus in multi-dimensions in the rural areas of Ceará, following step one on the Integrative Approach to the Energy-Poverty nexus (detail in chapter three, sub-section 3.2.1). In that way, the elements consider (i) the knowledge and perceptions of the local actors interviewed, (ii) the observations made in the communities visited and (iii) literature research. For each one of the elements identified, two or three development trends were defined.

The time horizon is 2050 but the development of the trends can vary according to the nature of the elements. On the one hand, there are trends that are more sensitive than others and can fluctuate in the short and medium term like the price of electricity and economic stability. On the other hand, there are trends that can become a reality only in the long term, such as different levels of capacity building and education in rural areas.

In total, 16 elements were identified (Table 4.4). The elements represent important pieces of the energy-poverty nexus in rural Ceará while the trends represent current views of plausible future development states. A detailed description of each one of the elements and their related future states is presented after Table 4.4. Whenever possible, the descriptions provide a brief historical review that provides support and explores in more detail the status quo of energy and poverty in the rural areas of Ceará presented in the previous section 4.3.

Table 4.4: Elements of the energy-poverty nexus for rural Ceará and future trends

ID	Element	Trend X1	Trend X2	Trend X3
A	Household infrastructure (basic services)	A1: Universal water supply	A2: Universal water supply and basic sanitation	A3: Universal water supply, basic sanitation and waste management
B	Income source and asset accumulation	B1: Low resilience	B2: High resilience	-
C	Indoor air pollution	C1: High	C2: Low	-
D	Costs of electricity and cooking fuels	D1: High	D2: Low	-
E	Farmers' organization	E1: Weak cooperation	E2: Strong cooperation	-
F	Irrigation	F1: Manual or per gravity	F2: Mechanized - poor irrigation management	F3: Mechanized - adequate irrigation management
G	Capacity building and education	G1: Limited	G2: Universalized	G3: Universalized and contextualized
H	Rural policies	H1: Limited opportunities	H2: Large and strong opportunities	-
I	Electricity demand	I1: Basic human needs	I2: Basic human needs and productive chains	-
J	Electricity market organization	J1: Regulated market. Prosumers are not allowed to sell electricity surplus	J2: Regulated market. Prosumers can sell electricity surplus to the local distribution company	J3: Non-regulated market. Prosumers can sell electricity surplus in a non-regulated market
K	Grid infrastructure	K1: Reliable to supply basic human needs	K2: Reliable to supply productive chains and prosumers, besides basic human needs	-
L	Electricity price	L1: High	L2: Moderate	L3: Low
M	Rural population	M1: Migration flows	M2: Slightly decreasing	M3: Stabilized or slightly increasing
N	Environmental risks and uncertainties	N1: High	N2: Medium	-
O	Economic stability	O1: Unstable	O2: Stable	-
P	Governance	P1: Non-adequate	P2: Adequate	-

4.4.1 Household infrastructure (basic services)

There is a lack of basic infrastructure in rural households in Ceará, primarily regarding water supply, basic sanitation and waste management (see detail in Table 4.2, sub-section 4.3.1). This situation is worse in poor rural communities, according to local actors interviewed and the transect walks conducted in the communities visited. Electricity is an exception and is universalized. To achieve universalization, efforts started in the 1990s through the Project São José, which represents the main programme carried out by the State government to foster rural development. The Project São José is supported by the World Bank, focuses on projects of infrastructure and socioeconomic development and on strengthening smallholder farmers. In 2003, the National government launched the rural electrification programme Light for All (*Luz para todos*) that universalized electricity services in almost all the Brazilian states, including Ceará. Through the programme, electricity access is provided free of charge for poor rural families (IICA, 2011). A similar programme, Water for All (*Água para Todos*), was created in 2011 to universalize water supply in the country (Presidência da República, 2011). Currently, a partnership between the Programme Water for All and the Project São José seeks to provide rural families with water supply and basic sanitation.

Based on the current situation of household infrastructure, the following development trends are considered (electricity is assumed to remain a universalized service in all trends).
Trend 1: universalization of water supply with lack of basic sanitation and waste management.
Trend 2: universalization of water supply and basic sanitation with lack of waste management.
Trend 3: universalization of water supply, basic sanitation and waste management.

4.4.2 Income source and asset accumulation

Poor rural families in Ceará have a high dependence on the conditional cash-transfer programme *Bolsa Família*, retirements and remittances. In general, the families are smallholder farmers that practice subsistence farming in which most of the agrarian production is consumed by the family members. The surplus is often commercialized in farmer markets in surrounding areas like villages and cities close to the communities (CETRA, 2014) or it is sold at low prices to middlemen (Marques, 2016). The agrarian production is diversified and the efficiency of production is low, mainly due to the lack of knowledge among small farmers to produce more efficiently and incapability (lack of capital and adequate infrastructure) to modernise agrarian processes. Although farming plays a key role in rural Ceará, non-agrarian economic activities are also relevant, especially in the construction sector and local business (in many cases, informal economy).

To promote food security, increase income generation and preserve local culture, NGOs and rural communities created the Project Backyards for Life (*Quintais para a Vida*). The project, which is supported by the State government, encourages diversification and dissemination of native seeds and animals, commercialization of production surplus in local markets and the use of the home backyards as a space for education and preservation of local culture (CETRA, 2014; Leonel, 2014). Also, the State government in partnership with the International Fund for Agricultural Development (IFAD) created the Project Paulo Freire that seeks to reduce poverty and increase living conditions of family farmers in 600 poor rural communities with a low level of Human Development Index. The Project focuses on capacity building, socioeconomic development and environmental sustainability (SDA, 2020; SEMEAR International, 2020).

To support family farming, there are also funding lines at the national and state level, such as the National Family Farming Support Program (*Programa Nacional de Fortalecimento da Agricultura Familiar* - PRONAF) and the Development Fund for Family Farming (*Fundo de Desenvolvimento da Agricultura Familiar* - FEDAF), respectively. However, the lack of information companioned by the lack of advisory services and land tenure issues represent some barriers that make the access to funding difficult to be achieved by smallholder farmers.

These barriers combined with low educational levels and low levels of formal employment contribute to a lower income generation among poor people, promoting the development of an informal economy in rural Ceará. Indeed, it is not difficult to find economic activities, services or commercialization of goods that are not monetary based. For instance, animals are often used as money.

Thus, the following future trends are considered. **Trend 1**: Low resilience of income generation and asset accumulation. High familiar dependence on limited and/or insecure income sources, such as cash-transfer programmes or the cultivation of monocultures. In case of crisis (e.g. illness, economy, crop failure or intensive drought), poor families may have difficulties to overcome it. **Trend 2**: High resilience of income generation and asset accumulation based on diversification (e.g. mixed livestock, fruit growing, polycultures and non-agrarian economic activities) and secure income sources on which families can rely to reduce risks and better deal with crises.

4.4.3 Indoor air pollution

In the last years, the use of biomass as the main fuel source for cooking has decreased in rural households in Ceará. This does not mean, however, that people are abandoning biomass for cooking because, in general, they have two types of cookstoves at home: one based on biomass and another on LPG according to the local actors interviewed and the transect walks conducted in the communities visited. To some extent, electricity is also used for cooking (see detail in Table 4.2, sub-section 4.3.1). This demonstrates the practice of fuel stacking in rural Ceará, in which the families continue using biomass even after having access to other modern fuel sources. The practice of fuel staking is also common in many rural areas around the world (IEA, 2017).

According to local actors interviewed in this study and the informal talks with community members, there are two main reasons for the use of cookstoves based on biomass. The first is to reduce costs with LPG because families usually assume biomass as a non-cost fuel that can be gathered in the properties or surroundings. However, the time and physical efforts used to gather material is not included in these costs and, normally, women and girls are in charge of gathering biomass. The second reason is because the families have a tradition of cooking food using biomass. For them, the food tastes better when prepared in these stoves. Thus, cookstoves based on biomass are normally used for cooking meals that need a long time to cook, such as beans and meat, while LPG stoves are used for short-time cooking.

High indoor air pollution is a common problem in poor rural households because the cookstoves based on biomass frequently work with open combustion chamber and do not have chimney to expel the smoke outside the houses. In general, the kitchens are poorly ventilated. In a recent past, there was a partnership between the State government and an NGO for the construction of improved stoves based on biomass. In total, 25,000 improved stoves were constructed and community members were instructed to build them, contributing to increase income generation. However, the project terminated and did not have continuity. There are also some initiatives lead by NGOs towards the local production and use of biogas for cooking. Finally, it is worth noting that indoor air pollution seems to be a concern often present on the agenda of local NGOs, but not on the agenda of governments (national, regional or local) and families.

For the future, it is expected that cookstoves based on LPG will continue to be used in almost all rural households but it is not expected that they will substitute those based on biomass. Thus, the following trends are considered: **Trend 1**: High indoor air pollution remains a problem due to three main reasons. The first refers to the lack of awareness of hazards to human health caused by particulate matter. The second is because low-income families do not have financial resources to change current means of cooking based on biomass to efficient and healthy ones, including well-ventilated kitchens. The third is the lack of adequate policy and programmes to increase access to clean cooking facilities. **Trend 2**: Low indoor air pollution by the adoption of clean means of cooking and well-ventilated kitchens. Clean means of cooking would include cookstoves based on LPG, biogas, solar and electricity as well as improved cookstoves based on biomass. For the cases of biogas, solar and biomass, community members could be trained to build the stoves, as well as well-ventilated kitchens.

4.4.4 Costs of electricity and cooking fuels

The costs of electricity and cooking fuel have a direct impact on the financial capacity of poor families and can compromise people's capacity to meet additional basic human needs. In Brazil, low-income families can have up to a 65% discount on their electricity bill (Ministério da Cidadania, 2019) and receive aid to afford LPG through the Programme *Bolsa Familia* (Governo do Brasil, 2017). However, in rural Ceará, the costs of electricity and cooking fuels are considered high among poor families. According to local actors, this is so not due to the lack of subsidies, but because the family income is in general low (aggravated in times of economic crisis or the current COVID-19 pandemic). Also, in many cases, families do not have access to the subsidies available due to the lack of knowledge about the social programmes available or the lack of formal documents to be included in the programmes.

The following trends are considered for the future: **Trend 1**: High costs of electricity and cooking fuels. Poor families have difficulties to afford modern energy services as is the case nowadays. **Trend 2**: Low costs of electricity and cooking fuels. Mainly driven by an increment on the family income, poor families have more facility to pay for modern energy services.

4.4.5 Farmers' organization

There are national and state policies to support collaborative work of farmers for land acquisition and development of productive chains (MDA, 2003). On the one hand, there are already some good initiatives of collaborative work in Ceará, such as cooperatives of fruit growing and craftwork associations. There is also the Milk Programme (*Programa do Leite*) that represents an additional positive example of collaboration that has developed and consolidated the milk production chain in Ceará, involving the State government, large and small farmers (ADECE, 2017). The programme also aims to increase food sovereignty and is present in 179 municipalities (Ceará has a total of 184 municipalities), benefiting more than 196,000 low-income families (Governo do Estado do Ceará, 2020).

On the other hand, in general, farmers do not believe in cooperatives, associations or public-private contracts. This disbelief is mainly rooted in negative experiences of non-adequate governance and corruption involving collaborative projects at different levels (national, regional or local).

As mentioned by local actors interviewed in this study, one such negative experience refers to the participation of family farmers in the supply chain of biodiesel. In 2008, the publicly-held company Petrobras started the operation of a new refinery in the municipality of Quixadá, with a capacity to produce up to 109 million litres of biodiesel per year (Petrobras, 2017). The refinery is considered one of the most modern refineries installed in the country for the production of biodiesel (Diário do Nordeste, 2017). One of the proposals of Petrobras was to have long-term agreements with family farmers to supply oilseeds from castor beans (Petrobras, 2010) since the plant is well adapted to semi-arid conditions (Garcia and Romeiro, 2010). Until 2011, the company had contracts with more than 21,500 family farmers, which had a peak production of 5,800 tons of oilseeds that year (MDA, 2017).

Although the central idea was to run the refinery mainly using oilseeds from castor beans, the main raw material used since the beginning of the activities was soybeans coming from other Brazilian regions (Diário do Nordeste, 2013). Through the years, the falling prices for commercialization of castor beans and the concurrence with soybeans led to the decrement of the participation of family farmers in the supply chain of biodiesel (Diário do Nordeste, 2017, 2013). By the end of 2016 and with contracts with around 1,300 family farmers, Petrobras decided to close the refinery (Folha de São Paulo, 2016). Consequently, in only eight years a complete productive chain with high economic capital and social investments was built and dismantled in Ceará. For Petrobras, it was a matter of driving efforts towards more rentable projects, as the company informed in an official note (Folha de São Paulo, 2016). For the region of Quixadá, the refinery created a high development expectation that culminated in strong disappointment (Diário do Nordeste, 2017).

For the future, the following trends are considered for farmers' organization: **Trend 1**: Weak cooperation. Most of the farmers do not believe in collaborative organizations. They can work together to access funding but tend to work individually as soon as funding is available. **Trend 2**: Strong cooperation. A trusted environment is fostered among farmers, providing an appropriate basis for collaboration. Transparency, capacity building and education represent key aspects towards the development of collaborative organizations.

4.4.6 Irrigation

There are initiatives with irrigation systems that have contributed to developing the sectors of fruit growing and milk production in Ceará (ADECE, 2012). However, in general, there is a lack of water supply for agrarian production, especially among smallholder farmers. Often, family farmers rely on cisterns (rainwater) and wells that provide a minimum of water to irrigate few vegetable beds and maintain animals. Due to the high concentration of mineral salts in the ground water and to elevated rates of water evaporation (typical of semi-arid regions), the soils in Ceará are very sensitive to irrigation. Thus, poor irrigation techniques commonly leads to soil salinization and land degradation (Fundação Konrad Adenauer, 2002; Waves, 2001).

Regarding strategies to increase water availability, there is a national programme to install cisterns at low costs in rural areas as an alternative to mitigate the effects of droughts (MDS, 2017). Also, there is a large national project to transport water from the river São Francisco (one of the biggest rivers in Brazil) to three north-eastern states, including Ceará. Nevertheless, according to local actors, it is not expected that family farmers will benefit from the project of water transportation because its main objective is to increase the reliability of water supply in urban centres.

The following development trends are considered: **Trend 1**: Manual or per gravity irrigation. The lack of water supply for agrarian production remains a concern, in particular among family farmers. **Trend 2**: Mechanized - poor irrigation management. Once water and adequate electricity supply are available for production, the use of mechanized irrigation systems is boosted. However, the irrigation systems adopted are not appropriate for semi-arid regions, leading to overuse of water resources, soil salinization and land degradation. **Trend 3**: Mechanized - adequate irrigation management. Once water and adequate electricity supply are available for production, the use of appropriate mechanized systems for semi-arid regions is promoted. Advisory services and agrarian policies can play an essential role to determine optimal irrigation systems, avoiding negative effects of poor irrigation management.

4.4.7 Capacity building and education

There is a national policy to promote capacity building of farmers through advisory services and technical assistance (Presidência da República, 2010a), which in Ceará is executed by governmental agencies and NGOs. In practice, however, there is a lack of capacity building, especially for smallholder farmers. According to local actors interviewed, the lack of financial resources and adequate policy strategies are two of the main reasons for the non-universalization of advisory services and technical assistance in rural areas. When these services reach rural communities, one concern arises regarding the development models promoted by the National and State governments, which, often, are external models not adapted to the local context. There are some experiences, most of them carried out by NGOs and the State government, in which the development models adopted are contextualized to the reality of the communities. In general, contextualized models have proved positive results in improving the quality of life in rural areas, in particular in poor rural communities.

Regarding education, this is universalized but the number of rural schools has decreased in the last years (INEP, 2017). High operational costs and precarious infrastructure of public rural schools, low population density (Folha de São Paulo, 2014a; G1, 2016b; O Povo, 2015) and the advance of the agribusiness model in rural areas (Jornal O Globo, 2011) have been pointed out as reasons for the reduction of the number of rural schools. Consequently, to attend school, many students need to go to cities. Moreover, the educational system is, in general, not adapted to the rural context, although Brazil has a legislation ensuring that the education should be adapted to the context of the students (cf. Presidência da República, 1996).

According to local actors interviewed, the education that rural people have access to, is a traditional education focused on the urban context. Consequently, the school calendar and teaching methods pay less or no attention to the context of rural areas. In this traditional education, urban areas, high-tech agriculture, large farming and monoculture represent progress and development, while family farming and its community context represent backwardness. This traditional education was already reported by scholars in Brazil (e.g. Arroyo et al., 2011; Freire, 1994; Reis, 2015; TV Caatinga, 2016). There are some positive examples of schools applying an education contextualized for rural communities, in which the rural context, its problems and challenges are debated in the classrooms and involve community members in an active and participatory way. Often, these examples are promoted by the National Education Programme for Land Reform (*Programa Nacional de Educação na Reforma Agrária*) (Ipea, 2016a; Presidência da República, 2010b).

Considering the current situation described above, the following trends are considered: **Trend 1**: Limited capacity building and education. No significant advances are achieved to improve capacity building and education and the situation remains similar to today's. **Trend 2**: Universalized. Advisory services and technical assistance are universalized and education is improved, but little attention is given to contextualize these services to the local reality of rural areas, particularly in poor communities. **Trend 3**: Universalized and contextualized. Advisory services and technical assistance are universalized and education is improved. A contextualized and inclusive approach is adopted that considers local problems, challenges and opportunities faced by rural families.

4.4.8 Rural policies

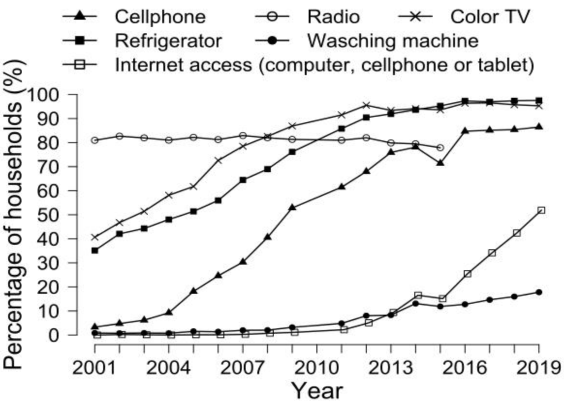
As mentioned in the previous elements of the energy-poverty nexus in rural Ceará, there are good initiatives to support rural families such as the projects Backyards for Life, São José and Paulo Freire, PRONAF, FEDAF, the Milk Programme and the programmes Light for All and Water for All (detail in sub-sections 4.4.1, 4.4.2 and 4.4.5). There is also legislation to ensure technical assistance and adequate education in rural areas, as presented in sub-section 4.4.7. However, poor families frequently have no access to governmental programmes and policies. According to local actors, lack of information, mistrust and poor management of financial resources represent key factors that hinder poor rural families benefiting from policies and programmes in a broad and effective way.

For the future, the following trends are considered: **Trend 1**: Limited opportunities. Rural policies and programmes do not reach most disadvantaged social groups in rural Ceará and are not effective in addressing the main challenges faced by poor rural people and communities, being inefficient to reduce the gap of opportunities that could result in less social and economic inequalities. **Trend 2**: Large and strong opportunities. Rural policies and programmes are more effective in addressing sociocultural and economic challenges faced by rural people and contemplate different social groups with adequate opportunities according to the needs of these groups, seeking to reduce extreme inequalities among them.

4.4.9 Electricity demand

According to local actors interviewed in this study, poor rural families use electricity mainly to meet basic human needs while consuming from 30 to 100 kWh of electricity per month per household. This information is of relevance because, considering the current electricity consumption in rural Ceará (detail in sub-section 4.3.3), it may indicate disparities among different social groups, where high-income groups consume much more electricity than low-income groups. To corroborate this indication, the concentration of land discussed in sub-section 4.3.2 also represents an indicator for the existence of disparities in electricity consumption between high- and low-income social groups.

Although electricity is generally used for basic human needs by poor families, it is important to note that this use represents an advance in the quality of life of these families, especially in comparison with about 10 years ago when they had no access to electricity. This improvement in the quality of life may be reflected by the proportion of households that acquired domestic electric appliances in the last years and have access to the internet in rural Ceará (Figure 4.3).



Notes: Data for radio appliance are available until 2015.

Own calculation (unweighted) based on data from the PNAD sample survey from 2001 to 2019.

Source: IBGE, 2020a

Figure 4.3: Use of electric appliances and internet in rural households

For the future, two development trends are considered: **Trend 1**: Electricity demand continues to increase slowly and the pattern of electricity consumption remains similar to today's. **Trend 2**: Electricity demand increases at a more accelerated rate, supporting productive chains and basic human needs also among poor rural people and communities.

4.4.10 Electricity market organization

In Brazil, there are two electricity markets: one regulated and the other non-regulated. Households are supplied by the regulated market, where consumers buy electricity from the distribution utility responsible for a specific region. In Ceará, there is one distribution utility and the demand is supplied by centralized power plants (detail in sub-section 4.3.3). The participation of micro (≤ 0.075 MW) and mini (0.075 ≤ 5 MW) distributed generation (prosumers according to ANEEL (2015)) is low in the electricity mix of Ceará. In 2019, the power capacity of micro and mini distributed generation installed in the State reached 76 MW, corresponding to 1.7% of the total power capacity installed (EPE, 2020b). However, the participation of this kind of distributed electricity generation is expected to increase in the medium-term due to regulatory changes which took place in Brazil in 2016 (ANEEL, 2016) and due to policies to foster distributed generation (MME, 2015b). Among the measures adopted to stimulate micro and mini distributed generation, are: a) tax exemption for small generators to use the grid as a virtual battery, b) possibility to create cooperatives and associations of electricity generation, c) reduction of import tax on equipment and d) funding lines. For example, the PRONAF and the FEDAF offer specific funding to promote the use of renewable and distributed generation among family farmers (Banco do Nordeste, 2016; Governo do Estado do Ceará, 2008).

Currently, it is not possible to commercialize electricity surplus from mini and micro distributed generation, but to receive credits in kWh for their own use. Thus, the following trends are considered: **Trend 1**: Dwellings are supplied by a regulated market and prosumers are still receiving credits in kWh for the electricity surplus injected into the grid (similar to nowadays). **Trend 2**: Dwellings are supplied by a regulated market and prosumers can sell electricity surplus to the local distribution utility. **Trend 3**: Dwellings are supplied by a non-regulated market and prosumers can sell electricity surplus in a non-regulated market.

4.4.11 Grid infrastructure

Limited grid infrastructure represents a barrier to the development of productive chains and to the expansion of distributed electricity generation in the rural areas of Ceará, in particular among poor families and communities. In general, these families and communities are supplied by mono-phase and low power distribution grids, which can support basic human needs and subsistence farming. For big farmers, the grid infrastructure does not represent a concern in the sense that, in general, they have access to distributions grids of better energy quality.

For the future, the following trends are considered: **Trend 1**: The electricity grid is still able mainly to support basic human needs among poor people and communities (similar to today's). **Trend 2**: The electricity grid become reliable to support productive chains and prosumers, besides supporting basic human needs, in rural Ceará in general. Improvements in infrastructure (e.g. grid reinforcement and replacement of mono by three-phase grids) take place.

4.4.12 Electricity price

In rural areas, electricity is subsidised and families pay around R$ 0.45 (~USD 0.08) per kWh (reference year of 2021). This value can be reduced up to R$ 0.18 or up to R$ 0.31 per kWh for low-income families with a consumption up to 30 kWh or up to 100 kWh per month, respectively (ENEL, 2020). The following development trends are considered: **Trend 1**: High electricity price (about R$ 0.65 per kWh). **Trend 2**: Moderate electricity price (about R$ 0.55 per kWh). **Trend 3**: Low electricity price (about R$ 0.45 per kWh).

4.4.13 Rural population

Similar to other Brazilian states, rural people in Ceará are migrating to urban centres, although the State presents urbanization rate lower than the Brazilian average (detail in Table 4.2, sub-section 4.3.1). Currently, the rural population is decreasing at an annual rate of 0,05% (PNUD et al., 2013). In general, people (especially the young) are leaving regions with low economic activities and precarious access to basic services towards cities, looking for better opportunities.

Although the rural population is decreasing, no migration flows to the southern regions of Brazil have been observed in the last years, as occurred in the 1990s or years before (detail in sub-section 4.3.1). The monetary stabilization and investments in social policies occurred in the last two decades represent the main factors that contributed to stop migration flows.

For the future, the following trends are considered: **Trend 1**: Migration flows. Mainly driven by low economic activities, lack of social services and policies and adverse climate conditions, poor families migrate to other regions as occurred up to the 1990s. **Trend 2**: Slightly decreasing. Rural population decreases following current rates, young people being the most willing to migrate. **Trend 3**: Stabilized or slightly increasing. Rural areas become more attractive in terms of basic services and socioeconomic opportunities for better quality of life and raising income generation.

4.4.14 Environmental risks and uncertainties

Climate change, overuse and degradation of natural resources increase risks and uncertainties in rural areas. Consequently, they can reduce income generation and, in the worst case, the capability of families to produce and stay on their lands, forcing them to migrate. For the future, the following trends are considered: **Trend 1**: High environmental risks and uncertainties. Drought periods become more frequent and last longer. Natural resources (e.g. soil, water and biomass) are overused and become more degraded, hindering the capability of poor families to produce and live on their lands. **Trend 2**: Medium environmental risks and uncertainties. Drought periods become more frequent and longer. However, adaptation measures to live with the drought are promoted and natural resources are better managed, allowing families to go on producing in the semi-arid environment.

4.4.15 Economic stability

In the recent past of the Brazilian economy, it is possible to observe two distinct periods. The first from the 1980s until 1994 was characterized by economic stagnation, fiscal imbalance, instability and high inflation rates. The second, after 1994, is characterized by monetary stabilization, privatizations and economic deregulation, that have contributed to open the Brazilian market to external investments (Cardoso, 2013). In between, economic crises can be identified leading to economic instability and recession, uncertain environment for investments, unemployment and the increment of poverty such as occurred from 2014 to 2016 in the so-called “big Brazilian recession” (Oreiro, 2017). It should be noted that the current COVID-19 pandemic is also negatively impacting the Brazilian economy, but to what extent is still unclear.

Fur the future, two trends are identified. **Trend 1**: Unstable economy leading to economic recession and uncertain environment for investments. **Trend 2**: Stable economy with reduced market risks and uncertainties.

4.4.16 Governance

Governance is here considered at the macro level including the national government of Brazil and the state government of Ceará. Adequate governance is key for the design and implementation of policies and programmes to promote equity, socioeconomic development and the well-being of society. But non-adequate governance can increase the gap between rich and poor people and is frequently associated with lack of transparency in decision-making processes and corruption not only at the political level but also in the economic market.

Thus, this study considers adequate and non-adequate governance as two future states that can take place in Brazil in general and in Ceará in particular. **Trend 1**: Non-adequate governance. High socioeconomic inequalities remain a concern in Brazil in general and in rural Ceará in particular and governments are not able or willing to bring forward political agendas to reduce poverty and high socioeconomic inequality. **Trend 2**: Adequate governance. Governments of Brazil and Ceará pay more attention to promote vulnerable and disadvantaged social groups, aiming to reduce the gap of opportunities for different social groups and to reduce poverty and high socioeconomic inequality.

4.5 Interrelating the elements of the energy-poverty nexus in rural Ceará

This section focuses on the causal interrelationships between the 16 elements that compose the complex and dynamic system of the energy-poverty nexus in rural Ceará. Defining causal interrelationships corresponds to the second step of the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, sub-section 3.2.2). In the case of rural Ceará, all the causal interrelationships were defined by the author of this dissertation based on the inputs of local actors as well as on desk research. The next sub-section 4.5.1 discourses about the importance of multidiscipline and the context described by the elements in the process of setting their interrelationships. Then, sub-section 4.5.2 addresses the procedure to systematize and interrelate the 16 elements, composing the multifaceted socio-energy system of the energy-poverty nexus in rural Ceará.

4.5.1 Multidiscipline and context of the system elements

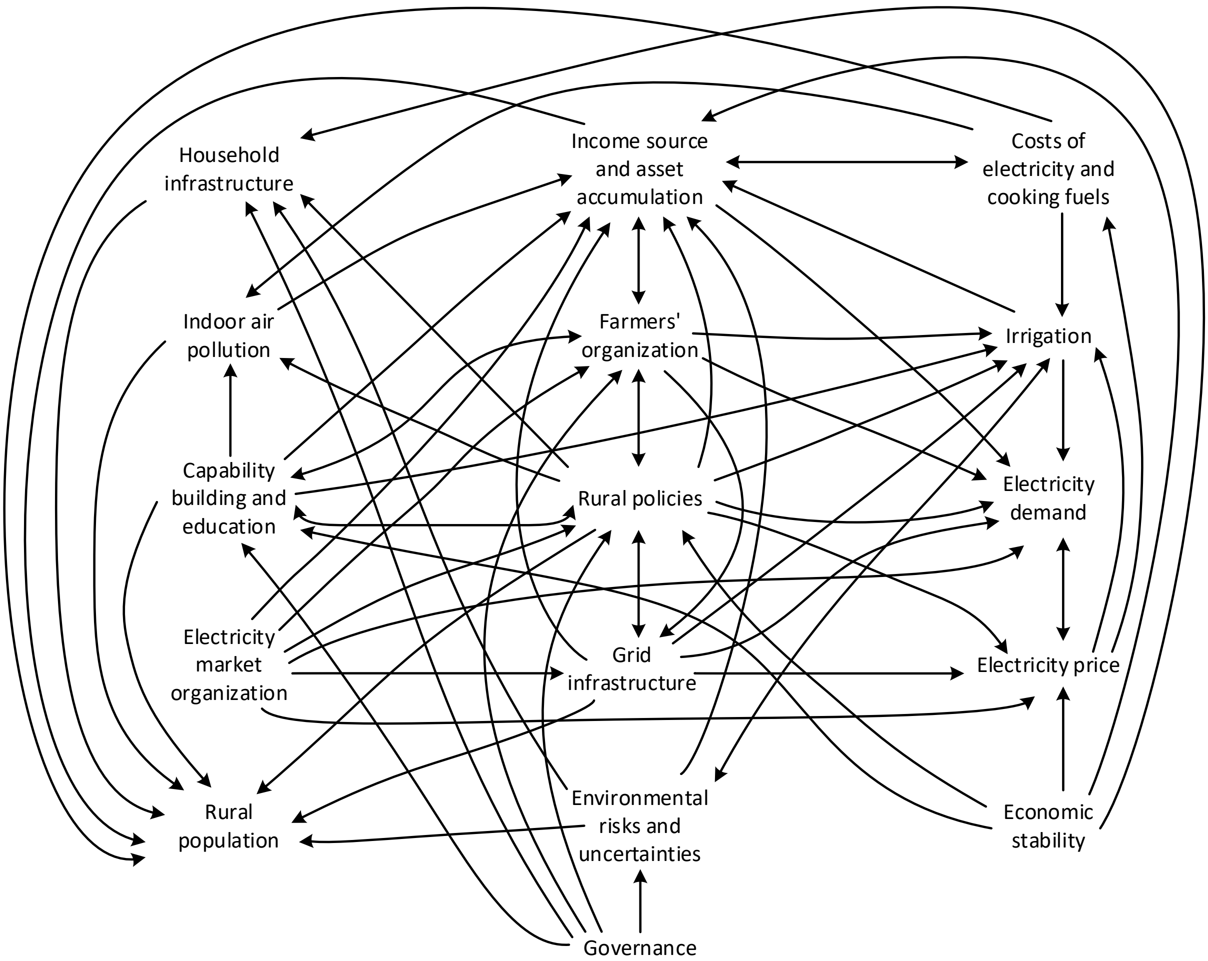
When considering the elements described in section 4.4 as pieces of a complex and dynamic socio-energy system, it is important to note two key characteristics of the elements that contribute to interrelate them. The first is that the elements cross disciplines and cover a wide range of subjects, as is expected by the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, section 3.2). For instance, the element "*Indoor air pollution*" does not describe the matter only as a consequence of the lack of access to clean cooking facilities, as is often presented in the literature, but as a matter that at least involves five dimensions, namely: technological (i.e. inadequate cookstoves), economical (i.e. low capacity of the families to afford clean cooking fuels, adequate stoves and properly ventilated kitchens), sociocultural (i.e. the family preference for using biomass for cooking and the gender inequality in gathering it), environmental (i.e. availability of biomass) and political (i.e. the limited capability of governments at different levels to promote strategies and actions towards the reduction of high indoor air pollution).

The second characteristic refers to the context described by the elements since they do not only describe current states and plausible future development trends but also try to find reasons to explain current states. For instance, the element "*Farmers' organization*" does not only explain *how* the farmers are organized in Ceará but it seeks to shed some light on understanding *why* the farmers tend to work individually. In that sense, there are cases of non-adequate governance and negative experiences of cooperation in Ceará, involving also corruption, that contribute to increasing the distrust of rural people on collaborative projects (detail in sub-section 4.4.5). There is also a lack of capacity building, in particular among small farmers (detail in sub-section 4.4.7). Thus, one can note that the surrounding environment on which the farmers live and act does not represent an adequate environment to promote cooperation. In such an inadequate environment, it is not surprising that farmers are not willing to join their efforts.

4.5.2 The socio-energy system of the energy-poverty nexus in rural Ceará

The two characteristics presented above (multidiscipline and context) are of relevance because they help to interrelate the system elements. That means that the multifaceted elements presented in section 4.4 are not isolated and one can influence or be influenced by another one, composing the socio-energy system of the energy-poverty nexus in rural Ceará.

For instance, the element "*Income source and asset accumulation*" can be directly related to "*Costs of electricity and cooking fuels*" because income influences the capacity of families to pay for different energy sources. Similarly, the financial situation of families can have an influence on deciding to live or not in rural areas. Thus, there is a direct relationship between "*Income source and asset accumulation*" and "*Rural population*". The element "*Capacity building and education*" can also be related to "*Income source and asset accumulation*" because it is expected that the level of advisory services and education have an impact on family income. By doing so with the 16 elements of the energy-poverty nexus in rural Ceará, a total of 66 relationships were identified, resulting in a map of interrelationships between the system elements (Figure 4.4). This map of interrelationships will be useful for the third step of the Integrative Approach (detail in chapter three, sub-section 3.2.3), which aims to analyse how the energy-poverty nexus may unfold in the future considering all level of interrelationships between the system elements and their trends. The third step of the Integrative Approach is applied for the case of rural Ceará in the next chapter of this study.



Note: The arrows connecting the system elements indicate direct relationship and respective direction of influence between the elements interconnected.

Figure 4.4: Map of interrelationships between the elements of the energy-poverty nexus in rural Ceará

In the map, it is to be noted that almost all elements have indirect interrelationships. For instance, there is not a direct relationship between "*Farmers' organization*" and "*Rural population*". However, according to the map, the way in which farmers are organized has a direct influence on the elements "*Income source and asset accumulation*", "*Capacity building and education*", "*Rural policies*" and "*Grid infrastructure*", while these elements are directly related to "*Rural population*". Consequently, there is an indirect connection between "*Farmers' organization*" and "*Rural population*".

A last aspect to be mentioned about the map refers to the classification of each of the elements according to its endogenous or exogenous nature. Generally, most elements of a system have an endogenous nature, which means that they can be influenced by other elements considered inside the system. On the other hand, exogenous elements refer to those that are not influenced by internal elements. When systematizing the energy-poverty nexus in the rural areas of Ceará, the elements "*Electricity market organization*", "*Economic stability*" and "*Governance*" were assumed as exogenous variables. This does not mean, however, that these elements are immutable. It means that external factors not considered in the system may exercise such an influence over them that it is not possible to draw insights about the behaviour of these elements considering only those present inside the system. For instance, "*Governance*" can influence "*Economic stability*". However, external markets play an essential role in a globalized economy such as the Brazilian one. Consequently, it would be inadequate to consider that "*Economi*c stability" is driven only by "*Governance*" inside the system described.

4.6 Closing remarks - The man-made conjuncture that generates poverty

The status quo of energy and poverty presented in section 4.3 companioned by the elements of the energy-poverty nexus presented in section 4.4 shown a context in which advances have been achieved in the last years to reduce poverty in rural Ceará. However, poverty is still a concern in these areas and has increased in the last five years due to the Brazilian economic recession. Poverty is also expected to increase due to the current COVID-19 pandemic.

On the one hand, efforts to reduce poverty and to increase the quality of life can be observed through the universalization of electricity access (detail in sub-sections 4.3.1 and 4.4.1) and through the different initiatives adopted at social and economic levels, such as legislation to ensure advisory services and adequate education (detail in sub-section 4.4.7), electricity subsidies (detail in sub-section 4.4.9), the projects Backyards for Life, São José and Paulo Freire, the programmes Water for All, *Bolsa Família*, PRONAF and FEDAF and governmental incentives to promote farmers' cooperation and family farming (detail in sub-sections 4.4.1, 4.4.2, 4.4.5 and 4.4.8).

On the other hand, the status quo and the elements of the energy-poverty nexus also report an inadequate social, political and economic conjuncture in which policies, programmes and development models do not reach most of the social groups living in poverty or do not properly meet their needs to enable them moving out of poverty. In some cases, these groups are even excluded from developing plans, as can be observed in the agribusiness model, the expansion of the wind energy sector in Ceará and the case of the biodiesel refinery in the municipality of Quixadá (detail in sub-section 4.3.2, 4.3.4, 4.3.5 and 4.4.5). Additional examples are provided in the next chapter of this dissertation, in particular in sub-section 5.4.1.

That way, one can argue that this inadequate conjuncture is present at different levels (local, regional and national) and is resistant to change towards the construction of a less unequal society with no poverty. In other words, one can argue that this conjuncture is, in fact, an unequal conjuncture that benefits determined social groups, mainly well-off and high-income people, that already hold the economic power in the country, while keeping poverty a common reality among people from the lower classes[4]. This does not suggest that poor people do not benefit from such a conjuncture, but that the level of benefits is limited and not enough to reduce extreme inequalities between well-off and poor people. Such a conjuncture is also reported by other scholars in Brazil (e.g. de Castro, 1984; Freire, 2005; Ipea, 2016b; Maluf et al., 2011; OXFAM, 2017; Souza, 2019, 2018) and is rooted in the historic development of Brazilian society.

[4] According to Souza (2019), the Brazilian modern society can be divided into four classes: the elite, the middle class, the working class and the "riff-raff". Such a division considers the formation and reproduction of different social classes firstly as a sociocultural phenomenon and not only as an economic one. Being different from the concept of social classes based solely on income, understanding social classes as a sociocultural phenomenon reveals that people from different classes have access to different opportunities and forms of capitals (e.g. economic, social relationships, cultural and technical capital), which are decisive for an individual to succeed or fail in a competitive world. The *elite* represents a small fraction of the Brazilian population (e.g. owners of big industries, building contractors, large investors and big farmers) that concentrates the economic power in the country. This economic power allows it to invest in key economic sectors, as for example, in infrastructure, business models and agribusiness and to create jobs. The *middle class* is represented by those people with high cultural capital, such as judges, university professors, doctors, engineers and the press. The fact that the middle class has high cultural capital does not mean that it does not have access to the economic capital or to the capital of social relationships. Nevertheless, the access to these capitals (especially the economic one) is limited when compared to the elite. The *working class* is represented by people with a small access to economic capital, but with sufficient access to cultural and, especially, technical capital to execute determined functions useful in society. Examples of people from the working class are teachers, operators, builders, small farmers and the police. Finally, there is a social class that Souza (2018) provocatively calls as the "riff-raff" of new "slaves", in reference to the excluded and marginalized in Brazilian society. About one-third of the Brazilian population can be included in this class that live in poverty and excluded from society with no perspective of social ascension if no public action is taken to change the social preconditions that reproduce this class. Convicts, informal workers, maids, street dwellers, waste pickers and prostitutes are typical examples of people from this class. The people from the "riff-raff" have no or very limited access to different forms of capital (economic capital, capital of social relationships, technical capital and cultural capital). Thus, the only "capital" that these people can use is their own body in form of muscular strength to do dirty, heavy and badly paid jobs or in form of sexual services in the case of prostitutes. These four classes can be roughly subdivided into upper classes (the first two) and lower classes (the last two) (Souza, 2019, 2018). For the purposes of this study, this last classification of upper and lower classes seems to be appropriate and sufficient. This is so because this study focuses on poverty, which affects people from the lower classes.

Even when development programmes reach poor people in a way to promote them, these programmes, in general, do not contemplate additional needs that could contribute to reduce social and economic inequalities. This seems to be the case of the programme Light for All that universalized access to electricity in Ceará. The programme improved the quality of life of poor people by providing electricity to mainly supply basic human needs. Nevertheless, the provision of electricity to supply productive chains is still deficient in poor rural communities (details in sub-sections 4.4.9 and 4.4.11). In a similar way, there is a lack of adequate public services (e.g. education and health care) in these communities, which, if available, could be enhanced by the use of electricity.

Consequently, one can say that, in general, the main difference between before and after the electrification of poor rural communities is the follows: before, these communities were poor without access to electricity. Now, they are still poor, but with a better quality of life through the access to electricity. Thus, although the programme Light for All represents an improvement on the quality of life of poor people, it is not enough to provide significant changes to break down the unequal conjuncture that causes poverty in Brazil in general and in Ceará in particular. This is of importance and reinforces the reflections and arguments presented in chapter two, sub-sections 2.7 and 2.8, that the end of energy poverty or the provision of modern energy access in poor rural communities is essential to reduce poverty but not enough to do so.

Finally, it is worth noting that this unequal conjuncture is man-made, which highlights that poverty is also a man-made phenomenon and not a fatalism in modern societies with no one being responsible. This is important because it points out the existence of dominant social groups (e.g. big farmers and large investors in the energy sector in the context of this study) in Brazil and in Ceará that are reluctant to social and economic changes, contributing not only to keep poverty and high inequalities but also to explore and oppress those already living in poverty. The existence of dominant social groups in Brazil and in Ceará does not suggest that such groups do not exist inside the communities among people from lower classes. However, since this study dealt with the macro-level of rural Ceará, it is not possible to infer about dominant social groups inside poor rural communities. This matter is further discussed in chapters five, sub-section 5.4.4, and seven, section 7.5. Moreover, the conjuncture presented above does not mean, however, that it is unchangeable. The more knowledge is generated to understand it and the mechanisms that generate poverty, the easier it may be to create effective strategies to foster a less unequal society without poverty.

Appendix - Supplementary material for chapter four

Guideline of topics and questions for discussion during the interviews in Ceará.

I - Electricity access and use

a) How access has electricity been/is being provided in rural areas (e.g. electrification programmes)?

b) Are there cases of off-grid solutions? If yes, which technologies have been used and who provides the maintenance of these systems?

c) What is the quality of the electricity that is delivered to rural areas?

d) Are there limitations on electricity access? If yes, which limitations exist? How is it possible to overcome these limitations?

e) How can the infrastructure of the distribution grid be characterized in rural areas, in particular for poor families and communities?

f) How have poor families and communities benefited from electricity access?

g) What electricity is used for in rural areas (i.e. basic human needs and production)? Are there different forms of use according to different social groups? In the case of electricity use for production:

i) Which productive chains have been promoted through electricity?

ii) Do rural people have access to programmes and training to foster productive chains using electricity?

iii) Which are the limitations in the use of electricity in productive chains? How is it possible to overcome these limitations?

h) Which are the potential uses of electricity in the rural areas of Ceará?

i) How do subsidies work in rural areas regarding electricity consumption?

II - Electricity production

a) Considering that the electricity produced in Ceará comes from central power plants, what is the current situation in the use of decentralized energy systems in the State?

b) Considering different aspects (e.g. market regulation, economy, social and environment), does it make sense today to expand the use of decentralized energy systems in rural areas of Ceará?

c) Is the grid infrastructure in rural areas able to support energy production from decentralized systems?

d) Who can benefit today (and how) from decentralized energy systems?

e) Are there incentives for the use of decentralized energy systems? Which incentives would be important to expand the use of these systems?

f) Which barriers exist for the expansion of decentralized energy systems?

g) How can poor families and communities benefit from decentralized electricity systems?

h) Which technologies would be appropriate for decentralized energy systems in the rural areas of Ceará?

III - Means of cooking

a) Which energy sources are used for cooking in the rural areas of Ceará?

b) In case of LPG, do poor families have subsidies to buy LPG cylinders? If so, is it possible to say that LPG is affordable for poor people?

c) In case of biomass or charcoal:

i) Why are rural people still using biomass or charcoal as cooking fuel? Are there cultural, social or economic reasons for the use of these fuels?

ii) Who is responsible in the families for gathering biomass?

iii) Where is the raw material coming from?

iv) How are kitchens ventilated?

v) Which kind of cookstoves do rural families use?

vi) Are there programmes for biomass management in rural communities?

vii) Are there programmes for the substitution from cookstoves based on biomass to technologies based on other energy sources?

IV – Poverty, socioeconomic inequalities and quality of life

a) Which strategies have been adopted for the reduction of poverty and inequalities in rural areas? Who is responsible for these strategies and who executes them?

b) What is the current situation regarding the provision of additional basic services in rural areas (except electricity services)?

c) Which have been the impacts of energy services (electricity and means of cooking) on the reduction of poverty and inequalities and the improvement of the quality of life in rural areas?

d) Which factors have contributed to stopping migration flows to other Brazilian regions?

e) How are farmers organized in rural areas?

f) What is the current status of education in rural areas (e.g. content, access, illiteracy levels)? Is the education contextualized for the reality of rural families?

g) Which factors contribute to the maintenance of poverty and inequalities in rural areas? (e.g. environmental aspects, sociocultural structures and access to basic services).

Chapter five

Context energy scenarios for the energy-poverty nexus in rural Ceará

5.1 Introduction

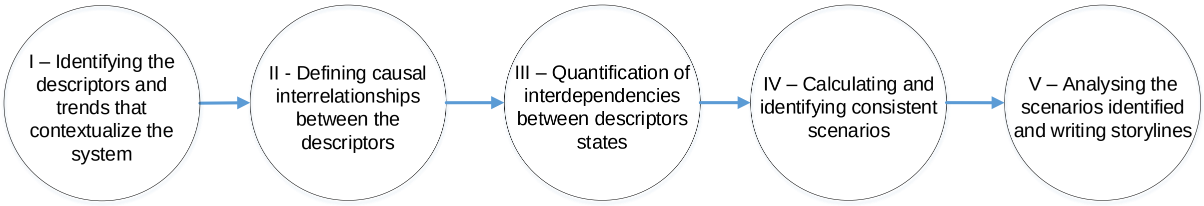
This chapter focuses on the analysis of the energy-poverty nexus in the rural areas of Ceará, using the scenario technique Cross-Impact Balance Analysis (CIB) (Weimer-Jehle, 2006) to design future views and identify possible conditions in which clean means of cooking and decentralized electricity generation can contribute to reduce poverty in the long term in rural Ceará. This corresponds to step three of the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, sub-section 3.2.3).

This study opted to use CIB because this scenario technique is able to deal with complex and multifaceted systems by analysing the level of influences between system elements and their future states (Weimer-Jehle, 2006). Also, CIB improves transparency, traceability and objectivity in the construction of context scenarios (Lloyd and Schweizer, 2014; Weimer-Jehle et al., 2020, 2016). Last but not least, the scope of this study considering the macro region of rural Ceará, that is influenced as well by the national context as discussed in the previous chapter, and the actors involved in this research allowed for the use of this scenario technique.

This chapter is divided into five sections, including this introduction. The next section 5.2 presents an analytical description of the methodology used to conduct the CIB analysis in this study aiming to generate future views of the energy-poverty nexus in rural Ceará. Section 5.3 is reserved for reflections on the methodology used. Section 5.4 presents storylines for the future views created in this study. Section 5.5 closes this chapter by grouping the future views created in two contrary pathways of development and identifying the main conditions to change pathways in the future. The identification of the main conditions to change pathways answers the research question proposed in this research, aiming to identify conditions in which modern and renewable energies can contribute to reducing poverty in the rural areas of Ceará in the long term.

5.2 Analytical description of the CIB analysis

This section describes the methodology used in this study to design future views of the energy-poverty nexus in rural Ceará using CIB analysis. CIB is a systematic scenario method based on expert judgments of interrelationships between descriptors (i.e. elements in the case of this study) and their possible variants of future trends that contextualize a determined system, which normally involves multi-dimensions (Weimer-Jehle, 2006). The procedures to conduct a CIB analysis can be divided in five main steps (Figure 5.1).



Note: Adapted from Weimer-Jehle (2006) and Weimer-Jehle et al. (2020).

Figure 5.1. Steps to conduct a CIB analysis

The two first steps to conduct a CIB analysis (Figure 5.1) are similar to the two first steps of the Integrative Approach to the Energy-Poverty Nexus (detail in sub-sections 3.2.1 and 3.2.2, chapter three) and, therefore, they are summarized in the following. The first step of the CIB analysis aims to determine a set of descriptors and future trends that contextualize the system under analysis. This is frequently done with the support of experts and desk research (Weimer-Jehle, 2006). In this study, this step was done in the previous chapter in which the elements that compose the energy-poverty nexus in rural Ceará were identified with the help of local actors and desk research (detail in section 4.4). In the second step of the CIB analysis, all relationships between the system descriptors should be identified, which can also be achieved with the help of experts knowledge and literature (Weimer-Jehle, 2006). In the case of the energy-poverty nexus in rural Ceará, this was done in chapter four, section 4.5.

Based on the interrelationships between the system elements, CIB allows to identify the most active and passive elements in the system. That means, those elements that exercise more influence in the system and those that are more influenced, respectively. In the case of the energy-poverty nexus in rural Ceará, the most active elements are "*Rural policies*", "*Capacity building and education*", "*Farmers' organization*", "*Governance*" and "*Economic stability*" while the most passive elements are "*Rural population*", "*Electricity demand*", "*Household infrastructure*", "*Indoor air pollution*" and "*Income source and asset accumulation"*.

The third, fourth and fifth steps of the CIB analysis (Figure 5.1) are related to step three of the Integrative-Approach to the Energy-Poverty Nexus and are described in detail in the following considering the case of rural Ceará.

5.2.1 Quantifying interdependencies between system elements

In the third step of the CIB analysis, all levels of interrelationships between the trends of the interconnected descriptors should be quantified and transposed to a cross-impact matrix. Frequently, experts are asked to judge the level of interrelationships between the states of the descriptors. For that, a scale from -3 to +3, from hindering to promoting, is frequently used (Weimer-Jehle, 2006). Such a procedure was realized in the case of the energy-poverty nexus in rural Ceará (see below).

According to the map of interrelationships between the system elements that compose the energy-poverty nexus in rural Ceará (Figure 4.4 in the chapter four), there are 66 direct relationships between the system elements. Considering that each element has from two to three future development trends, a total of 363 relationships between the trends of the elements were identified, the level influence of which was judged by experts.

The collection of expert judgments occurred from May to July 2016 through an online survey created using the platform SoSci Survey (SoSci Survey GmbH, 2020). The local actors interviewed in Ceará in 2015 (detail in chapter four, section 4.2) and additional Brazilian and international experts, totalizing 118 experts, were invited to participate in the survey. Each expert received an invitation letter explaining the purpose of this study and a web link to the online questionnaire. Additionally, the experts received the description of each one of the 16 system elements and their corresponding trends, as presented in section 4.4.

The 66 direct relationships between the elements generated 66 sets of questions, while the 363 relationships between the trends generated 363 questions in the online questionnaire. For example, the relationship between the elements "*Farmers' organization*" and "*Grid infrastructure*" (Figure 4.4 in chapter four) was considered as one set of questions, including four questions related to the two trends of each element. Thus, in the above example, experts were asked to judge the influence that:

i) "*Weak*" cooperation of farmers may have on the grid infrastructure to be "*reliable to supply basic human needs*";

ii) "*Weak*" cooperation of farmers may have on the grid infrastructure to be "*reliable to supply productive chains and prosumers, besides basic human needs"*;

iii) "*Strong*" cooperation of farmers may have on the grid infrastructure to be "*reliable to supply basic human needs*";

iv) "*Strong*" cooperation of farmers may have on the grid infrastructure to be "*reliable to supply productive chains and prosumers, besides basic human needs"*.

Considering that a total of 363 questions would be a high number of questions to be answered by one expert, the 66 sets of questions were divided in four thematic groups of "rural development", "economy", "energy" and "international". Each group received from 16 to 17 sets of questions. The Brazilian experts, including the local actors interviewed in Ceará, were allocated in the first three groups according to their main expertise, while the international experts were allocated in the last group. The experts were asked to answer the sets of questions corresponding to their specific thematic group. However, no restriction was configured in the online survey in case that one expert would like to answer questions of additional sets, or even the whole questionnaire.

The participation rate in the online survey was 32%, corresponding to 38 experts who answered the questionnaire. Regarding nationality, 27 experts were from Brazil, five from Germany, three from Canada, one from Spain, one from Columbia and one from Bolivia. From the 27 Brazilian experts, 13 have participated in the semi-structured interviews conducted in Ceará in 2015. Regarding the number of experts per thematic group, the “rural development” group was composed of 11 experts, the “economy” of seven, the “energy” of nine and the “international” group was composed of 11 experts. Most of the experts were academics (18 experts), while the remaining are working for or represent governmental agencies (nine), NGOs (five), electricity utilities (three) and consulting companies (one). Two experts preferred not to inform affiliation (Table 5.1).

Table 5.1: Representativeness and affiliation of the experts that participated in the online survey organized according to the thematic groups

Thematic group	Representative	Affiliation	Nº of experts
Rural development	Governmental Agency	Embrapa Agroindústria Tropical (Embrapa)	1
		Secretaria do Desenvolvimento Agrário (SDA)	2
		Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (EPAGRI)	1
	Academia	Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT)	1
		Forest and Nature Conservation Policy Group, University of Wageningen	1
	Non-Governmental Agency	Centro de Desenvolvimento Agroecológico Sabiá	1
		Instituto Sociedade, População e Natureza (ISPN)	1
		Centro de Estudos do Trabalho e de Assessoria ao Trabalhador (CETRA)	1
	Anonymous	Anonymous	2
Economy	Governmental Agency	Instituto de Pesquisa e Estratégia Econômica do Ceará (IPECE)	1
		Secretaria de Desenvolvimento Agrário (SDA)	2
		Secretaria da Ciência, Tecnologia e Educação Superior (Secitece)	1
	Academia	Universidade de São Paulo (USP)	1
		Universidade Federal do Ceará (UFC)	1
		Pontifical Catholic University of São Paulo (PUCSP)	1
Energy	Governmental Agency	Federação das Indústrias do Estado do Ceará (FIEC)	1
	Academia	Universidade Federal do Ceará (UFC)	2
		Universidade Estadual do Ceará (UECE)	1
		Universidade of São Paulo (USP)	1
		Universidade de Brasília (UnB)	1
	Electricity Utility	ENEL	1
		Companhia Estadual de Energia Elétrica (CEEE)	1
		Cooperativa de Distribuição de Energia Teutônia (Certel Energia)	1

Thematic group	Representative	Affiliation	Nº of experts
International	Academia	Affordable Energy for Humanity Global Change Initiative (AE4H)	1
		Fraunhofer Institute for Solar Energy Systems (Fraunhofer ISE)	1
		Institute of Applied Informatics and Formal Description Methods (AIFB), Karlsruhe Institute of Technology (KIT)	1
		University of British Columbia	1
		Institute for Entrepreneurship, Technology management and Innovation (EnTechnon), Karlsruhe Institute of Technology (KIT)	1
		Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology (KIT)	2
		Stuttgart Research Centre for Interdisciplinary Risk and Innovation Studies (ZIRIUS), University of Stuttgart	1
	Non-Governmental Agency	Practical Action	1
		Light up the World	1
	Consulting Company	Trama TecnoAmbiental	1
Total			**38**

To answer each question, experts could indicate one level of influence that one trend may have on another one, varying in a scale of: strong promoting influence (weight +3), promoting influence (weight +2), slightly promoting influence (weight +1), no influence (weight 0), slightly inhibiting influence (weight -1), inhibiting influence (weight -2) and strong inhibiting influence (weight -3). The experts could also opt not to answer a determined question and could provide comments to the questions. Since it was expected that each question would be answered by more than one expert, the median value of the expert judgments for each question was calculated to determine the final level of influence between the related trends. The median value was used because it enables to find a typical value between the expert judgments, avoiding discrepancies among the answers. As an example, in Table 5.2 all judgments and comments provided by the experts on the set of questions related to the elements "*Farmers' organization*" and "*Grid infrastructure*" are listed. According to the median value of the expert judgments, the following influences were found:

i) "*Weak*" cooperation of farmers has **no influence** on the grid infrastructure to be "*reliable to supply basic human needs*";

ii) "*Weak*" cooperation of farmers has a **slightly inhibiting influence** on the grid infrastructure to be "*reliable to supply productive chains and prosumers, besides basic human needs"*;

iii) "*Strong*" cooperation of farmers has a **promoting influence** on the grid infrastructure to be "*reliable to supply basic human needs*";

iv) "*Strong*" cooperation of farmers has a **promoting influence** on the grid infrastructure to be "*reliable to supply productive chains and prosumers, besides basic human needs"*.

Table 5.2: Influence levels between the elements "Farmers' organization" and "Grid infrastructure"

Expert_ID	Influence levels that the trends of the element "***Farmers' organization***" may have on trends of the element "***Grid infrastructure***"				Experts' comments
	"*Weak cooperation*" to "*Reliable to supply basic human needs*"	"*Weak cooperation*" to "*Reliable to supply productive chains and prosumers, besides basic human needs*"	"*Strong cooperation*" to "*Reliable to supply basic human needs*"	"*Strong cooperation*" to "*Reliable to supply productive chains and prosumers, besides basic human needs*"	
Expert_1	2	0	2	3	"Maybe I need to discuss these questions with you, but I believe that the weak cooperation of farmers can contribute to maintain the grid infrastructure as it is. A strong cooperation can contribute to maintain the current state and to improve the grid infrastructure to support productive chains."
Expert_2	-1	-2	3	3	
Expert_3	-2	-2	3	2	
Expert_4	-1	-3	1	1	"I don't believe that it is likely that cooperation will have a great impact in such a complex sector as the energy one… it is a sector very well structured and organized… I don't believe that the cooperation of farmers can interfere in that… governmental policies can interfere in the energy sector much more than farmers."
Expert_5	1	1	3	3	
Expert_6	0	0	0	1	
Expert_7	-3	-3	2	3	
Expert_8	0	1	2	3	
Expert_9	-3	-3	3	3	"Considering the energy potential available in the rural properties, the cooperation of farmers should be promoted. If there is cooperation, then the scale of prosumers will increase."
Expert_10	-1	-1	1	1	
Expert_11	0	0	0	1	
Expert_12	0	-1	0	2	
Expert_13	1	-2	3	2	
Expert_14	-2	-2	2	2	
Expert_15	2	-1	2	3	
Expert_16	2	-2	-2	2	
Expert_17	-1	-1	1	2	"The productive use of electricity will just occur if the farmers cooperate. If they cooperate, then they can claim for better energy services."
Median	**0**	**-1**	**2**	**2**	

To proceed with the CIB analysis, the expert judgments need to be transposed to a cross-impact matrix, which is used to identify raw and consistent scenarios. The matrix represents a complete network of influences between all pairs of trends of system elements and is composed of $n^2 - n$ judgment sections, where n is the number of system elements analysed (Weimer-Jehle, 2006). One judgment section refers to the levels of influence that trends of one element may have on trends of another one. Considering that the system under analysis in this study has 16 elements, the resulting cross-impact matrix has 240 judgment sections (i.e. $16^2 - 16 = 240$). To fill out the judgment sections, the median values from each set of questions were used. For instance, the procedure for filling out the judgment section corresponding to the influences that the two trends of the element "*Farmers' organization*" have on the two trends of the element "*Grid infrastructure*" is represented in Figure 5.2.

	Trends of the element "Farmers' organization" related to trends of the element "Grid infrastructure"			
	"*Weak cooperation*" to "*Reliable to supply basic human needs*"	"*Weak cooperation*" to "*Reliable to supply productive chains and prosumers, besides basic human needs*"	"*Strong cooperation*" to "*Reliable to supply basic human needs*"	"*Strong cooperation*" to "*Reliable to supply productive chains and prosumers, besides basic human needs*"
Median value of the expert judgments	0	-1	2	2

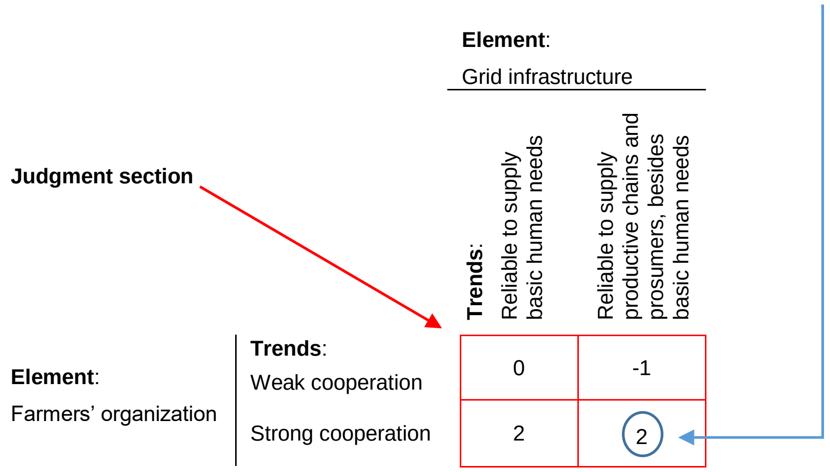


Figure 5.2: Example of filling out one judgment section in the cross-impact matrix

Once transposing all 66 set of questions to their respective judgment sections in the cross-impact matrix, the resulting matrix is the one shown in Figure 5.3. The row elements in the matrix indicate the sources of influence, while the column elements the targets. In the matrix, it is to be noted that there are 174 judgment sections that do not present any number (i.e. grey cells), meaning that there is no direct relationship between the crossed elements. These cells could also be filled out with the value 0, meaning "no influence". Finally, one can say that the rules of the system under analysis are established in the cross-impact matrix (Weimer-Jehle, 2006).

Cross-Impact Matrix "The energy-poverty nexus in the rural areas of Ceará" — Elements and trends	A. Household infrastructure (basic services)			B. Income source and asset accumulation		C. Indoor air pollution		D. Costs of electricity and cooking fuels		E. Farmers' organization		F. Irrigation			G. Capacity building and education			H. Rural policies		I. Electricity demand		J. Electricity market organization			K. Grid infrastructure		L. Electricity price			M. Rural Population			N. Environtal risks and uncertainties		O. Economic stability		P. Governance	
Elements and trends	A1.Universal water supply	A2. Universal water supply and basic sanitation	A3. Universal water supply, basic sanitation and waste management	B1. Low resilience	B2. High resilience	C1. High	C2. Low	D1. High	D2. Low	E1. Weak cooperation	E2. Strong cooperation	F1. Manual or per gravity (e.g. cisterns)	F2. Mechanized - poor irrigation management	F3. Mechanized - adequate irrigation management	G1. Limited	G2. Universalized	G3. Universalized and contextualized	H1. Limited opportunities	H2. Large and strong opportunities	I1. Slightly increasing to supply basic human needs	I2. Increasing to supply basic human needs and productive chains	J1. Regulated market: Prosumers are not allowed to sell elect. surplus, just to receive credits in kWh	J2. Regulated market: Prosumers may sell elect. surplus to the local distribution company	J3. Non-regulated market. Prosumers may sell electricity surplus in a non-regulated market	K1. Reliable to supply basic human needs	K2. Reliable to supply productive chains and prosumers	L1. High	L2. Moderate	L3. Low	M1. Migration flows	M2. Slightly decreasing	M3. Stable or slightly increasing	N1. High	N2. Medium	O1. Unstable	O2. Stable	P1. Non-adequate	P2. Adequate
A. Household infrastructure (basic services)																																						
A1. Universal water supply																														-2	-1	2						
A2. Universal water supply and basic sanitation																														-3	-2	2						
A3. Universal water supply, basic sanitation and waste management																														-3	-2	3						
B. Income source and asset accumulation																																						
B1. Low resilience								2	-2	1	0									0	-1									3	2	-2						
B2. High resilience								-1	1	0	1									1	2									-3	-2	2						
C. Indoor air pollution																																						
C1. High				1	-1																									1	1	0						
C2. Low				0	1																									0	0	0						
D. Costs of electricity and cooking fuels																																						
D1. High				2	-2	1	-1					1	0	0																1	1	-1						
D2. Low				-1	1	-1	1					0	1	1																-2	-1	1						
E. Farmers' organization																																						
E1. Weak cooperation				2	-2							0	2	0	2	-1	-2	1	-1	1	-1				0	-1												
E2. Strong cooperation				-2	3							2	-2	3	-2	2	3	-2	2	1	2				2	2												
F. Irrigation																																						
F1. Manual or per gravity (e.g. cisterns)				-2	2															0	0												-1	0				
F2. Mechanized - poor irrigation management				2	-2															1	1												2	2				
F3. Mechanized - adequate irrigation management				-2	2															1	2												-1	0				
G. Capacity building and education																																						
G1. Limited				2	-2	2	-1			3	-2	0	2	-1				2	-2											2	2	-1						
G2. Universalized				-1	1	0	1			-1	2	1	-1	2				-1	2											-2	-1	1						
G3. Universalized and contextualized				-3	3	-2	2			-2	3	2	-2	3				-2	3											-2	-2	2						
H. Rural policies																																						
H1. Limited opportunities	-1	-1	-2	2	-2	1	-1			0	0	1	1	-2	1	-1	-2			1	0				1	0	0	0	0	2	2	-2						
H2. Large and strong opportunities	2	2	3	-2	3	-2	2			0	0	1	0	2	-2	2	3			2	2				2	3	-1	0	1	-2	-2	2						
I. Electricity demand																																						
I1. Slightly increasing to supply basic human needs																											0	0	0									
I2. Increasing to supply basic human needs and productive chains																											1	1	-1									
J. Electricity market organization																																						
J1. Regulated market. Prosumers are not allowed to sell electricity surplus, just to receive credits in kWh				-1	1					0	1							1	1	1	1				1	1	0	1	0									
J2. Regulated market. Prosumers may sell electricity surplus to the local distribution company				-1	1					0	2							1	2	1	1				1	2	-1	0	1									
J3. Non-regulated market. Prosumers may sell electricity surplus in a non-regulated market				0	2					0	2							0	2	1	2				1	2	-1	1	2									
K. Grid infrastructure																																						
K1. Reliable to supply basic human needs				0	0							0	0	1				1	1	1	-1						0	0	0	-1	-1	1						
K2. Reliable to supply productive chains and prosumers				-2	2							0	0	2				-1	2	2	2						1	1	1	-2	-2	2						
L. Electricity Price																																						
L1. High								2	-2			3	-2	-1						-2	-2																	
L2. Moderate								1	1			1	-1	1						0	0																	
L3. Low								-1	2			-1	1	2						1	2																	
M. Rural Population																																						
M1. Migration flows																																						
M2. Slightly decreasing																																						
M3. Stable or slightly increasing																																						
N. Environmental risks and uncertainties																																						
N1. High	-2	-2	-2	3	-2							-2	-1	-1																3	2	-2						
N2. Medium	-1	-1	-1	1	0							0	0	0																0	1	0						
O. Economic stability																																						
O1. Unstable	-2	-2	-3	2	-2										2	-2	-3	2	-2								2	1	-2									
O2. Stable	2	2	3	-1	2										-1	1	2	0	2								-2	1	1									
P. Governance																																						
P1. Non-adequate	1	-2	-3							3	-2				3	-2	-3	3	-2														1	1				
P2. Adequate	-1	2	3							-2	3				-2	2	3	-1	3														-1	0				

Figure 5.3: Cross-impact matrix for the energy-poverty nexus in the rural areas of Ceará

5.2.2 Identification of consistent scenarios

In the identification process of consistent scenarios (step four in Figure 5.1), the levels of influence set in the cross-impact matrix limit combinational scenarios regarding their plausibility (Weimer-Jehle, 2016, 2006). One combinational scenario is defined by joining one development trend of each system element. For example, combining the first trend of each one of the 16 elements analysed in this study, as presented in Figure 5.4.

Combinational Scenario "x"

- A1: Universal water supply
- B1: Low resilience of income source and asset accumulation
- C1: High indoor air pollution
- D1: High costs of electricity and cooking fuels
- E1: Weak cooperation of farmers
- F1: Manual or per gravity irrigation systems
- G1: Limited capacity building and education
- H1: Rural policies of limited opportunities
- I1: Electricity demand slightly increasing to supply basic human needs
- J1: Regulated electricity market, on which prosumers are not allowed to commercialize electricity surplus, just to receive credits in kWh
- K1: Grid infrastructure reliable to supply basic human needs
- L1: High electricity price
- M1: Migration flows of rural population
- N1: High environmental risks and uncertainties
- O1: Unstable economy
- P1: Non-adequate governance

Figure 5.4: Example of a combinational scenario

To create another combinational scenario, it is necessary only to change one trend in the above example, as "*P1: Non-adequate governance*" by "*P2: Adequate governance"*, for instance. The total number of possible combinational scenarios in a cross-impact matrix is defined multiplying the number of trends of the system elements. Thus, once multiplying all trends of the 16 system elements considered in this study (i.e. $3 \times 2 \times 2 \times 2 \times 2 \times 3 \times 3 \times 2 \times 2 \times 3 \times 2 \times 3 \times 3 \times 2 \times 2 \times 2$), 746,496 possible combinational scenarios can be generated.

One combinational scenario is said consistent if it does not break the rules of the system present in the cross-impact matrix. To identify if a scenario is consistent with the system rules, the CIB method follows the principle of compensation and the principle of consistency (Weimer-Jehle, 2006). Considering the combinational scenario presented above as a test scenario "x", the principle of compensation balances the impact that the trends assumed in scenario "x" have on each one of the trends present in the system and indicates the predominant trend (i.e. higher score) of each element in relation to the assumptions made in scenario "x". This is done by adding up, by columns in the cross-impact matrix, the influence values of the trends of scenario "x" and by pointing out the trend with higher resulting score for each system element in the impact balances (Figure 5.5). In the figure, the trends assumed in scenario "x" are highlighted in grey colour while the resulting impact balances of the assumed trends and their respective predominant trends are shown at the bottom of the image.

Cross-Impact Matrix
"The energy-poverty nexus in the rural areas of Ceará"

Elements and trends	A. Household infrastructure (basic services)			B. Income source and asset accumulation		C. Indoor air pollution		D. Costs of electricity and cooking fuels		E. Farmers' organization		F. Irrigation			G. Capacity building and education			H. Rural policies		I. Electricity demand		J. Electricity market organization			K. Grid infrastructure		L. Electricity price			M. Rural Population			N. Environtal risks and uncertainties		O. Economic stability		P. Governance	
	A1.Universal water supply	A2. Universal water supply and basic sanitation	A3. Universal water supply, basic sanitation and waste management	B1. Low resilience	B2. High resilience	C1. High	C2. Low	D1. High	D2. Low	E1. Weak cooperation	E2. Strong cooperation	F1. Manual or per gravity (e.g. cisterns)	F2. Mechanized - poor irrigation management	F3. Mechanized - adequate irrigation management	G1. Limited	G2. Universalized	G3. Universalized and contextualized	H1. Limited opportunities	H2. Large and strong opportunities	I1. Slightly increasing to supply basic human needs	I2. Increasing to supply basic human needs and productive chains	J1. Regulated market: Prosumers are not allowed to sell elect. surplus, just to receive credits in kWh	J2. Regulated market: Prosumers may sell elect. surplus to the local distribution company	J3. Non-regulated market. Prosumers may sell electricity surplus in a non-regulated market	K1. Reliable to supply basic human needs	K2. Reliable to supply productive chains and prosumers	L1. High	L2. Moderate	L3. Low	M1. Migration flows	M2. Slightly decreasing	M3. Stable or slightly increasing	N1. High	N2. Medium	O1. Unstable	O2. Stable	P1. Non-adequate	P2. Adequate
A. Household infrastructure (basic services)																																						
A1. Universal water supply																														-2	-1	2						
A2. Universal water supply and basic sanitation																														-3	-2	2						
A3. Universal water supply, basic sanitation and waste management																														-3	-2	3						
B. Income source and asset accumulation																																						
B1. Low resilience								2	-2	1	0									0	-1									3	2	-2						
B2. High resilience								-1	1	0	1									1	2									-3	-2	2						
C. Indoor air pollution																																						
C1. High				1	-1																									1	1	0						
C2. Low				0	1																									0	0	0						
D. Costs of electricity and cooking fuels																																						
D1. High				2	-2	1	-1					1	0	0																1	1	-1						
D2. Low				-1	1	-1	1					0	1	1																-2	-1	1						
E. Farmers' organization																																						
E1. Weak cooperation				2	-2							0	2	0	2	-1	-2	1	-1	1	-1				0	-1												
E2. Strong cooperation				-2	3							2	-2	3	-2	2	3	-2	2	1	2				2	2												
F. Irrigation																																						
F1. Manual or per gravity (e.g. cisterns)				-2	2															0	0												-1	0				
F2. Mechanized - poor irrigation management				2	-2															1	1												2	2				
F3. Mechanized - adequate irrigation management				-2	2															1	2												-1	0				
G. Capacity building and education																																						
G1. Limited				2	-2	2	-1			3	-2	0	2	-1				2	-2											2	2	-1						
G2. Universalized				-1	1	0	1			-1	2	1	-1	2				-1	2											-2	-1	1						
G3. Universalized and contextualized				-3	3	-2	2			-2	3	2	-2	3				-2	3											-2	-2	2						
H. Rural policies																																						
H1. Limited opportunities	-1	-1	-2	2	-2	1	-1			0	0	1	1	-2	1	-1	-2			1	0				1	0	0	0	0	2	2	-2						
H2. Large and strong opportunities	2	2	3	-2	3	-2	2			0	0	1	0	2	-2	2	3			2	2				2	3	-1	0	1	-2	-2	2						
I. Electricity demand																																						
I1. Slightly increasing to supply basic human needs																											0	0	0									
I2. Increasing to supply basic human needs and productive chains																											1	1	-1									
J. Electricity market organization																																						
J1. Regulated market. Prosumers are not allowed to sell electricity surplus, just to receive credits in kWh				-1	1					0	1							1	1	1	1				1	1	0	1	0									
J2. Regulated market. Prosumers may sell electricity surplus to the local distribution company				-1	1					0	2							1	2	1	1				1	2	-1	0	1									
J3. Non-regulated market. Prosumers may sell electricity surplus in a non-regulated market				0	2					0	2							0	2	1	2				1	2	-1	1	2									
K. Grid infrastructure																																						
K1. Reliable to supply basic human needs				0	0							0	0	1				1	1	1	-1						0	0	0	-1	-1	1						
K2. Reliable to supply productive chains and prosumers				-2	2							0	0	2				-1	2	2	2						1	1	1	-2	-2	2						
L. Electricity Price																																						
L1. High								2	-2			3	-2	-1						-2	-2																	
L2. Moderate								1	1			1	-1	1						0	0																	
L3. Low								-1	2			-1	1	2						1	2																	
M. Rural Population																																						
M1. Migration flows																																						
M2. Slightly decreasing																																						
M3. Stable or slightly increasing																																						
N. Environmental risks and uncertainties																																						
N1. High	-2	-2	-2	3	-2							-2	-1	-1																3	2	-2						
N2. Medium	-1	-1	-1	1	0							0	0	0																0	1	0						
O. Economic stability																																						
O1. Unstable	-2	-2	-3	2	-2										2	-2	-3	2	-2								2	1	-2									
O2. Stable	2	2	3	-1	2										-1	1	2	0	2								-2	1	1									
P. Governance																																						
P1. Non-adequate	1	-2	-3							3	-2				3	-2	-3	3	-2														1	1				
P2. Adequate	-1	2	3							-2	3				-2	2	3	-1	3														-1	0				
Trends assumed in the test scenario X:	↓			↓		↓		↓		↓		↓			↓			↓		↓		↓			↓		↓			↓			↓		↓		↓	
Impact balances:	-4	-7	-10	11	-10	4	-3	4	-4	7	-3	3	1	-4	8	-6	-10	10	-5	2	-4	0	0	0	2	0	2	2	-2	9	8	-5	0	1	0	0	0	0
Predominant trends according to impact balance (higher score):	↑			↑		↑		↑		↑		↑			↑			↑		↑		↑			↑		↑			↑				↑	↑		↑	

Figure 5.5: Impact balances for the test scenario "x"

Finally, the principle of consistence indicates if the trends assumed in scenario “x” are in accordance with the rules of the system. This is done by verifying if the predominant trends indicated by the impact balances correspond to the trends assumed in scenario “x”. The arrows shown at the bottom of Figure 5.5 indicate that the above is true for all trends assumed in scenario “x”, except for the trend of the element “*Environmental risks and uncertainties*” (marked in red in the figure). Indeed, the scenario “x” assumes the trend “*N1: High environmental risks and uncertainties*” which contradicts the predominant trend indicated by the impact balance (i.e. “*N2: Medium environmental risks and uncertainties*”). This contradiction indicates that the scenario “x” is inconsistent with the rules of the system and, therefore, is not plausible to occur and should be rejected.

The procedure presented above for calculating and identifying consistent scenarios using the CIB method needs be accomplished for each one of the 746,496 possible combinational scenarios for the energy-poverty nexus in rural Ceará. Such a procedure is inviable to be manually realized. Thus, it is possible to use CIB-algorithms, as the ScenarioWizard (ZIRIUS, 2017), which scan the cross-impact matrix and identify all consistent scenarios. After running the ScenarioWizard using the cross-impact matrix analysed in this study (Figure 5.3), a total of 29 consistent scenarios were identified. The consistent scenarios were clustered according to main divergent trends that can be sources of further developments (details in section 5.4).

For methodological reasons, the manual procedure for identifying a consistent scenario is shown in Figure 5.6. The trends assumed in the scenario are highlighted in grey and the impact balances are presented at the bottom of the figure. In the figure, it can be observed that no trend assumed in the scenario contradicts the predominant trends identified by the impact balances. Thus, the scenario is considered consistent and plausible.

Cross-Impact Matrix
"The energy-poverty nexus in the rural areas of Ceará"

Elements and trends	A1. Universal water supply	A2. Universal water supply and basic sanitation	A3. Universal water supply, basic sanitation and waste management	B1. Low resilience	B2. High resilience	C1. High	C2. Low	D1. High	D2. Low	E1. Weak cooperation	E2. Strong cooperation	F1. Manual or per gravity (e.g. cisterns)	F2. Mechanized - poor irrigation management	F3. Mechanized - adequate irrigation management	G1. Limited	G2. Universalized	G3. Universalized and contextualized	H1. Limited opportunities	H2. Large and strong opportunities	I1. Slightly increasing to supply basic human needs	I2. Increasing to supply basic human needs and productive chains	J1. Regulated market: Prosumers are not allowed to sell elect. surplus, just to receive credits in kWh	J2. Regulated market: Prosumers may sell elect. surplus to the local distribution company	J3. Non-regulated market. Prosumers may sell electricity surplus in a non-regulated market	K1. Reliable to supply basic human needs	K2. Reliable to supply productive chains and prosumers	L1. High	L2. Moderate	L3. Low	M1. Migration flows	M2. Slightly decreasing	M3. Stable or slightly increasing	N1. High	N2. Medium	O1. Unstable	O2. Stable	P1. Non-adequate	P2. Adequate
	A. Household infrastructure (basic services)			**B. Income source and asset accumulation**		**C. Indoor air pollution**		**D. Costs of electricity and cooking fuels**		**E. Farmers' organization**		**F. Irrigation**			**G. Capacity building and education**			**H. Rural policies**		**I. Electricity demand**		**J. Electricity market organization**			**K. Grid infrastructure**		**L. Electricity price**			**M. Rural Population**			**N. Environtal risks and uncertainties**		**O. Economic stability**		**P. Governance**	
A. Household infrastructure (basic services)																																						
A1. Universal water supply																														-2	-1	2						
A2. Universal water supply and basic sanitation																														-3	-2	2						
A3. Universal water supply, basic sanitation and waste management																														-3	-2	3						
B. Income source and asset accumulation																																						
B1. Low resilience								2	-2	1	0									0	-1									3	2	-2						
B2. High resilience								-1	1	0	1									1	2									-3	-2	2						
C. Indoor air pollution																																						
C1. High				1	-1																									1	1	0						
C2. Low				0	1																									0	0	0						
D. Costs of electricity and cooking fuels																																						
D1. High				2	-2	1	-1					1	0	0																1	1	-1						
D2. Low				-1	1	-1	1					0	1	1																-2	-1	1						
E. Farmers' organization																																						
E1. Weak cooperation				2	-2							0	2	0	2	-1	-2	1	-1	1	-1				0	-1												
E2. Strong cooperation				-2	3							2	-2	3	-2	2	3	-2	2	1	2				2	2												
F. Irrigation																																						
F1. Manual or per gravity (e.g. cisterns)				-2	2															0	0												-1	0				
F2. Mechanized - poor irrigation management				2	-2															1	1												2	2				
F3. Mechanized - adequate irrigation management				-2	2															1	2												-1	0				
G. Capacity building and education																																						
G1. Limited				2	-2	2	-1			3	-2	0	2	-1				2	-2											2	2	-1						
G2. Universalized				-1	1	0	1			-1	2	1	-1	2				-1	2											-2	-1	1						
G3. Universalized and contextualized				-3	3	-2	2			-2	3	2	-2	3				-2	3											-2	-2	2						
H. Rural policies																																						
H1. Limited opportunities	-1	-1	-2	2	-2	1	-1			0	0	1	1	-2	1	-1	-2			1	0				1	0	0	0	0	2	2	-2						
H2. Large and strong opportunities	2	2	3	-2	3	-2	2			0	0	1	0	2	-2	2	3			2	2				2	3	-1	0	1	-2	-2	2						
I. Electricity demand																																						
I1. Slightly increasing to supply basic human needs																											0	0	0									
I2. Increasing to supply basic human needs and productive chains																											1	1	-1									
J. Electricity market organization																																						
J1. Regulated market. Prosumers are not allowed to sell electricity surplus, just to receive credits in kWh				-1	1					0	1							1	1	1	1				1	1	0	1	0									
J2. Regulated market. Prosumers may sell electricity surplus to the local distribution company				-1	1					0	2							1	2	1	1				1	2	-1	0	1									
J3. Non-regulated market. Prosumers may sell electricity surplus in a non-regulated market				0	2					0	2							0	2	1	2				1	2	-1	1	2									
K. Grid infrastructure																																						
K1. Reliable to supply basic human needs				0	0							0	0	1				1	1	1	-1						0	0	0	-1	-1	1						
K2. Reliable to supply productive chains and prosumers				-2	2							0	0	2				-1	2	2	2						1	1	1	-2	-2	2						
L. Electricity Price																																						
L1. High								2	-2			3	-2	-1						-2	-2																	
L2. Moderate								1	1			1	-1	1						0	0																	
L3. Low								-1	2			-1	1	2						1	2																	
M. Rural Population																																						
M1. Migration flows																																						
M2. Slightly decreasing																																						
M3. Stable or slightly increasing																																						
N. Environmental risks and uncertainties																																						
N1. High	-2	-2	-2	3	-2							-2	-1	-1																3	2	-2						
N2. Medium	-1	-1	-1	1	0							0	0	0																0	1	0						
O. Economic stability																																						
O1. Unstable	-2	-2	-3	2	-2										2	-2	-3	2	-2								2	1	-2									
O2. Stable	2	2	3	-1	2										-1	1	2	0	2								-2	1	1									
P. Governance																																						
P1. Non-adequate	1	-2	-3							3	-2				3	-2	-3	3	-2														1	1				
P2. Adequate	-1	2	3							-2	3				-2	2	3	-1	3														-1	0				
Trends assumed in the scenario number 29:			↓		↓		↓		↓		↓			↓			↓		↓		↓			↓		↓			↓			↓		↓		↓		↓
Impact balances:	2	5	8	-12	19	-5	5	-2	3	-4	9	4	-3	13	-6	7	11	-6	14	9	14	0	0	0	5	7	-2	3	4	-14	-10	12	-2	0	0	0	0	0
Predominant trends according to impact balance (higher score):			↑		↑		↑		↑		↑			↑			↑		↑		↑			↑		↑			↑			↑		↑		↑		↑

Figure 5.6: Example of the identification of a consistent scenario using CIB

5.2.3 Analysing consistent scenarios and writing storylines

Scenarios should be interpreted, analysed and tell a story on how the system elements may unfold in the future (Kosow and Gaßner, 2008; Weimer-Jehle et al., 2020). This corresponds to the last step of the CIB analysis (see Figure 5.1) in which the consistent scenarios identified are analysed and storylines are created for them. Storylines seek to present in a logic, transparent and comprehensive way how trends of the system elements are interconnected and influence each other in one scenario.

In the case of the energy-poverty nexus in rural Ceará, through interpretation and argumentation, storylines were created for each one of the clusters of scenarios identified. The storylines are presented in section 5.4.

5.3 A critical review of the methodology used

This section presents the advantages and disadvantages observed during the collection of expert judgements via an online survey to fill out the cross-impact matrix in this study (sub-section 5.3.1). Also, this section suggests one additional interpretation for the value 0 (zero) in the cross-impact matrix (sub-section 5.3.2), assumed in the literature as no influence between pairs of trends.

5.3.1 (Dis)advantages of collecting expert judgments through an online survey

The expert judgments to fill out the cross-impact matrix are usually collected through workshops or interviews (Weimer-Jehle et al., 2016). In this study, due to financial limitations and constrained agenda to return to Ceará, an online survey was used instead, which presented disadvantages and advantages relative to workshops.

The main disadvantage lies in the lack of debate and impossibility to exchange experiences and ideas between experts, which typically occurs in workshops. As an alternative to minimize this disadvantage, some experts were contacted after the realization of the online survey to discuss their ideas presented in the comments of the sets of questions. Nonetheless, in the case of workshops, debates can also be a disadvantage because in the presence of dominant experts, these can dampen or influence the opinion of shy or indecisive experts. This can occur because dominant experts often tend to give priority to personal agendas (WFP, 2000). In such cases, an adequate moderation is essential to promote equal opportunities and a fair debate between the participants.

Another disadvantage lies in the large extension of the online survey, with a total of 66 sets of questions. It was estimated that the experts could answer (i.e. provide judgments) the sets of questions corresponding to their thematic groups in around one hour. In practice, however, several experts took more than two or three hours to answer the questions. The platform used to conduct the survey allows participants to take a pause during the questionnaire and continue answering it later. Some experts took advantage of this feature and answered the questions in the interval of one or two weeks. Nevertheless, the long time needed to answer the questionnaire led experts to fatigue and inattention in answering the questions, as was reported by experts and observed in the answers of some questions. Thus, in the set of questions where was observed possible inattention, experts were contacted once again to review and justify their answers.

Although the extension of the online survey represented a disadvantage in this study, signs of high engagement of some experts in participating in the survey were observed because even considering that each expert was asked to answer from 16 to 17 sets of questions, some provided judgments for much more than 17 sets. That way, each set of questions received judgments from at least 12 experts, while the maximum number of experts that provided judgments in one set of questions was 21.

Among the advantages of online surveys in relation to workshops, this study shows that at least five can be mentioned. First, the experts can express their own opinions without the interference of other experts, avoiding the disadvantage mentioned above in relation to dominant experts. Second, online surveys avoid possible conflicting situations between contrary experts. Third, the number of participants in surveys can be higher than in workshops, which can increase plurality to the study. According to Weimer-Jehle (2014), workshops with 5 to 12 experts have been indicated as optimum for the CIB method. In contrast, this study involved 38 experts from six nationalities and different backgrounds. Fourth, online surveys represent low cost solutions for data collection, avoiding travel expenses and daily rates. Fifth, experts are free to answer the survey according to their time availability.

In relation to the time needed to conduct an online survey, it seems that it does not present neither advantage nor disadvantage in relation to workshops. In this study, the preparation and realization of the survey and the data analysis were time-consuming. This happened because the questionnaire, the 16 elements and their trends needed to be translated into Portuguese and also because the contact made with some experts after the online survey to clarify answers or to discuss ideas took more time than expected.

5.3.2 A possible additional meaning for the value 0 (zero) in the cross-impact matrix

According to Weimer-Jehle (2016, 2014, 2006), the value 0 (zero) in the cross-impact matrix means that a trend “x” has no direct influence on a trend “y”. The analysis of the data collected in this study suggests that the value 0 can have an additional meaning of precaution, in the sense that: trend “x” may have a direct influence on trend “y”, but, with the current knowledge about possible effects of the trends, it is neither possible to indicate the level nor the direction of the influence. This study recognises that this suggestion needs to be further assessed to prove its consistency or not.

The above suggestion is based on the analysis of two situations which occurred during the collection of expert judgments. The first refers to contrary judgments provided in questions of the online survey. For example, the question related to the influence that "*weak*" cooperation of farmers may have on the grid infrastructure so that it remains "*reliable to supply basic human needs*" in the rural areas of Ceará. Once observing the corresponding judgments provided by experts (see the second column of Table 5.2), it is possible to note a high plurality of judgments. Some experts are likely to believe that if farmers do not cooperate, this "*weak*" cooperation can contribute to maintain the grid infrastructure as it is nowadays (i.e. weights 1 and 2 in the second column of Table 5.2). Other experts are of the opinion that there is no influence between the two trends (i.e. weights 0 in the second column of Table 5.2). A last group of experts is likely to believe that if the farmers do not join their efforts, the current reliability of the grid infrastructure to supply basic human needs can be negatively affected (i.e. weights -1, -2 and -3 in the second column of Table 5.2).

Such plurality of judgments can also occur if there are conflicting groups of experts with contrary opinions, leading to contrary judgments on a given subject. In these cases, the value 0 in the cross-impact matrix would mean precaution because there are evidences (i.e. expert judgments) pointing to the existence of positive and negative influences between the trends analysed.

The second situation observed in this study refers to the analysis of the influences that trends of the element "*Rural policies*" may have on trends of the element "*Farmers' organization*". In this set of questions, experts were asked to evaluate the influences that:

i) Rural policies of "*limited opportunities*" may have on "*weak cooperation*" of farmers;

ii) Rural policies of "*limited opportunities*" may have on "*strong cooperation*" of farmers;

iii) Rural policies of "*large and strong opportunities*" may have on "*weak cooperation*" of farmers;

iv) Rural policies of "*large and strong opportunities*" may have on "*strong cooperation*" of farmers.

Once answering this set of questions, one expert provided the following comment:

> "Impossible to answer the questions. Depends on how farmers react to each condition. I can imagine scenarios in which limited opportunities as provided by policy result in farmers not getting together but also scenarios where this spurs farmers to cooperate to overcome the lack of policies. Similarly, for large and strong opportunities. Farmers could get together to best take advantage of those opportunities but could also see that as a disincentive to cooperate if the policies are designed in a way that they are satisfied."

The above comment is important because it does not argue that there is no influence of rural policies on the organization of farmers, but it argues that the influences can be so dynamic that it is not possible to infer how farmers will react to each development trend. Thus, also in this case, the value 0 in the cross-impact matrix can mean precaution because it is not possible to make further statements about the influences, which does not mean that there is no influence between the trends.

Another alternative to deal with the two situations presented above can be the creation of additional cross-impact matrices, representing contrary levels of influences between trends of elements. Consequently, different scenarios could be discussed with contrary experts.

5.4 Storylines for the energy-poverty nexus in the rural areas of Ceará

The consistent scenarios identified through the CIB analysis were arranged in five clusters according to divergent trends that can be key for the development of further trends. These divergent trends were observed in the elements "*Capacity building and education*", "*Environmental risks and uncertainties*", "*Economic stability*" and "*Governance*" the most (Table 5.3). One should note that the elements "*Capacity building and education*", "*Economic stability*" and "*Governance*" are also part of the most active elements identified via CIB, as described in section 5.2. The five clusters were named "S1-Conservative", "S2-Migration", "S3-Failed transition", "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará".

Table 5.3: Main divergent trends between the clusters of scenarios

<table>
<tr><th rowspan="2">System elements</th><th colspan="5">Cluster of scenarios</th></tr>
<tr><th>S1-Conservative</th><th>S2-Migration</th><th>S3-Failed transition</th><th>S4-Transition through contextualized education</th><th>S5-Overcoming poverty in rural Ceará</th></tr>
<tr><td>G: Capacity building and education</td><td colspan="3">G1: Limited</td><td colspan="2">G3: Universalized and contextualized</td></tr>
<tr><td>N: Environmental risks and uncertainties</td><td>N2: Medium</td><td>N1: High</td><td colspan="3">N2: Medium</td></tr>
<tr><td>O: Economic stability</td><td colspan="2">O1: Unstable
O2: Stable</td><td>O1: Unstable</td><td>O2: Stable</td><td>O1: Unstable
O2: Stable</td></tr>
<tr><td>P: Governance</td><td colspan="2">P1: Non-adequate</td><td>P2: Adequate</td><td>P1: Non-adequate</td><td>P2: Adequate</td></tr>
</table>

The following Table 5.4 presents all the 29 consistent scenarios grouped in five clusters. For each one of the clusters, storylines were developed, which are presented in the next sub-sections.

Table 5.4: The 29 consistent scenarios for rural Ceará grouped in five clusters

	The 29 scenarios grouped in five clusters																												
	S1-Conservative								S2-Migration						S3-Failed transition		S4-Transition through contextualized education					S5-Overcoming poverty in rural Ceará							
System elements and trends	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
A: Household infrastructure (basic services)																													
A1: Universal water supply	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*	*	*	*								
A2: Universal water supply and basic sanitation															*	*													
A3: Universal water supply, basic sanitation and waste management																						*	*	*	*	*	*	*	*
B: Income source and asset accumulation																													
B1: Low resilience	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
B2: High resilience																	*	*	*	*	*	*	*	*	*	*	*	*	*
C: Indoor air pollution																													
C1: High	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
C2: Low																	*	*	*	*	*	*	*	*	*	*	*	*	*
D: Costs of electricity and cooking fuels																													
D1: High	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
D2: Low																	*	*	*	*	*	*	*	*	*	*	*	*	*
E: Farmers' organization																													
E1: Weak cooperation	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
E2: Strong cooperation																	*	*	*	*	*	*	*	*	*	*	*	*	*
F: Irrigation																													
F1: Manual or per gravity	*	*													*														
F2: Mechanized - poor irrigation management			*	*	*	*	*	*	*	*	*	*	*	*		*													
F3: Mechanized – adequate irrigation management																	*	*	*	*	*	*	*	*	*	*	*	*	*
G: Capacity building and education																													
G1: Limited	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
G3: Universalized and contextualized																	*	*	*	*	*	*	*	*	*	*	*	*	*
H: Rural policies																													
H1: Limited opportunities	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
H2: Large and strong opportunities																	*	*	*	*	*	*	*	*	*	*	*	*	*
I: Electricity demand																													
I1: Basic human needs	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													

	The 29 scenarios grouped in five clusters																												
	S1-Conservative								S2-Migration						S3-Failed transition		S4-Transition through contextualized education					S5-Overcoming poverty in rural Ceará							
System elements and trends	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
I2: Basic human needs and productive chains																	*	*	*	*	*	*	*	*	*	*	*	*	*
J: Electricity market organization																													
J1: Regulated market. Prosumers are not allowed to sell electricity surplus	*		*			*			*			*			*	*	*					*			*				
J2: Regulated market. Prosumers can sell electricity surplus to the local distribution company		*		*			*			*			*					*		*			*			*		*	
J3: Non-regulated market. Prosumers can sell electricity surplus in a non-regulated market					*			*			*			*					*		*			*			*		*
K: Grid infrastructure																													
K1: Reliable to supply basic human needs	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*													
K2: Reliable to supply productive chains and prosumers, besides basic human needs																	*	*	*	*	*	*	*	*	*	*	*	*	*
L: Electricity price																													
L1: High	*	*													*														
L2: Moderate			*	*	*	*			*	*	*	*				*	*	*	*			*	*	*	*	*	*		
L3: Low							*	*					*	*						*	*							*	*
M: Rural population																													
M1: Migration flows									*	*	*	*	*	*															
M2: Slightly decreasing	*	*	*	*	*	*	*	*							*	*													
M3: Stabilized or slightly increasing																	*	*	*	*	*	*	*	*	*	*	*	*	*
N: Environmental risks and uncertainties																													
N1: High									*	*	*	*	*	*															
N2: Medium	*	*	*	*	*	*	*	*							*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
O: Economic stability																													
O1: Unstable	*	*	*	*	*				*	*	*				*	*						*	*	*					
O2: Stable						*	*	*				*	*	*			*	*	*	*	*				*	*	*	*	*
P: Governance																													
P1: Non-adequate	*	*	*	*	*	*	*	*	*	*	*	*	*	*			*	*	*	*	*								
P2: Adequate															*	*						*	*	*	*	*	*	*	*

Note: Grey cells with a "*" represent the occurrence of the element-trend in the corresponding scenario.

Regarding further development trends mentioned above, that can be triggered by key divergent trends in the clusters of scenarios, they are clarified in detail throughout the storylines of the clusters. Nevertheless, it is worth giving three short examples of further developments as a way to justify the selection of the trends of the four system elements mentioned in Table 5.3. Once observing the trends of the scenarios numbers 01 to 14 that compose the clusters “S1-Conservative” and “S2-Migration” (see Table 5.4), it is possible to note that most trends suggest the continuance of poverty, in comparison to the trends of the scenarios numbers 22 to 29 that compose the cluster “S5-Overcoming poverty in rural Ceará”. The big difference between the scenarios numbers 01 to 14 and 22 to 29 refers to a change in the trends of the elements “*Capacity building and education*” and “*Governance*” that can be decisive for the occurrence of further developments including, for example, the way in which farmers cooperate, the set of rural policies available and the capability of poor people to benefit or not from modern and renewable energies to help them overcome poverty (detail in the following sub-sections 5.4.1, 5.4.2 and 5.4.5).

The second example focuses only on the scenarios numbers 01 to 14 (Table 5.4). As mentioned above, these scenarios have similar trends suggesting the continuance of poverty. Nevertheless, there is a key difference between the block of scenarios numbers 01 to 08 (cluster “S1-Conserative”) and the block of scenarios numbers 09 to 14 (cluster “S2-Migration”). The crucial difference lies in the trends of the element “*Environmental risks and uncertainties*”. While in the cluster “S1-Conservative” poor rural families are expected to be able to produce in their lands owing to “*medium*” environmental risks and uncertainties, the same is not expected in the cluster “S2-Migration” due to the trend “*high*” environmental risks and uncertainties. Thus, an increment in the level of environmental risks and uncertainties from the trend “*medium*” to “*high*” can lead to a future development related to migration flows of poor rural people (detail in sub-sections 5.4.1 and 5.4.2).

The last example refers to the transitional clusters “S3-Failed transition” and “S4-Transition through contextualized education”. In these clusters, “*Economic stability*” becomes particularly important for the explanation of the scenarios. In the clusters S1, S2 and S5, economic stability is not that crucial and the scenarios that compose these clusters present both trends “*stable*” and “*unstable*” economy (see Table 5.3). Detail are presented and discussed in the storylines of the clusters of scenarios that follows.

5.4.1 Cluster of scenarios “S1-Conservative”

The cluster “S1-Conservative” is composed of eight scenarios (Table 5.5) and is characterized by an overall context that reproduces poverty and high socioeconomic inequality, similar to today’s (detail about the status quo in chapter four). Such a context in this cluster of scenarios is mainly driven by the trends “*non-adequate*” governance and “*limited*” capacity building and education. Some scenarios in "S1-Conservative" (e.g. scenarios 03 and 06 in Table 5.5) can characterize the current situation in many rural areas in Brazil, where people have access to some basic services (e.g. universal electricity and water supply) that contribute to a better life, but high socioeconomic inequality remains a problem and poor people do not have access to adequate opportunities that enable them to escape from a vicious cycle of poverty. These scenarios can become reality in Ceará, in a stable or unstable economy, as soon as water supply is universalized in rural areas. Thus, the storyline presented in this cluster represents the reference story in this study for the continuance of the status quo of the energy-poverty nexus in the rural areas of Ceará. In summary, in this cluster of scenarios poverty is not expected to be reduced with the support of modern and renewable energies, but to remain or to increase due to inappropriate socio and political conditions (detail below).

Table 5.5: Cluster of scenarios "S1-Conservative"

	Scenarios and Trends							
System elements	Scenario 01	Scenario 02	Scenario 03	Scenario 04	Scenario 05	Scenario 06	Scenario 07	Scenario 08
A: Household infrastructure (basic services)	A1: Universal water supply							
B: Income source and asset accumulation	B1: Low resilience							
C: Indoor air pollution	C1: High							
D: Costs of electricity and cooking fuels	D1: High							
E: Farmers' organization	E1: Weak cooperation							
F: Irrigation	F1: Manual or per gravity		F2: Mechanized - poor irrigation management					
G: Capacity building and education	G1: Limited							
H: Rural policies	H1: Limited opportunities							
I: Electricity demand	I1: Basic human needs							
J: Electricity market organization	J1	J2	J1	J2	J3	J1	J2	J3
K: Grid infrastructure	K1: Reliable to supply basic human needs							
L: Electricity price	L1: High		L2: Moderate				L3: Low	
M: Rural population	M2: Slightly decreasing							
N: Environmental risks and uncertainties	N2: Medium							
O: Economic stability	O1: Unstable					O2: Stable		
P: Governance	P1: Non-adequate							

Notes: J1: Regulated market. Prosumers are not allowed to sell electricity surplus.
J2: Regulated market. Prosumers can sell electricity surplus to the local distribution company.
J3: Non-regulated market. Prosumers can sell electricity surplus in a non-regulated market.

One of the main drivers in "S1-Conservative" refers to the trend "*non-adequate*" governance. Thus, corruption and lack of transparency in decision-making processes involving the government at different levels and the economic market are expected to continue and little attention should be given to reduce high socioeconomic disparities and to promote most vulnerable and disadvantaged social groups in Brazil in general and in Ceará in particular. A non-adequate governance also contributes to the non-universalisation of basic sanitation and waste management in all the scenarios that compose “S1-Conservative”, as well as the availability of adequate policies and opportunities that could promote equity. Consequently, rural policies are expected to continue benefiting primarily groups that are already in a better social and economic position or those that are politically well represented, similar to current agrarian policies focusing on monocultures and big farming (detail in chapter four, sub-section 4.3.2). All this is expected to reinforce the unequal social, political and economic conjuncture discussed in section 4.6 that benefits well-off and high-income people the most while keeping poverty a common problem among people from the lower classes.

The second main driver refers to the trend “*limited*” capacity building and education. That way, advisory services and technical assistance are expected to continue as non-universalized services in rural Ceará. When available in rural communities, these services will promote models that in general idealize big farming and high-tech agriculture as progress and family farming as backwardness. Also, education in rural areas will continue focusing on the urban context (detail in chapter four, sub-section 4.4.7).

This limited capacity building and education will continue to promote what Freire (2005) calls cultural invasion, that is related to the information content that people have access to. According to the author, cultural invasion is a mechanism adopted by dominant social groups (aware of their acts or not) to manipulate poor people, maintaining them subjugated. This contributes as well to the idealization of the upper classes and their privileges among people from the lower classes, that incorporate in themselves the oppressor of their pairs (detail below).

Thus, in “S1-Conservative”, a limited capacity building and education supports a passive and indifferent environment in society in relation to poverty. This is important in this study because it promotes the non-reflection of the causes of poverty. In the energy access sector, such limited capacity building and education also contribute to the idealization that energy access will bring only positive results in rural areas, disregarding the fact that energy can also cause negative impacts, as discussed in chapter two, sections 2.3 and 2.7.

The above can be observed in the common assumption widely used in the literature that energy can empower poor people by increasing information access (detail in chapter two, section 2.2). In part, this assumption is true because through electricity people can use radios, televisions and cell phones and can have access to a wide range of information channels. Schools with access to electricity can offer lectures in the evening, which also increase access to information in rural communities. However, the above assumption tells only one part of a more complex story. To understand this story on a broad level, at least two questions should be considered: which kind of information content do poor people have access to? Is this information helping them to overcome poverty? Often, the assumption presented above does not consider these questions or takes for granted that poor people will have access to information contents that will help them improve their quality of life and reduce poverty, which does not always happen. On the contrary, frequently, people have access to information that contribute to maintain the status quo of poverty, as the following examples indicate.

In Brazil, two of the main sources of information in the evening on television are soap operas (the *Telenovelas*) and news, and in rural areas of Ceará this is no different. In the case of soap operas, one can even say that they are entertainment sources, but in fact, they are also information sources and opinion makers in the sense that they, in general, present contexts based on real life and on the common sense of people in general. However, the Brazilian soap operas rarely present the context of rural areas. When the rural context is presented, it is, often, in a context of big farmers producing and prospering. Through soap operas, people can also see, for example, how people live in big cities such as São Paulo and Rio de Janeiro. They can see children playing in parks and families enjoying life by consuming products. They can even see social problems like violence and poverty, but not in a systematic and critical way to deal with the sources of these problems. Consequently, the cultural invasion occurs when people assume that what they are seeing on television (television is taken here as an example of technology information) is a normal or a desired life without problematizing and critically reflecting on the information they are receiving. This leads to the overlapping of local culture and opens space for the acceptance of social problems as normal problems or fatalism of modern societies as if no one is responsible for them (Freire, 2005).

Another example refers to the superficial and distorted way in which social problems are presented and discussed in the Brazilian TV news. As Souza (2018) noted, these problems are simplified as much as possible to label poor people as violent and a danger for society and politicians as corrupt, for example. Nonetheless, the Brazilian TV news in particular and the press in general do not discuss the social preconditions that lead poor people to commit crimes and do not discuss the Brazilian political system as a system constructed to be corrupt. Such a superficial and distorted way to present the news does not occur only in Brazilian television but in television in general in modern societies, as Bourdieu (1997) noted. The discussion presented above may be extended to the use of the internet as a means to spread out fake news.

For the energy access sector, the examples presented above do not argue against the universalization of modern energy access, but highlight the importance of reflecting on how energy is used in society. In the cases explored above, one can suggest that energy is used through information channels to manipulate people and keep poverty something “normal” in modern societies (this matter is further discussed in chapter seven, section 7.4).

Thus, the criticism itself is not of information technologies, but of the information content spread out that contributes to keeping the status quo of poverty and high inequality in Brazilian society. This information content is not only disseminated by information channels, such as radio, television and the internet, but also through several public services in rural areas, such as technical assistance and education, since these services rarely consider the context of poor rural communities (see detail in chapter four, sub-section 4.4.7). Such a criticism was also reported by scholars in Brazil (e.g. Arroyo et al., 2011; Freire, 2005, 1994; Reis, 2015; TV Caatinga, 2016) and by experts in this study, as demonstrated in the following comments mentioned during the interviews in Ceará in 2015 and the online survey in 2016.

> "Until now, the official advisory services (technical assistance) have caused more cultural and productive disorganization of family farmers than the strengthening of any process of productive inclusion."

> "[…] where irrigation projects were implemented in Ceará, they (government) used a "tractor" not only to implement monocultures, but also to run over the culture of the people, because even the family organization was interfered by them. Thus, where irrigation projects took place, the big concern was to cut the bond with the past. It was a counter-development. While the press reported it as a big development step, they (government and the press) were killing the culture of the people."

> "[…] we have few pedagogic experiences focused on the reality of rural areas […] the traditional school that we have access to does not consider the needs of rural people."

> "[…] rural children are not educated in the school to like the place they are living [...] the lectures do not discuss the rural context. The lectures discuss another reality (urban) ... it seems that the idea of it is to form people to leave rural areas."

The cultural invasion leads to the spread of false beliefs in society that can be manifested in several ways (Freire, 2005). This study identifies at least four of such false beliefs. First, the belief that small farmers have as many opportunities as big farmers and if the former do not prosper, it is because they are lazy and unproductive, when in fact, there is no appropriate space for small farming in the Brazilian agrarian policy which promotes land concentration and conflicts and is based on monocultures and big farming (detail in chapter four, sub-section 4.3.2). Second, the belief that electricity access is no longer a concern in rural Ceará because it is a public service already universalized. Nevertheless, in general, poor rural people have access to electricity to meet basic human needs but have no access to electricity to meet additional productive needs (detail in sub-sections 4.4.9 and 4.4.11). Third, the belief that small farmers do not want to cooperate, when in fact, there are several negative experiences of cooperation in Ceará, some of them even led by governmental actions (detail in sub-section 4.4.5). Fourth and most important, the belief that poverty is a fatalism in Brazilian society, when in fact, there is a man-made conjuncture that generates poverty and high inequality (detail in sub-section 4.3.5 and section 4.6).

In all the scenarios that compose the cluster "S1-Conservative", limited capacity building and education companioned by non-adequate governance foment the current distrust environment among farmers in collaborative organizations, so that they remain disarticulated. This disarticulation and the low level of instruction will have negative effects on income source and asset accumulation of poor families, which can be intensified in times of economic instability (in the cases of scenarios 01 to 05, Table 5.5). The low financial resilience of families contributes in all scenarios to maintaining high the costs of electricity and cooking fuels, even considering the use of subsidies to keep electricity at low or moderate prices (in the cases of scenarios 03 to 08, Table 5.5). Regarding indoor air pollution, the lack of policies to deal with the matter associated with limited education and high costs of cooking fuels are expected to promote the use of unhealthy means of cooking, so that high indoor air pollution remains a problem in poor rural communities. A limited education is also expected to contribute to maintaining poor people unaware of the unequal social, economic and political conjuncture in which they are inserted (detail in chapter four, section 4.6). Moreover, such unawareness promotes a people's passive behaviour in accepting this unequal conjuncture as something "normal" in society.

This passive environment can even lead poor families to believe that they are moving out of poverty, since, for example, they are expected in all the scenarios of "S1-Conservative" to have access to some basic services such as electricity and water supply. Nonetheless, due to a limited capacity building and education, poor families are not expected to be encouraged to reflect on the services that could be available if they had a conjuncture that promotes more socioeconomic equity. The belief of social climbing can be reinforced through the opportunity to buy products such as electric appliances that 10 years ago would not have made sense, since most of the poor people did not have access to electricity in rural Ceará at that time (detail in chapter four, sub-section 4.4.9). This is so because the capacity to consume products is a form of social recognition in modern societies and legitimization of the life that people live, although for poor people the real possibility of social climbing in Brazilian society is limited (Souza, 2018).

Having discussed the two main driving forces of "S1-Conservative" and consequent developments, other relevant aspects should be discussed in this cluster of scenarios. Economic stability is expected to occur in scenarios 06 to 08 (Table 5.5) and will contribute to keep electricy prices at low or moderate levels (detail about these levels in chapter four, sub-section 4.4.12). Electricity prices are also influenced in scenarios 07 and 08 (Table 5.5) by the possibility of commercialization of electricity surplus produced by micro (≤ 0.075 MW) and mini (0.075 ≤ 5 MW) distributed generation (detail in sub-section 4.4.10). Economic stability, however, is not expected in this cluster of scenarios to contribute to changing the status quo that generates poverty in rural Ceará, as most of the trends in "S1-Conservative" suggest the continuance of poverty in multi-dimensions, supported by non-adequate governance and limited capacity building and education. In scenarios 01 to 05 (Table 5.5), economic instability is expected to take place and will contribute to increasing electricity prices to moderate and high levels. In these scenarios also poverty is expected to increase, similar to what happened during the recent Brazilian recession from 2014 to 2016 (detail in sub-section 4.4.15) and seems to happen now in 2020-21, triggered by economic recession combined with the impacts of the COVID-19 pandemic.

Due to medium environmental risks and uncertainties, poor farmers are expected to continue using cisterns to collect rainwater that can be used to grow vegetables and raise animals for their own family consumption and commercialization of surplus (scenarios 01 and 02, Table 5.5). In the case that farmers can install mechanized systems (scenarios 03 to 08, Table 5.5), the problem of land degradation can arise due to the adoption of inadequate irrigation systems, which is strengthened by the lack of adequate technical assistance.

In "S1-Conservative", all trends of the element "*Electricity market organization*" can occur, which are expected to increase the use or renewable power generation, in particular wind and solar. However, it is not expected that poor rural families will be able to profit from or have access to different market structures as energy producers. The trends "*low resilience*" of income source, "*limited*" capacity building and education, "*weak*" cooperation of farmers, "*non-adequate*" governance and "*limited*" grid infrastructure represent economic, social, political and technical conditions in the cluster that prevent poor people from benefiting from decentralized electricity generation. Thus, in a similar way that rural policies focusing on agribusiness, it is likely that different electricity market organizations, that can promote wind and solar energy in Ceará, will benefit well-off and high-income social groups the most, such as big farmers and private investors. This can be expected because these groups have the economic capital to invest in decentralized energy technologies and have access to a grid infrastructure of better quality to connect energy generators. Similarities can also be traced with the current wind energy sector in Ceará (detail in chapter four, sub-section 4.3.4). That way, different electricity markets can serve as means to support the unequal social, political and economic conjuncture reported in section 4.6.

Finally, the multifaceted context of "S1-Conservative" can be summarized as one that provides minimal conditions for poor families to stay in rural areas, nevertheless, living in poverty. The use of inadequate means of cooking that cause high indoor air pollution is expected to remain a problem among poor rural families. Also, although in this cluster of scenarios the use of decentralized electricity generation is expected to increase, poor families will not have appropriate conditions and opportunities to benefit from modern energy services (besides electricity for basic human needs), neither as energy producers nor as energy consumers in productive chains nor as users of clean means of cooking. Thus, "S1-Conservative" represents the continuance of the status quo of the energy-poverty nexus in rural Ceará.

5.4.2 Cluster of scenarios “S2-Migration”

The cluster “S2-Migration” is composed of six scenarios (Table 5.6) and is similar to the previous cluster analysed; with the exception of high environmental risks and uncertainties, leading to migration flows of poor rural people. Thus, the overall context of this storyline can be in general explained by three central trends of “*non-adequate*” governance, “*limited*” capacity building and education and “*high*” environmental risks and uncertainties, which represent the main driving forces in this cluster of scenarios. Similar to “S1-Conservative” also in “S2-Migration” the use of decentralized electricity generation based on wind and solar power is expected to increase in rural Ceará, but it is not expected that poor people will benefit from this kind of electricity generation. On the contrary, it is expected that renewable energies in the form of decentralized electricity generation will negatively impact local communities, similar to the current state of the wind energy sector in Ceará (detail in chapter four, sub-section 4.3.4). In summary, “S2-Migration” presents the worst scenarios for poor rural people because they are not expected to have appropriate socio, political and environmental conditions to live in rural areas, culminating in migratory flows similar to what happened in Ceará in the 1990s and years before (detail in section 4.3.1).

Table 5.6: Cluster of scenarios “S2-Migration”

	Scenarios and Trends					
System elements	Scenario 09	Scenario 10	Scenario 11	Scenario 12	Scenario 13	Scenario 14
A: Household infrastructure (basic services)	A1: Universal water supply					
B: Income source and asset accumulation	B1: Low resilience					
C: Indoor air pollution	C1: High					
D: Costs of electricity and cooking fuels	D1: High					
E: Farmers’ organization	E1: Weak cooperation					
F: Irrigation	F2: Mechanized - poor irrigation management					
G: Capacity building and education	G1: Limited					
H: Rural policies	H1: Limited opportunities					
I: Electricity demand	I1: Basic human needs					
J: Electricity market organization	J1	J2	J3	J1	J2	J3
K: Grid infrastructure	K1: Reliable to supply basic human needs					
L: Electricity price	L2: Moderate				L3: Low	
M: Rural population	M1: Migration flows					
N: Environmental risks and uncertainties	N1: High					
O: Economic stability	O1: Unstable			O2: Stable		
P: Governance	P1: Non-adequate					

Notes: J1: Regulated market. Prosumers are not allowed to sell electricity surplus.

J2: Regulated market. Prosumers can sell electricity surplus to the local distribution company.

J3: Non-regulated market. Prosumers can sell electricity surplus in a non-regulated market.

The cluster "S2-Migration" presents the same socio and political conditions presented in "S1-Conservative", that are mainly driven by non-adequate governance and limited capacity building and education. In such a context, the causes of poverty as the ones discussed in section 4.6 (chapter four) are not expected to be problematized and critically analysed by a limited capacity building and education in poor rural communities. Also, a non-adequate governance, representing the interests of dominant social groups the most, is not expected to be willing to change this context as it would imply modifications in the current political, social and economic structures in Brazil in general and in Ceará in particular. Instead, a non-adequate governance can take advantage of the electricity that poor people have access to in order to propagate false beliefs as those presented in "S1-Conservative", contributing to maintaining a passive and indifferent environment in society in relation to poverty and high inequalities.

The key difference between "S1-Conservative" and "S2-Migration" is the change from "*medium*" to "*high*" environmental risks and uncertainties, which is promoted by non-adequate agricultural practices and non-adequate governance that disregards or gives less importance to anthropogenic causes of climate change and contributes to land degradation. This seems to be the case of the current national government in Brazil. In power since 2019, the national government has facilitated forest devastation, stimulated land conflicts, mining activities in indigenous lands and the expansion of the agribusiness model, in particular in the Amazon region (BBC, 2020a; G1, 2020a; Greenpeace, 2020).

In this cluster of scenarios, high environmental risks and uncertainties will cause large drought periods, affecting the collection of rainwater in cisterns and making it more difficult for family farmers to maintain agrarian and animal production also for their own consumption. For farmers that can implement mechanized irrigation systems, a limited capacity building will pay little attention to ensure that the systems adopted are appropriate to the region, causing soil salinization and land degradation.

As in "S1-Conservative", all trends of the element "*Electricity market organization*" can occur in "S2-Migration". However, it is not expected that poor rural communities will benefit from or have access to different market structures as energy producers. Thus, it is expected that different market organizations that promote decentralized electricity production will primarily benefit those social groups that are already in a better socioeconomic position. According to the discussion presented in chapter four, sub-sections 4.3.4 and 4.3.5, supported by some of the local actors interviewed in Ceará, there is evidence indicating that this is already the case of the wind energy sector in Ceará that has caused more negative than positive impacts on local communities. Also, since land degradation is expected to increase in "S2-Migration", it can become more attractive for investors to buy cheap land from poor people to install decentralized energy systems, especially when considering a context in which agrarian production is no longer attractive or viable on these lands.

It is worth noting that similar thoughts were reflected by another scholar in Brazil (Aquino, 2020, 2018). The author suggests that the use of renewable energies can increase migration in the Brazilian semi-arid, including rural Ceará. This is so because climate change, extensive drought periods and unsustainable agrarian practices are expected to increase the percentage of unproductive lands in the semi-arid, which can be bought by private and external investors at low prices to produce electricity from solar and wind, forcing local families to migrate. Aquino (2020) provocatively uses the term “monoculture” of renewable energies, which remember the implementation of agrarian monocultures in Brazil that are a key driver of the rural exodus of small farmers, as discussed in chapter four, sub-section 4.3.2.

Finally, the cluster “S2-Migration” presents a multidisciplinary context similar to “S1-Conservative” in which poor families do not have appropriate conditions and opportunities to benefit from modern and renewable energies to reduce poverty. This context is highly influenced by high environmental risks and uncertainties that can hamper many poor families from living on their lands. The likely alternative for these families is to migrate to other regions or cities, as occurred in the past. However, this strategy will not solve the problem of poverty because most regions and cities in Brazil do not have adequate socio and economic conditions to receive poor migrants (Ipea, 2016b). Thus, poverty is expected to be a constant among the poor families that remain on their lands in Ceará as well as the families that migrate to other regions. In such a context, decentralized energy systems can contribute to the continuance of poverty, because considering that degraded land can be used to generate electricity, it is not expected that a non-adequate governance will spend efforts to avoid land degradation in rural areas or to promote poor families and communities to produce electricity. Instead, those social groups that hold the political and economic power in Brazil and Ceará can even profit from this context because cheap land can be bought to produce electricity, contributing to the rural exodus of poor people and to maintain or increase social and economic inequalities.

5.4.3 Cluster of scenarios “S3-Failed transition”

The cluster “S3-Failed transition” is composed of two scenarios (Table 5.7) and presents the main political change from “*non-adequate*” to “*adequate*” governance, in comparison to the two previous clusters of scenarios analysed. This makes “S3-Failed transition” a particularly interesting storyline for this study because it demonstrates that only adequate governance, with enhanced propositions for poor people, is not enough to break down a conjuncture that generates poverty and high socioeconomic inequalities, especially in an environment of “*unstable*” economy and “*limited*” capacity building and education as presented in this cluster of scenarios. Instead, the storyline here presented indicates that the combination of these three main driving forces can result in the continuance or increment of poverty, similar to the two first clusters previously discussed.

Table 5.7: Cluster of scenarios "S3-Failed transition"

System elements	Scenarios and Trends	
	Scenario 15	Scenario 16
A: Household infrastructure (basic services)	A2: Universal water supply and basic sanitation	
B: Income source and asset accumulation	B1: Low resilience	
C: Indoor air pollution	C1: High	
D: Costs of electricity and cooking fuels	D1: High	
E: Farmers' organization	E1: Weak cooperation	
F: Irrigation	F1: Manual or per gravity	F2: Mechanized - poor irrigation management
G: Capacity building and education	G1: Limited	
H: Rural policies	H1: Limited opportunities	
I: Electricity demand	I1: Basic human needs	
J: Electricity market organization	J1: Regulated market. Prosumers are not allowed to sell electricity surplus	
K: Grid infrastructure	K1: Reliable to supply basic human needs	
L: Electricity price	L1: High	L2: Moderate
M: Rural population	M2: Slightly decreasing	
N: Environmental risks and uncertainties	N2: Medium	
O: Economic stability	O1: Unstable	
P: Governance	P2: Adequate	

Among the trends present in "S3-Failed transition", it should be noted that almost all of them (except A2, L1, L2 and P2) represent the current situation in the rural areas of Ceará described in chapter four and in the cluster "S1-Conservative" that represents the continuance of the status quo. Thus, the analysis of this cluster is not difficult to perform since the main change in the status quo lies in the trend "*adequate*" governance. However, before discussing the storyline of this cluster in detail, three aspects previously discussed need to be recapitulated to better identify possible effects of an adequate governance under the circumstances presented in this cluster.

The first aspect refers to the mainstream of the Brazilian agrarian policy, which is based on agribusiness to supply national and global commodity markets (details in chapter four, sub-section 4.3.2). This policy supports a historical characteristic in Brazil of vast extensions of land belonging to few people, and in Ceará this reality is no different. The agribusiness model and consequent land concentration were already reported by scholars as two of the main drivers of high social and economic inequalities in the country. Also, it is worth noting that big farmers, represented in Congress by the Rural bloc, play an essential role in Brazilian politics to sustain policies that promotes land concentration and the expansion of the agribusiness model in the country. There are also high indicatives that the fires in the Amazon region in the last years and more recently in the Brazilian wetlands are caused mainly by big farmers as a way to expand agribusiness in these regions (Fox, 2020; G1, 2020b-c), contradicting the official discourse defended by the national government that seeks to minimize the fires in the regions while blaming native and indigenous people for part of the fires caused (BBC, 2020b; ONU News, 2020) or suggesting that NGOs are connected to environmental crimes in Brazil (G1, 2020d).

The second aspect refers to the man-made conjuncture resistant to social, political and economic changes in Brazil and in Ceará pro-poor (details in chapter four, section 4.6). Although signs of progress can be observed towards the reduction of poverty and improvement in the quality of life, they are still insufficient to break down historical high inequalities in the country. There are even indicatives that this progress can contribute to cultural invasion by fostering a passive environment in society in relation to this unequal conjuncture, as discussed in the two previous clusters of scenarios. Also, some progresses achieved are very sensitive to economic stability. That way, the recent economic crisis pushed since 2014 more than 4.5 million people back to extreme poverty in Brazil (Jiménez, 2019).

The last aspect to be recapitulated refers to the limited and non-contextualized education and capacity building offered in rural areas (details in chapter four, sub-section 4.4.7), which do not encourage people to problematize the situation in which they live. Consequently, dominant social groups (aware of their acts or not) can benefit from this situation to maintain the status quo of high socioeconomic inequality. For that, several mechanisms can be used, as for example, information technologies to propagate false beliefs and overlap local culture, as discussed in the previous clusters analysed.

Having recapitulated these three aspects, possible impacts of an adequate governance in “S3-Failed transition” can be better discussed. An adequate governance in a democratic society is expected to create institutional reforms to reduce high social and economic inequalities at least. Consequently, adequate governance is expected to contradict the current unequal conjuncture and the interest of dominant (but minority) social groups that support this conjuncture. However, these groups, in general, are also those who hold the economic power in the country. Thus, a conflicting situation between adequate governance and dominant social groups is expected to occur in this cluster of scenarios. On the one hand, the first will try to reduce the privileges and redistribute the power of the latter to disadvantaged social groups, looking for the reduction of extreme disparities. On the other hand, dominant social groups will try to obstruct this redistribution to maintain their privileges and the status quo of high socioeconomic inequality.

Considering the situation described above, an adequate governance is expected to achieve some progress to benefit poor people such as the universalization of water supply and basic sanitation, as indicated in the two scenarios that compose “S3-Failed transition”. However, dominant social groups are expected to disturb initiatives proposed by the government seeking more social and economic equity, which will lead to economic instability in this cluster of scenarios. Under an environment of economic instability, well-off and high-income people can be negatively affected, but they are much more prepared to overcome crises than poor people, which will be the most affected. In addition, considering an environment of limited and non-contextualized education and capacity building, an adequate governance cannot expect to have the support of poor people, especially of those who idealize the upper classes and incorporate in themselves the oppressor of their pairs, as discussed in "S1-Conservative". Without the problematization of the sociocultural, political and economic situation, poor people can even support dominant social groups to change the government aiming for economic stability, though this stability means living in a society with high inequalities and poverty. Thus, this cluster of scenarios is considered a failed transition because, despite the goodwill of the government to push reforms aiming for development with more equity, this government is not likely to succeed with the implementation of such reforms.

Finally, it is worth noting that, in the 1960s, Brazil had already experienced a history similar to the story described above. At that time, the indicative of possible basic reforms associated with an unstable economy (in 1963 the inflation rate was 79,9% (Folha de São Paulo, 2014b)) contributed to the military coup in 1964. In 1961, when João Goulart assumed the presidency of Brazil, basic reforms were announced aiming to reduce social and economic inequalities. Among others, the reforms included education reform (around 40% of the Brazilian population were illiterate in the 1960s (INEP, 2003)), land reform and the extension of voting rights to the illiterates. These reforms, in particular the land reform, found strong resistance in Congress and among conservative sectors of civil society, especially among those from the upper classes, that contributed significantly to the military coup in 1964 that was also supported by the United States (Bercovici, 2013; Cardoso, 2013). Such a behaviour of dominant social groups is not a surprise because, as Freire (1994) and Souza (2017) noted, democracy for these groups is good as long as they are the main beneficiaries. The reforms proposed by President Goulart were not implemented and Brazil lived under a military dictatorship until 1985.

5.4.4 Cluster of scenarios "S4-Transition through contextualized education"

The cluster "S4-Transition through contextualized education" is composed of five scenarios (Table 5.8) and indicates the possibility for poor people, even under non-adequate national or regional governance, to join their efforts, plan strategies and grasp new opportunities to access and use energy to increase income generation, cultural capital and food sovereignty as well as to enhance the quality of life and reduce poverty in rural communities. In this cluster, the main driving force able to trigger a transition out of poverty lies in the trend "*universalized and contextualized"* capacity building and education. The cluster is considered a transition out of poverty because the scenarios that compose it are sensitive to economic stability, which is volatile and subject to crises in the long term. That way, economic "*stability*" and "*non-*

adequate" governance are also considered main drivers in this cluster of scenarios. Finally, it should be noted that this cluster of scenarios can occur in single or a group of communities and not necessarily in whole rural Ceará (detail below).

Table 5.8: Cluster of scenarios "S4-Transition through contextualized education"

System elements	**Scenarios and Trends**				
	Scenario17	Scenario 18	Scenario 19	Scenario 20	Scenario 21
A: Household infrastructure (basic services)	A1: Universal water supply				
B: Income source and asset accumulation	B2: High resilience				
C: Indoor air pollution	C2: Low				
D: Costs of electricity and cooking fuels	D2: Low				
E: Farmers' organization	E2: Strong cooperation				
F: Irrigation	F3: Mechanized – adequate irrigation management				
G: Capacity building and education	G3: Universalized and contextualized				
H: Rural policies	H2: Large and strong opportunities				
I: Electricity demand	I2: Basic human needs and productive chains				
J: Electricity market organization	J1	J2	J3	J2	J3
K: Grid infrastructure	K2: Reliable to supply productive chains and prosumers, besides basic human needs				
L: Electricity price	L2: Moderate			L3: Low	
M: Rural population	M3: Stabilized or slightly increasing				
N: Environmental risks and uncertainties	N2: Medium				
O: Economic stability	O2: Stable				
P: Governance	P1: Non-adequate				

Notes: J1: Regulated market. Prosumers are not allowed to sell electricity surplus.
J2: Regulated market. Prosumers can sell electricity surplus to the local distribution company.
J3: Non-regulated market. Prosumers can sell electricity surplus in a non-regulated market.

A key aspect to be analysed in "S4-Transition through contextualized education" is the combination of the trends "*non-adequate*" governance and "*stable*" economy, which are considered two main driving forces of the cluster. Such a combination makes this cluster of scenarios particularly interesting in this study because, under a stable economy, even governments with limited capacity or willingness to promote poor people and to reduce high socioeconomic disparities between different social groups in society can enhance and enlarge policies that increase opportunities for poor people. The Programme Light for All, that universalized access to electricity in Ceará, can be considered one example of a large energy policy created under an environment of stable economy and large corruption in the Brazilian national government and the economic market (large corruption is used here as one example of non-adequate governance). In a similar way, the public services related to education and technical assistance in rural areas are expected to be universalized in all the scenarios that compose the cluster "S4-Transition through contextualized education".

Nevertheless, as indicated in the cluster, only the universalization of these services is not enough to put poor rural communities in the way of poverty reduction (one should highlight that education is already universalized in Ceará but capacity building – detail in chapter four, sub-section 4.4.7). Thus, more important than the universalization, the education and capacity building in rural areas need to be contextualized for the reality of these areas. Alternatively, this cluster of scenarios can occur in single communities or clusters of communities that already enjoy a contextualized education and capacity building. In this sense, one should highlight that Ceará already presents interesting initiatives and experiences of contextualized education and capacity building in rural communities that have presented positive results towards the reduction of local poverty (detail in chapter four, sub-section 4.4.7).

The contextualization of education and capacity building means a shift in the current state of these services and has to do with what Freire (2005) calls a cultural revolution. This contextualization, and consequent cultural revolution, is not a trivial task to be achieved as it implies the problematization of the rural context *with* the poor people and not *for* the poor people. Once involving poor people in this educational process, the problematization of the sociocultural, political and economic situation in which they live and their communities exist contradicts the passive and indifferent environment fostered by the cultural invasion presented in the cluster “S1-Conservative”. As Freire (2005, 2003) noted, while the cultural invasion represents a mechanism used by dominant social groups to dominate poor people, the cultural revolution is a mechanism to free the last from the domination of the former. While the cultural invasion is an anti-dialogical action in which false beliefs are spread out across society to support the status quo, the cultural revolution is an action that requires constant dialogue with the poor to problematize together with them their situation, deconstructing beliefs and creating strategies and actions towards a less unequal society with no poverty. Thus, one can argue that the contextualization of the education and capacity building can lead families to new socialization opportunities, in which the causes of poverty and inequalities are deconstructed and strategies are defined to break down (or at least to reduce the impact of) the mechanisms that generate poverty and high inequalities.

Through a contextualized education and capacity building, poor rural families in Ceará are expected to problematize the energy-poverty nexus in their communities. For that, the participatory methods suggested in the Integrative Approach to the Energy-Poverty Nexus are useful (detail in chapter three, section 3.2). This problematization can start through the discussion of questions related to poverty and energy in multi-dimensions with the community members. For instance: what does poverty mean in their communities? What are the possible causes of poverty? What does poverty cause in their communities? What does energy mean for the communities? Why do big farmers have, in general, better energy services than poor communities? Which economic activities can be fostered by energy services in the communities? Which are the barriers that impede the use of energy for economic activities? How can energy be used to reduce poverty and inequalities? Are there dominant social groups outside and inside the community? How dominant social groups (inside and outside the community) can be characterized? Which mechanisms do these groups use to dominate poor and marginalized people and keep the status quo of poverty and high socioeconomic inequality?

Once discussing such and other questions with the families, it is possible that they arrive at two main conclusions. First, that poverty is not a fatalism in their communities and there is a man-made conjuncture that causes this poverty, as discussed in section 4.6 (chapter four). In many cases, this man-made conjuncture can even be found inside or between communities, in which determined groups exclude and oppress the others (see the example from the Bolivian Amazon presented in chapter two, section 2.3). Second, that although the universalization of electricity access represents an advance in their quality of life, it does not mean that they are able to take full advantage of this energy to help them move out of poverty.

These two conclusions (the families can even arrive at more conclusions) can lead to the reflection about possible strategies to reduce poverty with the support of modern and renewable energies. Observing the trends presented in “S4-Transition through contextualized education”, one possible strategy expected to occur in all the scenarios is the strong cooperation of farmers, which is also valid for community members involved in non-agrarian activities. In a contextualized education, the current disbelief in collaborative actions (detail in chapter four, sub-section 4.4.5) is replaced by a trusting environment because farmers and community members are expected to arrive at the conclusion that if they collaborate with each other, they can increase the opportunities to move out of poverty more than if they work individually. Moreover, they can join efforts to press governments and electricity utilities to improve the grid infrastructure in their communities. This improvement, which is expected to occur in all the scenarios of this cluster, can enable the use of electricity in productive chains that need reliable and adequate electricity supply, such as for water pumping and for processing fruits and milk, which are typical agricultural activities that can be boosted in rural Ceará. Similarly, engaged farmers and community members can be more effective in requesting enhanced policies to commercialize local products, which is expected to increase the resilience of income sources and asset accumulation among the families.

Considering the context presented above, small farmers and community members can grasp an additional opportunity in this fourth cluster of scenarios, namely the possibility to access different electricity market structures as prosumers. For that, they can create energy associations (already allowed by the Brazilian legislation) to install and use decentralized electricity generation connected to the distribution grid, which can increase energy reliability in the communities and contribute to keep electricity prices at moderate or low levels, as indicated in the scenarios of “S4-Transition through contextualized education”. Through associations, rural people can already benefit from available funding in Ceará to install decentralized electricity generation based on renewables (detail in chapter four, sub-section 4.4.10).

Through a contextualized education and capacity building, rural people can also problematize irrigation and environmental impacts, which can lead them to adopt irrigation systems adequate to semi-arid regions, contributing to avoid land degradation and overuse of water resources. The level of indoor air pollution is expected to decrease in all the scenarios due to its problematization with regard to its hazards to human health, enabling families to create strategies to reduce indoor air pollution while maintaining their tradition of cooking food using biomass. For instance, the adoption of efficient cooking facilities based on biomass and well-ventilated kitchens can be strategies to be adopted. In case the families opt for them, it is important to problematize two additional concerns. The first is related to the overuse of biomass resources near households. To avoid this overuse, strategies related to sustainable forest management (Faggin and Offermans, 2016) and agroecology (Guzmán and Montiel, 2009; Rural 21, 2018) can be adopted in which the families continue using the biomass resources available but the harvest of biomass is not bigger than its reposition. There are already some positive experiences in Ceará involving small farmers and agroecological systems that has contributed to decreased social and economic vulnerability of poor families (CETRA, 2014; Leonel, 2014). The second concern is related to gender equality because the task of gathering biomass is often executed by women in rural areas. In a contextualized education, gender equality is a central topic of discussion to foster it (Cruz, 2013). Another strategy to reduce indoor air pollution refers to the adoption of biogas and solar cookstoves[5]. In all these technologies, including well-ventilated kitchens, community members can be trained to build the technologies and kitchen facilities.

The advances achieved in this cluster of scenarios and discussed above (i.e. trends B2, C2, D2, E2, F3, G3, H2, I2 and K2 in Table 5.8) will open space for new socialization processes inside the communities, which are expected to increase and create new capabilities among the families to take more advantage of modern and renewable energies to reduce poverty in their communities. Also, this overall context of better quality of life with reduced poverty and enhanced opportunities for local families will make rural areas more attractive, especially for young people, contributing to avoid migration to the cities. During the fieldwork campaign in Ceará, the author of this study visited one community that seems to be on the way of this cluster of scenarios. In the community, young people are not willing to move to the city because, according to them, living and working conditions in the community are better than in the city. Considering that this cluster of scenarios can also occur in rural Ceará as a whole,

[5] The author of this dissertation visited successful experiences related to biogas and solar cooking technologies in Ceará and in the Amazon and Andean regions in Bolivia in another project related to the social value of energy, conducted in partnership with the Arizona State University (ITAS, 2018).

one can assume that the rural population will become stabilized or even slightly increase as suggested by all the scenarios that compose the cluster.

Finally, the storyline presented in "S4-Transition through contextualized education" indicates the possibility of poor people to benefit from modern and renewable energies, in the forms of decentralized electricity generation and clean cooking, to reduce poverty through the problematization of the energy-poverty nexus in their communities. Consequently, the stabilization or slight increment of the rural population can occur. However, due to its sensibility to economic stability, this cluster is assumed as a transition out of poverty and its storyline does not necessarily need to be interpreted as covering the entire rural areas in Ceará. Instead, this storyline can occur in single communities or clusters of communities that have access to a contextualized education and capacity building. That way, this cluster represents the easier possibility for local communities to promote the social value of energy towards poverty reduction.

5.4.5 Cluster of scenarios "S5-Overcoming poverty in rural Ceará"

The cluster "S5-Overcoming poverty in rural Ceará" is composed of eight scenarios (Table 5.9) and presents a multidisciplinary context in which poor families are able to benefit from modern and renewable energies to help them move out of poverty. The cluster is similar to the previous one analysed, but it presents the key difference of "*adequate*" governance that is one of the main drivers that can accelerate the development and implementation of strategies to overcome poverty in rural Ceará. Also, in contradiction to the three first clusters of scenarios analysed in this study, this cluster presents the trend "*universalized and contextualized"* capacity building and education as another main force. The combination of these two driving forces reveals the importance of having people aware of their sociocultural, political and economic situation to foster, together with an adequate governance, a less unequal society with no poverty. Consequently, the cluster "S5-Overcoming poverty in rural Ceará" presents, between all the clusters analysed, the best conditions to promote the social value of energy as a mechanism of poverty reduction in the rural areas of Ceará.

Table 5.9: Cluster of scenarios "S5-Overcoming poverty in rural Ceará"

	Scenarios and Trends							
System elements	Scenario 22	Scenario 23	Scenario 24	Scenario 25	Scenario 26	Scenario 27	Scenario 28	Scenario 29
A: Household infrastructure (basic services)	A3: Universal water supply, basic sanitation and waste management							
B: Income source and asset accumulation	B2: High resilience							
C: Indoor air pollution	C2: Low							
D: Costs of electricity and cooking fuels	D2: Low							
E: Farmers' organization	E2: Strong cooperation							

System elements	Scenarios and Trends: Scenario 22	Scenario 23	Scenario 24	Scenario 25	Scenario 26	Scenario 27	Scenario 28	Scenario 29
F: Irrigation	F3: Mechanized – adequate irrigation management							
G: Capacity building and education	G3: Universalized and contextualized							
H: Rural policies	H2: Large and strong opportunities							
I: Electricity demand	I2: Basic human needs and productive chains							
J: Electricity market organization	J1	J2	J3	J1	J2	J3	J2	J3
K: Grid infrastructure	K2: Reliable to supply productive chains and prosumers, besides basic human needs							
L: Electricity price	L2: Moderate						L3: Low	
M: Rural population	M3: Stabilized or slightly increasing							
N: Environmental risks and uncertainties	N2: Medium							
O: Economic stability	O1: Unstable			O2: Stable				
P: Governance	P2: Adequate							

Notes: J1: Regulated market. Prosumers are not allowed to sell electricity surplus.
J2: Regulated market. Prosumers can sell electricity surplus to the local distribution company.
J3: Non-regulated market. Prosumers can sell electricity surplus in a non-regulated market.

One of the important aspects in “S5-Overcoming poverty in rural Ceará” lies in reforms that an adequate governance can promote to reduce high socioeconomic inequality. Thus, when comparing this cluster with the cluster “S3-Failed transition”, there is strong evidence that one of the main reforms to be performed refers to the universalization and contextualization of education and capacity building in rural areas. As described in chapter four, sub-sections 4.4.7, and the previous section 5.4.4, the contextualization of education and capacity building should encourage and empower people to think critically and to problematize the context in which they live. The association of adequate governance and contextualized education can create an environment between community members and governments, at different levels of local, regional and national, in which one trusts and supports the other. This environment is expected to at least decrease the power of the historical and unequal man-made conjuncture found in the country (detail in section 4.6), if not to break it down.

Through the problematization of the rural context in Ceará, community members and governments, together in constant dialogue, can address the energy-poverty nexus and set strategies that can enable poor communities to benefit from modern and renewable energies, in the forms of decentralized electricity generation and clean cooking, to reduce poverty. Also, in a contextualized environment, the benefits of regional or national policies towards poverty reduction can be maximized since rural families are expected to be active actors in solving local problems.

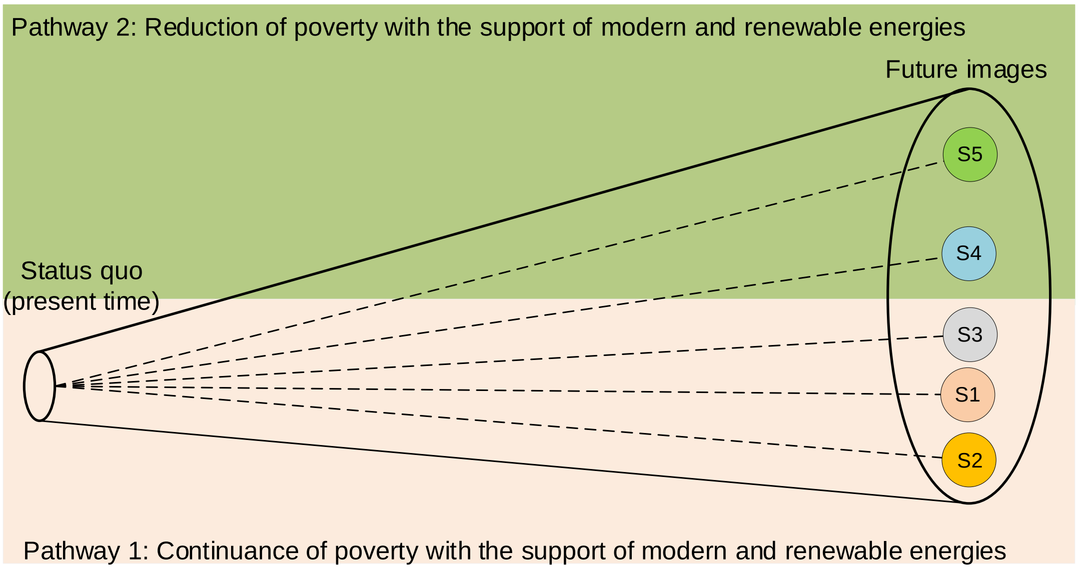
The strategies to be adopted in “S5-Overcoming poverty in rural Ceará” will be sensitive to the needs and context of each community or region. Some strategies were already mentioned in the previous cluster of scenarios, as for example: (i) improvement of the grid infrastructure in rural Ceará to support productive chains and decentralized electricity systems based on renewables, (ii) promotion of policies to open markets for agrarian and non-agrarian products produced in the communities, and (iii) implementation of clean means of cooking respecting local culture. One could argue that the implementation of these strategies, especially the improvement of the grid infrastructure, are challenging in the sense that they would involve too much money from the national and state governments that are already in a precarious financial situation. However, if reforms were conducted to reduce the high privileges of dominant social groups and to reduce corruption at the political and market level in Brazil, the financial situation of governments is not expected to be the main concern to implement the strategies proposed above.

Together, communities and governments can create even more strategies to increase opportunities to reduce poverty and high inequalities that can be difficult to be achieved in “S4-Transition through contextualized education”. For instance, a plan can be drawn and adopted to transfer current subsidies from electricity bills (details in chapter four, sub-section 4.4.12) to facilitate the acquisition and use of decentralized electricity systems connected to the grid in poor rural communities. The combination of such strategies with the contextualization of education and capacity building will open space for community members to rethink the context in which they live while creating new socialization opportunities in which poverty and high socioeconomic inequality are not treated as unavoidable in modern societies.

Finally, once a trusting and supportive environment is established between communities and governments and strategies create new opportunities to reduce poverty, an adequate governance can start to implement additional reforms. Similar to “S3-Failed transition”, dominant social groups can try to hinder governmental actions to promote poor and marginalized people. This can lead to economic instability, which is also expected to occur in the scenarios 22 – 24 (see Table 5.9). However, poor people would be aware of their sociocultural, political and economic situation and can, therefore, provide support to the government to realize reforms towards more socioeconomic equity. Moreover, adequate governance can conduct gradual reforms aiming to promote just transition (ILO, 2013a-b) and to avoid conflicting situations with dominant social groups. For instance, policies can be created to gradually move the agrarian sector from its economic model based on agribusiness and monocultures to a model that promotes diversification and small farming, such as agroecology (Rural 21, 2018). Such a gradual change would promote the reorganization of the agrarian sector and open space for new opportunities for growth with more equity in rural areas. Nonetheless, it needs to be recognized that this transformation in the agrarian sector would require new models of global food supply strengthening local and regional food production (Fuchs et al., 2020), since the global demand for staple food is one responsible for the adoption of the agribusiness model in Brazil (detail in chapter four, sub-section 4.3.2).

5.5 Two main pathways of development for the energy-poverty nexus in rural Ceará

The five clusters of scenarios analysed in the previous section indicate a range of possibilities varying from the continuance of poverty to its reduction with the support of modern and renewable energies. This range of possibilities and the status quo of the energy-poverty nexus can be reorganized in two main pathways of development that the nexus can follow in the future (Figure 5.7). Such reorganization is important because it prepares the ground for the analysis of how easy or difficult it is for society to move the energy-poverty nexus in rural Ceará from an undesired to a desired pathway, which is the central point of step four of the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, sub-section 3.2.4) to be discussed in the next chapter of this dissertation.



Legend:

- S1 — Cluster of scenarios "S1-Conservative" - main driving forces: "*limited*" capacity building and education and "*non-adequate*" governance
- S2 — Cluster of scenarios "S2-Migration" - main driving forces: "*limited*" capacity building and education, "*non-adequate*" governance and "*high*" environmental risks and uncertainties
- S3 — Cluster of scenarios "S3-Failed transition" - main driving forces: "*limited*" capacity building and education, "*unstable*" economy and "*adequate*" governance
- S4 — Cluster of scenarios "S4-Transition through contextualized education" - main driving forces: "*contextualized*" capacity building and education, "*stable*" economy and "*non-adequate*" governance
- S5 — Cluster of scenarios "S5-Overcoming poverty in rural Ceará" - main driving forces: "*contextualized*" capacity building and education and "*adequate*" governance

Figure 5.7: Two main pathways that the energy-poverty nexus in rural Ceará can follow in the future

In the first pathway of development, the clusters "S1-Conservative", "S2-Migration" and "S3-Failed transition" can be grouped while indicating that modern and renewable energies will contribute to the continuance of poverty and high inequalities in Ceará. According to the storylines of these three clusters, high indoor air pollution is to remain a problem in poor households and the use of decentralized and renewable electricity generation will benefit well-off and high-income social groups the most, such as private investors and big farmers, supported by a non-adequate governance. Also, the farmers are expected to remain disarticulated and low resilience of income sources and asset accumulation would remain a problem among poor rural families.

The storyline of the cluster "S1-Conservative" represents the reference story in this study because it is similar to the status quo, as discussed in sub-section 5.4.1. Thus, this study suggests that the energy-poverty nexus in rural Ceará is currently following the first pathway that represents the continuance of poverty with the support of modern and renewable energies.

The storyline of "S2-Migration" (detail in sub-section 5.4.2) represents the worst vison for poor people and migration flows are expected to occur, similar to what occurred in the 1990s and years before in Ceará. This is so expected because of high environmental risks and uncertainties, which are maximized by the adoption of inadequate agrarian practices and non-adequate governance that disregards anthropogenic causes of climate change and contributes to land degradation. The adoption of inadequate agrarian practices for the semi-arid region, such as poor irrigation management, is maximized by a limited and non-contextualized capacity building and education.

The cluster "S3-Failed transition" (detail in sub-section 5.4.3) presents an attempt to reduce poverty and high socioeconomic inequality through adequate governance, which can lead to a conflicting situation with dominant social groups and to economic instability. Such an attempt can be easily damped by these groups because, without a contextualized education, poor people can support them to change the government. Since poor people are the most affected by economic instability, their participation in pressuring to change the government can be understood as a way to seek economic stability, although this stability means the continuance of the status quo of poverty and high socioeconomic inequality.

A limited capacity building and education is expected in the three clusters of scenarios that compose the first pathway of development to be a main driver towards a passive environment in society in relation to poverty and high socioeconomic inequality. In such an environment, information technologies can be used as a mechanism to propagating false beliefs that reinforce the status quo and the man-made conjuncture that generate poverty in Brazil in general and in Ceará in particular. For instance, the false belief that poverty is a fatalism in modern societies and, therefore, should be accepted as something "normal" in Brazilian society.

The second pathway of development is composed of the clusters of scenarios "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará" and presents storylines in which the social value of energy as a mechanism of poverty reduction is fostered. In both clusters of scenarios, poor rural people are expected to take more advantage of modern and renewable energies, as consumers and producers, to reduce poverty in their communities and improve living conditions.

In “S4-Transition through contextualized education” (detail in sub-section 5.4.4), rural families are encouraged and empowered by a contextualized education and capacity building to problematize the energy-poverty nexus in their communities. This problematization can lead families to collaborate with each other and create strategies to improve energy access and use towards poverty reduction. Consequently, this cluster of scenarios represents the easier conditions to be achieved by single or group of communities to benefit from modern and renewable energies and create new opportunities and capabilities to reduce poverty.

The context of poverty reduction described in “S4-Transition through contextualized education” is maximized in “S5-Overcoming poverty in rural Ceará” (detail in sub-section 5.4.5) due to adequate governance, which is expected to conduct reforms seeking more social and economic equity. The storyline derived from a contextualized education and an adequate governance in the fifth cluster of scenarios indicates the best conditions, among all the clusters analysed, to minimize or break down the historical and unequal man-made conjuncture that maintain the status quo of poverty in Ceará.

Nevertheless, the author of this dissertation recognizes that imagining the world of “S5-Overcoming poverty in rural Ceará” was the most challenging in this study. This was so because the construction of future views considers real experiences from the past and present and assumptions about the future (Grunwald, 2011). In that sense, there are no real experiences from the past and present on a large scale similar to the image constructed in “S5-Overcoming poverty in rural Ceará”. Thus, this was the only storyline constructed in this study that took into consideration real experiences from a contextualized education on a small scale, including the matter of energy in poor rural communities, and extended them to the whole case of rural Ceará, under the political environment of adequate governance. For all other storylines, similar stories can be observed in the History of Brazil and Ceará – i.e. the cluster “S1-Conservative” represents the current status quo; the cluster “S2-Migration” presents similarities to what happened in Ceará in the 1990s and years before through migration flows of poor people; the cluster “S3-Failed transition” presents similarities to what happened in Brazil in the 1960s, leading to the military coup in 1964 and dictatorship until 1985; and finally, the cluster “S4-Transition through contextualized education” took into consideration experiences from the local level in rural communities.

Since this study suggests that the energy-poverty nexus in rural Ceará is following the first pathway, in particular the cluster “S1-Conservative”, it is of great interest to analyse how easy or hard it is for society to move the nexus from the first to the second pathway of development because this second pathway presents better views of the future in relation to poverty reduction. This analysis is carried out in detail in the next chapter of this dissertation.

Once observing the storylines of the clusters of scenarios present in each one of the pathways described above, it is to be noted that the main conditions that differentiate the first from the second pathway are related to the trends of the elements "*Capacity building and education*" and *"Governance*". Moreover, among the trends of these two elements, there is a strong indicative that a contextualized capacity building and education is the essential condition to start the movement of the energy-poverty nexus in the direction of the second pathway. This indicative considers that only an adequate governance without a contextualized education (i.e. corresponding to the cluster "S3-Failed transition") is not sufficient to conduct the energy-poverty nexus to the clusters of scenarios corresponding to the second pathway of development.

Therefore, going back to the research question proposed in this study, one can argue that the main condition to trigger modern and renewable energies as means of poverty reduction in rural Ceará refers to the contextualization of the capacity building and education in rural areas, which through the problematization of the energy-poverty nexus can enable people to create new opportunities and capabilities to take more advantage of energy to move out of poverty. This context can be maximized through an adequate governance, which is the second main condition identified in this study for the case of rural Ceará.

Chapter six

Moving the energy-poverty nexus in rural Ceará to a desired pathway

6.1 Introduction

The clusters of scenarios analysed in the previous chapter represent five images about how the energy-poverty nexus in rural Ceará may unfold in the future. These images were grouped in two contrary pathways of development. In the first pathway, poverty is expected to continue a reality because the pathway does not present adequate social and political conditions to enable poor people to benefit from modern and renewable energies in Ceará, in particular wind and solar power generation through decentralized systems, to reduce poverty. On the other hand, the second pathway presents possibilities in which poor families have mechanisms that enable them to benefit from decentralized energy systems and clean cooking facilities to create new opportunities and capabilities to reduce poverty in their communities. These mechanisms can be developed through the problematization of the energy-poverty nexus in rural communities and can be maximized through adequate governance. Currently, one can say that the energy-poverty nexus in rural Ceará is following the first pathway of development. The main conditions to change pathways refer to the trends of the system elements "*Capacity building and education*" and "*Governance*".

This chapter focuses on step four of the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, sub-section 3.2.4) applied for the case of rural Ceará and seeks to analyse possible trajectories of the energy-poverty nexus to better comprehend how easy or difficult it is for society to change the pathways of development in the future. For that, this study took advantage of the concepts of resilience, adaptability and transformability of social-ecological systems (SESs), which are used to analyse system dynamics and possible trajectories of development (Walker et al., 2004).

To perform step four of the Integrative Approach, other methodologies could be used. For example, Schmidt-Scheele et al. (2019) analysed transformation pathways for the German energy transition integrating in a systematic and participatory way the role that stakeholders play in such transformation pathways. This study opted to adapt and use the concepts of resilience, adaptability and transformability of SESs to the case of the energy-poverty nexus in rural Ceará because they can highlight the weaknesses and strengths of both pathways of development identified in this research. This indents to facilitate and improve the communication of the results of the cluster of scenarios presented in the previous chapter and facilitate the design of strategies aiming to reduce poverty and high inequalities with the support of modern and renewable energies in rural Ceará.

The remaining of this chapter is structured as follows. Section 6.2 presents a brief review on the concepts of resilience, adaptability and transformability of SESs. In section 6.3, step four of the Integrative Approach is performed to analyse the trajectories of the energy-poverty nexus in rural Ceará using the concepts discussed in the previous section adapted to this study. Section 6.4 presents a critical review on the Integrative Approach to the Energy-Poverty Nexus applied for the case of rural Ceará and discusses the limitations found in this study. Finally, section 6.5 closes this chapter with the main conclusions of the study.

6.2 Theoretical review: resilience, adaptability and transformability of SESs

The concept of resilience of ecological systems goes back to the 1960s and 1970s (Folke, 2006) and was defined by Holling (1973) as the capacity of a system to absorb disturbances and persist without changing its main characteristics and functions. According to the author, each system has a region of stability defined as domain of attraction. Inside this region, a system can absorb impacts and remain functioning, even reducing its resilience. If a system is resilient enough to absorb disturbances or if the disturbances are removed before it loses its resilience, the system can return to its original pre-disturbance state. Nevertheless, the resilience of a system has a limit which can be overcome depending on the type, intensity or duration of disturbances. Once a system loses its resilience, it tends to instability or to stability in a new domain of attraction in form of a new system, which no longer represents the characteristics and functions of the previous system. Without intervention (e.g. man-made interventions), the new system is unable to return to its previous condition.

Over time, the concept of resilience has evolved and its applicability was extended to the analysis of the dynamics of SESs (Folke, 2006). Walker et al. (2004) argued that resilience, adaptability and transformability are complementary attributes of SESs that drive the stability dynamics of these systems. According to the authors, resilience refers to the capacity of a system to absorb disturbances and reorganize itself while maintaining essentially the same structures, characteristics and functions. Thus, the main difference between this concept and the previous one proposed by Holling (1973) refers to the self-organization capacity of SESs (Folke, 2006). This is important because it is not always intended that a SES returns to its pre-disturbance state. A SES can learn and adapt itself to a new condition (Folke, 2006; Walker et al., 2004).

Each system has a domain, or a stability landscape, where all the possible states of the system can occur (Walker et al., 2004). A domain can be imagined as a valley (Figure 6.1) and can have one or more basins of attraction (sub-valleys). A basin of attraction represents a specific region inside the domain in which the system tends to stay. Under discrete disturbances, the state of the system is expected to change inside a specific basin of attraction (e.g. move from the state A1 to A2 and vice-versa in the Figure 6.1). Thus, a discrete disturbance is any disturbance that does not force the system to leave its current basin of attraction. Under salient disturbances, the state of the system can change to a new basin of attraction (e.g. move from the state A1 to A3 and vice-versa or from A2 to A3 and vice-versa) without losing its main characteristics and functions. Thus, the main difference between discrete and salient disturbances is that the first can change the state of the system inside the same basin of attraction while the second can move the system to a new basin of attraction inside the same domain or even move the system between domains (see below).

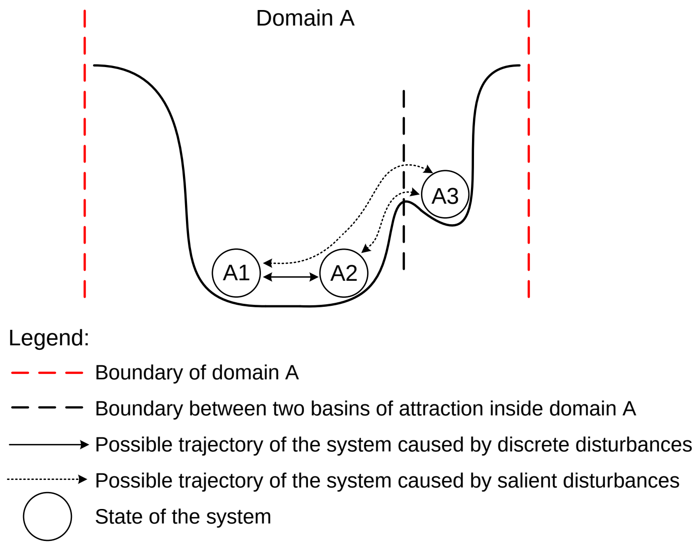


Figure 6.1: Example of a system domain with two basins of attraction

People influence SESs. Thus, they can influence the resilience of a system aiming to avoid or conduct it to cross boundaries. The human capacity to influence resilience refers to the concept of adaptability of SESs and can be achieved by changing following aspects of resilience: resistance, latitude, precariousness and panarchy (Walker et al., 2004). For instance, a salient disturbance can be intentionally caused to move the system from one basin of attraction to another, which increases or reduces the resistance of the system.

In Figure 6.2, the system in the state A2 is more resistant than in A1 or A3. People can also change the width of the basins of attraction (i.e. change the latitude of the system), reducing or increasing possibilities inside the basins. In Figure 6.1, the system in A3 has a smaller basin of attraction compared to the same in Figure 6.2. Thus, the latter is more resilient than the first. People can also conduct the system far or close to its boundaries, changing the precariousness of the system. In Figure 6.2, although the system in state A1 has a low resistance and a small basin of attraction, it is far from the boundary between domains A and B compared to the systems in A2 and A3 (i.e. the system in A1 is less precarious than in A2 or A3). The last aspect that can influence resilience is panarchy and refers to cross-scale influences between systems. A SES can be part of large system (upper scale) and can be composed of sub-systems (bottom scale), which together comprise a panarchy. If people influence resistance, latitude or precariousness of the systems from upper or bottom scales, this will influence the resilience of the system under analysis. Finally, it is worth noting that although people can influence the resilience of a SES, it is the system that will adapt itself to a new condition (Walker et al., 2004).

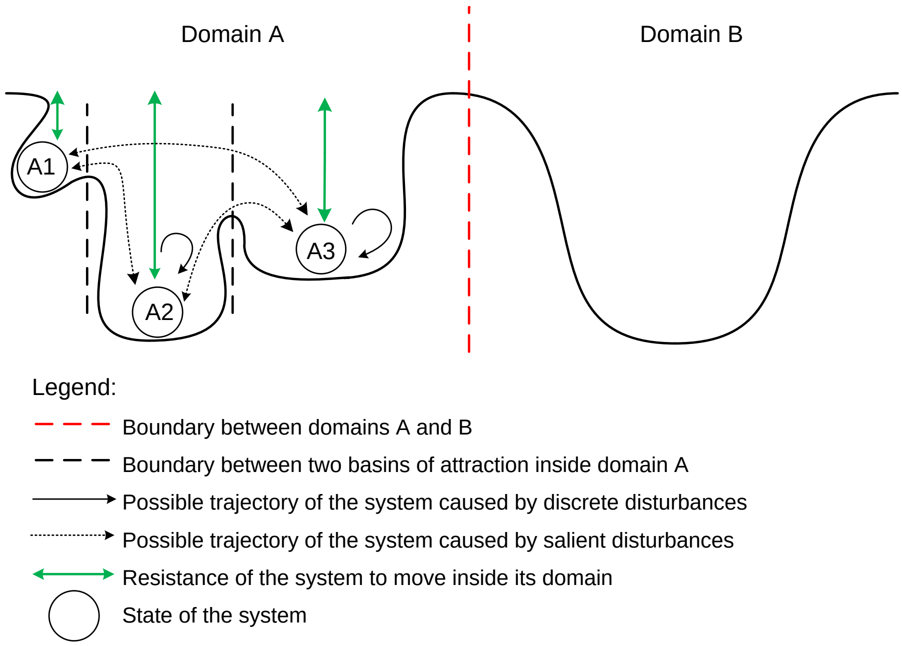


Figure 6.2: Example of how people can influence resilience of a system

The last important concept to be reviewed is the transformability of SESs and refers to the creation of a new system with new variables and states or a new system with the same variables and new states (Walker et al., 2004). This new system has different characteristics and functions compared to the previous one. Consequently, the system has a new domain. Such a new system can be observed in domain B in comparison to domain A in Figure 6.3. The creation of a new system with a new domain can be of interest when the current system becomes untenable or is unable to attend expected needs (Walker et al., 2004). People can interfere resilience by causing salient disturbances able to make or prevent the system to cross the boundaries of its domain. In Figure 6.3, intentional or unintentional salient disturbances can conduct the system A to cross its boundary with domain B (e.g. system A moves from the states A1, A2 or A3 to B1 and assumes the new configuration of system B, or vice-versa). Once a system crossed the boundary with another domain, it is unable to return to its previous domain without intervention.

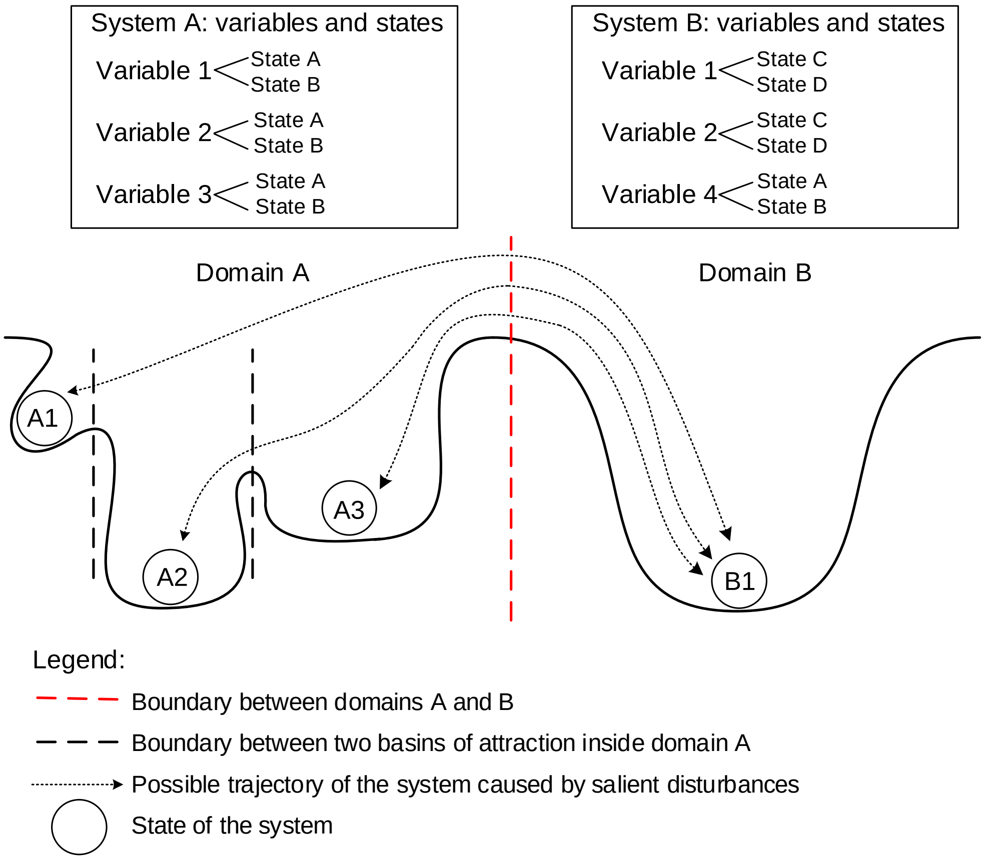


Figure 6.3: Example of transformability of social-ecological systems

6.3 Changing pathways in the future in rural Ceará

Although the energy-poverty nexus is not a SES but a socio-energy system, the concepts of resilience, adaptability and transformability of SESs can be useful for the analysis of possible future developments of the energy-poverty nexus in rural Ceará. This section focuses on the analytical description of how the concepts of resilience, adaptability and transformability were adapted and used in this study to perform step four of the Integrative Approach to the Energy-Poverty Nexus applied to the rural areas of Ceará.

6.3.1 Defining the system domains

The two pathways of development described in chapter five, section 5.5, were considered as two system domains, one representing the continuance of poverty and the other the reduction of poverty with the support of modern and renewable energies in rural Ceará. That way, the first domain is composed of all the trends present in the clusters of scenarios "S1-Conservative", "S2-Migration" and "S3-Failed transition" while the second domain is composed of all the trends present in the clusters of scenarios “S4-Transition through contextualized education” and “S5-Overcoming poverty in rural Ceará” (Figure 6.4).

Figure 6.4: The two domains of the energy-poverty nexus in rural Ceará

For instance, the trend "*universal water supply and basic sanitation*" occurs only in the cluster "S3-Failed transition", which is part of the first domain "Continuance of poverty with the support of modern and renewable energies". The trend "*universal water supply, basic sanitation and waste management*" occurs only in the cluster "S5-Overcoming poverty in rural Ceará" and, therefore, is part of the second domain "Reduction of poverty with the support of modern and renewable energies". Some trends are present in both domains such as "*universal water supply*" that occurs in the clusters "S1-Conservative", S2-Migration" and "S4-Transition through contextualized education" or the trend "*adequate*" governance that occurs in the clusters "S3-Failed transition", "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará" (detail in Table 5.4, chapter five). Such trends are present in both domains (see Figure 6.4).

The trends shared between the two domains can be interpreted as possible to assume dual functions (i.e. contribute to increase or reduce poverty). The way in which these shared trends act depends on additional conditions. For instance, the trends of the element "*Electricity market organization*" can contribute to increase or reduce poverty depending on the conjuncture that different electricity markets are used, as presented in the specific storylines of the clusters of scenarios (detail in chapter five, section 5.4). The trends of the element "*Governance*" can also be interpreted under this logic of dual function by the dependence of additional conditions. For example, a non-adequate governance can increase social policies to reduce poverty under a conjuncture of economic stability, as demonstrated in the storyline of the cluster "S4-Transition through contextualized education" (sub-section 5.4.4).

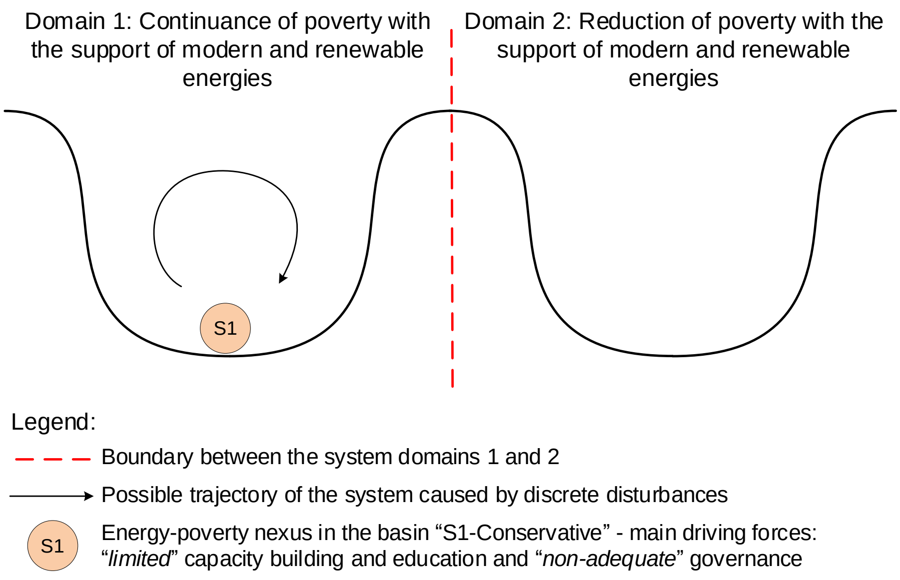
Considering the whole set of trends analysed in this study, one can argue that most trends present in the first domain represent conditions that contribute to keep or increase poverty with the support of modern and renewable energies, while most trends present in the second domain represent conditions that contribute to reduce poverty with the support of modern and renewable energies in rural Ceará.

6.3.2 The stable states and basins of attraction of the domains

The stable states of the two domains are represented by the 29 scenarios identified through the CIB analysis (detail in chapter five, Table 5.4). The scenarios can be defined as stable states because they are consistent and plausible according to the CIB. That way, the first domain "Continuance of poverty with the support of modern and renewable energies" has 16 stable states corresponding to the scenarios that compose the clusters "S1-Conservative", "S2-Migration" and "S3-Failed transition". Similarly, the second domain "Reduction of poverty with the support of modern and renewable energies" has 13 stable states representing the 13 scenarios part of the clusters "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará". The basins of attraction of each domain correspond to the clusters of scenarios. Thus, the first domain has three basins of attraction while the second domain has two basins of attraction. Finally, the main driving forces of the clusters can be interpreted as the main "attractors" of the basins of attraction.

6.3.3 Adaptability of the energy-poverty nexus in the rural areas of Ceará

Under the influence of discrete disturbances – i.e. changes in the trends of the system elements present in each one of the clusters of scenarios – the energy-poverty nexus will circulate inside the same cluster (i.e. basin of attraction) "S1-Conservative" that represents the continuance of the status quo in Ceará (Figure 6.5). This cluster has eight scenarios (i.e. stable states) and has the trends "*limited*" capacity building and education and "*non-adequate*" governance as the main driving forces (i.e. main attractors). As an example of a discrete disturbance, a change in the trends of the system element "*Economic stability*" from "*unstable*" to "*stable*" makes the energy-poverty nexus moves from the scenario number 03 to number 06 (see Table 5.4 in chapter five), which is located in the same cluster "S1-Conservative". In Table 5.4 (chapter five), it is worth noting that the mentioned change is the only difference between the scenarios numbers 03 and 06. Thus, although a change in economic stability influences the resilience of the energy-poverty nexus, the cluster "S1-Conservative" already expects such a change. Thus, this change is considered a discrete disturbance to the system.



Note: For reason of simplicity, the figure specifies only the basin of attraction referent to the cluster "S1-Conservative" in the first domain while in the second domain no basin is specified. In the text that follows in this chapter, additional basins are added and the current figure is reshaped.

Figure 6.5: The energy-poverty nexus under the influence of small changes

Society can cause changes in the energy-poverty nexus that are not expected to occur inside the cluster “S1-Conservative” (i.e. salient disturbances), which make the nexus lose resilience inside this basin of attraction and adapt itself to a new condition. For instance, as discussed in the storyline of the cluster “S2-Migration” (detail in chapter five, sub-section 5.4.2), the use of inadequate agrarian practices is expected to cause soil salinization and land degradation in the rural areas of Ceará, contributing to raising the level of environmental risks and uncertainties from the trend “*medium*” to “*high*” in the long term. High environmental risks and uncertainties are not expected to occur in the cluster “S1-Conservative”. Thus, after years of inadequate agrarian practices, the energy-poverty nexus can adapt itself to a new condition inside the same domain and create a new basin of attraction referent to the cluster “S2-Migration” (Figure 6.6).

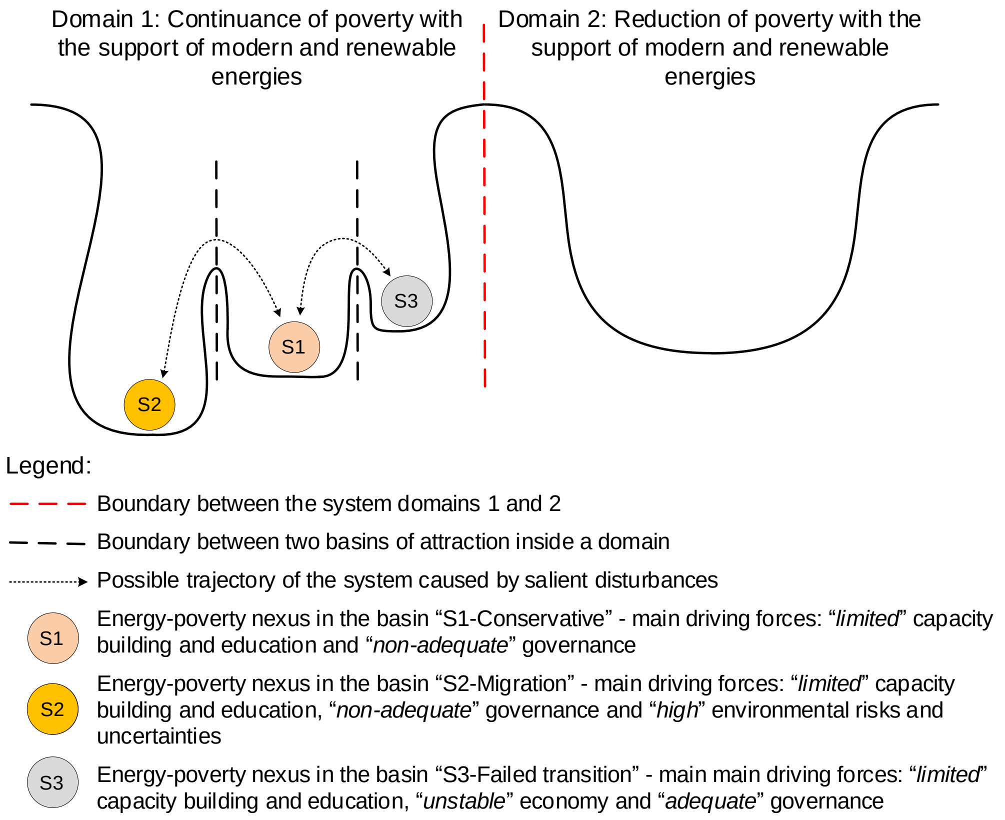


Figure 6.6: Adapting the energy-poverty nexus inside the same domain under salient disturbances

Once the energy-poverty nexus moves from the cluster “S1-Conservative” to “S2-Migration”, the resistance of the first domain increases, making the new basin of attraction deeper than the basin corresponding to the cluster “S1-Conservative”. Additionally, the nexus in this new basin is less precarious than in “S1-Conservative”, since it is far from the border with the second domain. This deeper and less precarious basin of attraction (i.e. the cluster “S2-Migration”) has a high resilience in comparison to the cluster “S1-Conservative” and indicates that the situation in which poor people live can become worse than it is nowadays in Ceará. Indeed, the storyline "S2-Migration" (detail in chapter five, sub-section 5.4.2) indicates the possibility of migration flows of poor families because the families are unlikely to be able to produce and live on their lands under high environmental risks and uncertainties. From the new position of the nexus in the cluster "S2-Migration", it is more difficult for society to make the nexus return to its previous basin of attraction (i.e. the cluster "S1-Conservative"), but not impossible.

From the cluster "S1-Conservative", the energy-poverty nexus can suffer another unexpected and salient change, conducting it to the basin of attraction referent to the cluster "S3-Failed transition" (Figure 6.6). This lies in the change of the trend "*non-adequate*" to "*adequate*" governance, which is one of the main driving forces of the last-mentioned cluster and, thus, can be the source of additional developments such as the improvement of basic public services from the trend "*universal water supply*" to "*universal water supply and basic sanitation*". These two changes move the energy-poverty nexus from scenario number 01 (cluster "S1-Conservative") to scenario number 15 that is already in the cluster "S3-Failed transition" (see Table 5.4 in chapter five).

The energy-poverty nexus in this new basin of attraction has a low resistance when compared to the basins of the clusters "S1-Conservative" and "S2-Migration". This low resistance derives from the association of the three main driving forces of the cluster "S3-Failed transition" namely "*limited*" capacity building and education, "*unstable*" economy and "*adequate*" governance. As discussed in the storyline "S3-Failed transition" (chapter five, sub-section 5.4.3), a governance aiming to reduce high socioeconomic inequality can enter in conflict with dominant social groups that hold the economic power in the country. Such a conflict can result in economic crises because these groups will try to hamper governmental initiatives seeking to reduce high socioeconomic inequality. Moreover, considering an environment of "*limited*" capacity building and education, poor people, unaware of the unequal social and economic conjuncture they live, can support dominant social groups to change the government seeking economic stability, similar to what occurred in Brazil in 1964. Therefore, the energy-poverty nexus in the cluster "S3-Failed transition" can easily lose resilience, making the nexus return to the cluster "S1-Conservative" (see Figure 6.6) or even move to the cluster "S2-Migration" in case of an additional change referent to high environmental risks and uncertainties. Therefore, the cluster "S3-Failed transition" can be understood in this study as the most sensible one among all the clusters analysed.

Finally, it is worth noting that although the energy-poverty nexus in the cluster "S3-Failed transition" is very sensible and can easily move back to the cluster "S1-Conservative", the driving force "*adequate*" governance lead the cluster "S3-Failed transition" to be closer to the border of the system domains (i.e. increase the precariousness of the system in the first domain) when compared to the clusters “S1-Conservative” and “S2-Migration”. Thus, an adequate governance represents a political condition that can help the nexus move from the domain “Continuance of poverty with the support of modern and renewable energies” to the domain “Reduction of poverty with the support of modern and renewable energies”.

6.3.4 Transformability of the energy-poverty nexus in the rural areas of Ceará

The adaptability capacity of the energy-poverty nexus to reorganize itself from the cluster “S1-Conservative” to the cluster “S3-Failed transition” highlights one important aspect to be considered when analysing transformability of the nexus from the first to the second domain: although a change in governance from the trend “*non-adequate*” to “*adequate*” represents one advance towards the reduction of poverty in the cluster “S3-Failed transition”, this change is not enough to make the nexus lose resilience to the point of crossing the boundary between the two system domains.

To make the energy-poverty nexus move from the first to the second domain, a critical change in the current system needs to occur which in this study lies in the contextualization of the capacity building and education in rural areas. This change goes in opposite direction to the trend “*limited*” capacity building and education that is one of the main driving forces of the clusters “S1-Conservative”, “S2-Migration” and “S3-Failed transition”. Thus, such a change in people’s education can turn the energy-poverty nexus untenable in the domain “Continuance of poverty with the support of modern and renewable energies” and transform it in a new system inside the domain “Reduction of poverty with the support of modern and renewable energies”. This new system has the same elements than the previous one, but most trends are different (detail in Figure 6.4).

A change in the trends of the element “*Capacity building and education*” from “*limited*” to “*universalized and contextualized*” causes the energy-poverty nexus to lose its resilience in the cluster “S3-Failed transition” and move to a new basin of attraction referent to the cluster “S5-Overcoming poverty in rural Ceará” (Figure 6.7). As discussed in the storyline of the last-mentioned cluster, the association of the trends “*universalized and contextualized*” capacity building and education and “*adequate*” governance provides a prosperous environment to maximize energy access and use towards poverty reduction (detail in chapter five, sub-section 5.4.5). This is so because the first-mentioned trend stimulates the problematization of the energy-poverty nexus in rural areas while an adequate governance can promote mechanisms and opportunities for rural families to take more advantage of modern and renewable energies to reduce poverty.

This problematization and the promotion of adequate mechanisms are of particular interest when analysing the impacts of decentralized and renewable energy systems in rural

Ceará. While in the first domain this kind of electricity generation is expected to benefit primarily well-off people, like big farmers and private investors, in the second domain poor rural communities are expected to profit from decentralized energy systems as consumers in productive chains or producers of electricity, which can contribute to reduce poverty in the communities. This does not mean that well-off people will have no opportunities in the second domain. It means that the second domain promotes equity opportunities between well-off and poor people seeking to reduce high disparities and poverty.

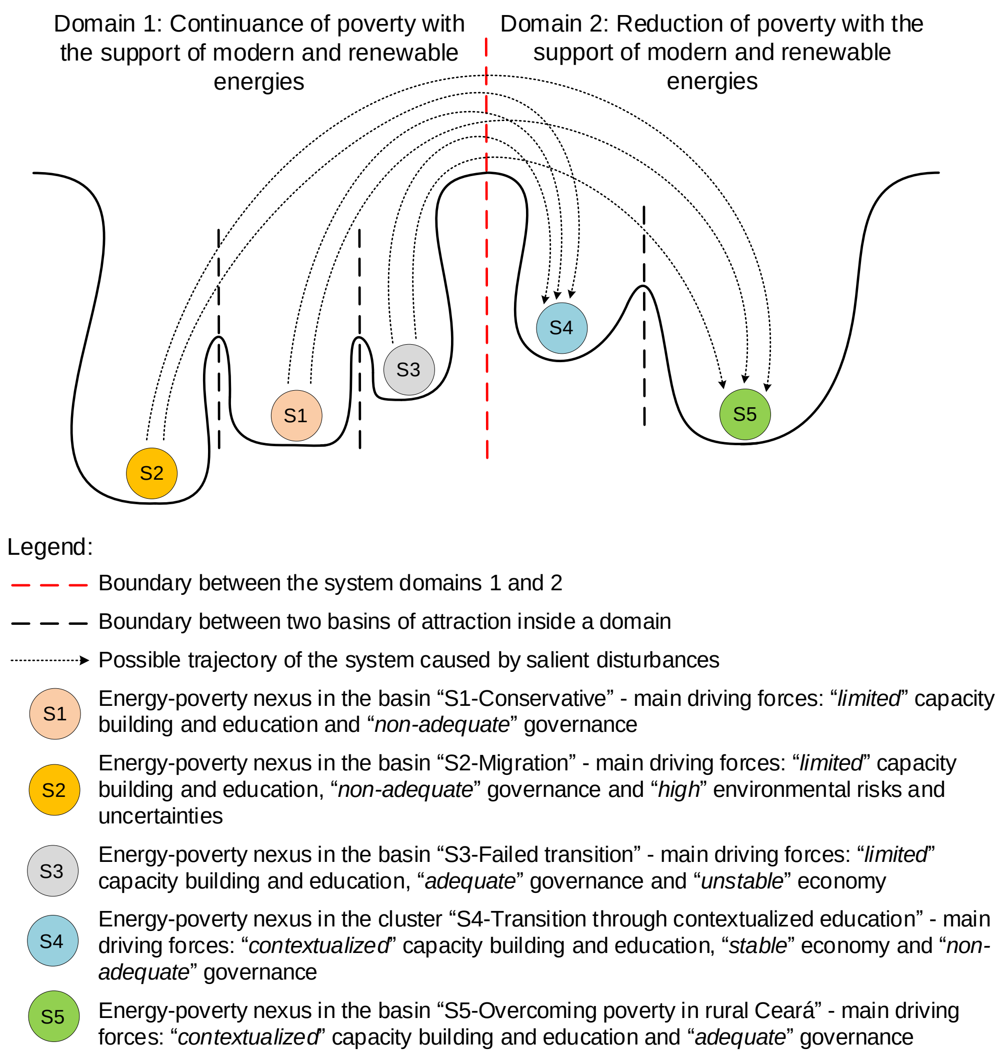


Figure 6.7: Moving the energy-poverty nexus from the first to the second domain

Considering that the status quo of the energy-poverty nexus is assumed to be closer to the cluster "S1-Conservative", the adoption of a contextualized education and capacity building can move the nexus from this basin to a new basin of attraction referent to the cluster "S4-Transition through contextualized education" (Figure 6.7). Although this new basin is less resilient than the one of the cluster "S5-Overcoming poverty in rural Ceará" due to the trends "*non-adequate*" governance and "*stable*" economy, the basin is already located in the second domain and is easier to be achieved when comparing to the cluster “S5-Overcoming poverty in rural Ceará”. This is so because the storyline of the cluster “S4-Transition through contextualized education” assumes that the problematization of the energy-poverty nexus can lead single or clusters of communities to create new opportunities and strategies to access and use modern and renewable energies to reduce poverty in their communities with limited support of governmental policies (detail in chapter five, sub-section 5.4.4).

In addition to the mentioned change in people’s education, a change in the element “*Governance*” from “*non-adequate*” to “*adequate*” can move the energy-poverty nexus from the cluster “S1-Conservative” to the cluster “S5-Overcoming poverty in rural Ceará”. From the cluster “S2-Migration”, the nexus can also move to one of the two clusters located in the second domain (Figure 6.7). However, many more efforts are needed from society to trigger such a transformation because it implies the reduction of environmental risks and uncertainties from the trends “*high*” to “*medium*”, which is not expected to be an easy task.

6.3.5 There is no guarantee of progress

Once the energy-poverty nexus moves from the first to the second pathway of development (i.e. domain), it is important to highlight that there is no guarantee that the nexus will remain ad infinitum in the domain “Reduction of poverty with the support of modern and renewable energies”. This is so because at the end people (i.e. society) will decide the direction they want to move the energy-poverty nexus. The nexus will adapt itself or be transformed in a new system in response to changes occurred. Thus, in a similar way that society can promote significant changes to make the nexus untenable in the first domain and move to the second domain, it can also cause significant changes in the second domain to make the nexus move back to the domain “Continuance of poverty with the support of modern and renewable energies”. A similar reflection was mentioned by one stakeholder interviewed in Ceará in 2015 when talking about the advances achieved in Brazil and in particular in Ceará towards the improvement of the quality of life and poverty reduction and the risk to lose advances achieved.

> “[…] you see that throughout this drought period that we are living in, there are no cases of invasions, robberies or loots (compared to the past in Ceará when rural people invaded cities looking for food, in particularly in the 1990s) … that means that you have a stability ... and you have several policies that contributed to that … it is not only the cash-transfer programme *Bolsa Família* … you have the programme My House my Life … you have the programme Light for All … you have the PRONAF … and above all you have a realistic salary policy that gave another dynamic to the economy (compared to the hyperinflation rates from the end of the 1980’s and beginning of the 1990’s (Ipea, 2015)) […] but there are a lot of people that do not accept that people from lower classes can travel by plane (referring to the fact that nowadays more people from the lower classes can fly in Brazil than in the past) … there are a lot of people that do not accept the rights of

> maids (referring to Law nº 150 that increased the rights of maids in Brazil in 2015 (Presidência da República, 2015)) … Are we going to lose all these advances? I don't know. As I said to you: nothing guarantees that History advances with a sense of progress. There is no guarantee. History also shows involution processes with the loss of important achievements ... I hope that this will not happen."

The possibility of losing advances achieved pro-poor can be already observed in Brazil, in particular after the election of President Jair Bolsonaro in 2018. Under his administration, the national government has led an agenda that has given less attention to social, educational and health policies (Folha de São Paulo, 2020), increased land conflicts (CPT, 2020) and contributed to increasing the gap between the rich and the poor (Coffey et al., 2020). Thus, considering that there is no guarantee of progress, Figure 6.8 represents all the possible trajectories of the energy-poverty nexus in rural Ceará considering the framework analysed in this study.

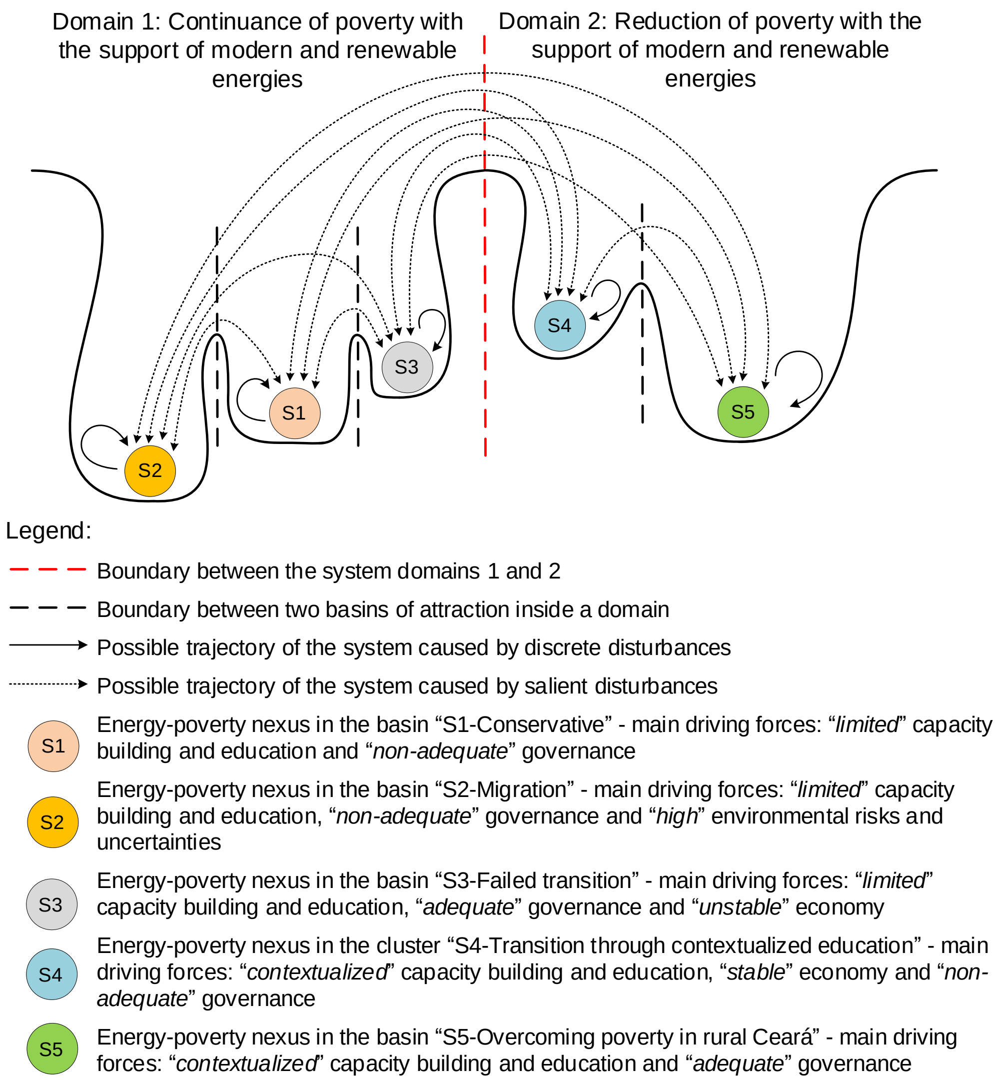


Figure 6.8: All possible trajectories of the energy-poverty nexus in rural Ceará

Once observing the Figure 6.8, six points discussed in this section are important to be recapitulated and summarized. First, once the energy-poverty nexus is inside one cluster of scenarios (i.e. basin of attraction), it remains circulating around the scenarios (i.e. stable states) of this cluster under the influence of discrete changes that can occur inside the cluster. Second, “S2-Migration” represents the most resilient cluster of scenarios in the first pathway of development (i.e. domain) because all its scenarios assume high environmental risks and uncertainties that can hamper poor people to produce and live on their lands. Thus, if the energy-poverty nexus gets into this cluster, high efforts are needed to move it to another cluster inside the first pathway and much more efforts are needed to move it to the second pathway of development. Third, “S3-Failed transition” represents the most sensible cluster identified in this study, in particular due to the main driving forces of the cluster. Fourth, “S4-Transition through contextualized education” represents the easier cluster to be achieved in the second pathway of development because the contextualization of the education and capacity building can lead community members to move the energy-poverty nexus in single or group of communities to this cluster of scenarios. Fifth, strong changes can move the energy-poverty nexus from one cluster to another inside the same pathway of development or move it from the pathway “Continuance of poverty with the support of modern and renewable energies” to the pathway “Reduction of poverty with the support of modern and renewable energies” and vice-versa. Six, people (i.e. society) are the main actors to promote the changes needed to move the nexus from one cluster to another and between the two different pathways of development.

Finally, the following Figure 6.9 summarizes the main conditions needed to move the energy-poverty nexus in rural Ceará from one cluster of scenarios to another and from one pathway of development to another. In the image, one can see that the main condition to move the nexus from the first to the second pathway refers to the contextualization of the capacity building and education that can produce better results if combined with adequate governance. These two social and political conditions, but in particular the first one, open space for the development of new socialization processes to strengthen capabilities and create new ones inside the communities to enable people to take more advantage of modern and renewable energies to reduce poverty.

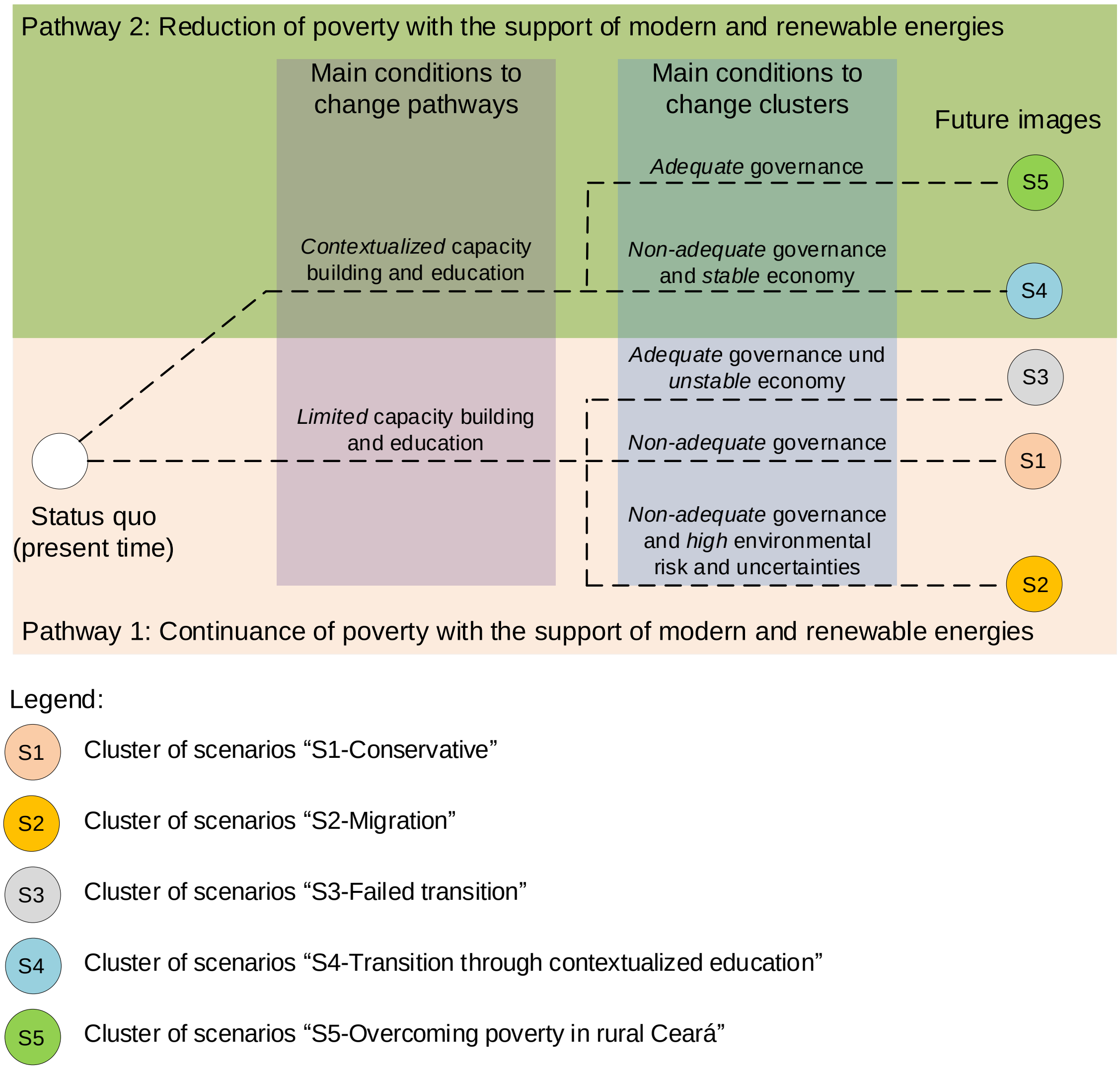


Figure 6.9: Main conditions to move the energy-poverty nexus in rural Ceará in the future

6.4 A critical review of the Integrative Approach to the Energy-Poverty Nexus

The Integrative Approach to the Energy-Poverty Nexus adds to the body of knowledge by providing a systematic and participatory approach to deal with energy and poverty in rural areas. The innovative aspect of the approach is the application of methods of participation and system thinking that allows for a systematic and multidimensional view of the interrelationships between energy and the causes of poverty. Ultimately, the approach can provide orientation for policies and planning to reduce poverty through energy access and use while minimizing risks of neutral and negative effects on poor rural communities. Nonetheless, rethinking the energy-poverty nexus in this study through the proposed approach also presented concerns and limitations, which are discussed in the following.

6.4.1 A transparent study but with limited participation

One concern refers to the application of the Integrative Approach to the Energy-Poverty Nexus in projects involving community members at the local level, especially regarding the discussion of outcomes and action planning post analysis. For example, once this study applied the Integrative Approach to the case of rural Ceará (chapters four, five and six), although the outcomes were discussed with some local actors, it was not possible to return to Ceará to discuss the research findings with all the people involved in the study. This can reduce the impacts of the outcomes produced.

Also, the conduction of step four of the Integrative Approach in this study contributes to increase communication and transparency of the results found. However, due to financial limitations and constrained agenda to return to Ceará, this step was conducted without the participation of local actors.

At the end of 2019, the author of this study had the opportunity to return to Ceará and to discuss the research findings with local actors in a workshop (some actors have participated in the interviews in 2015). After presenting the results, a few actors were surprised to know that this study suggests that rural Ceará is following the cluster “S1-Conservative”. For them, they were expecting that this study would suggest that Ceará is following the cluster “S5-Overcoming poverty in rural Ceará”. There may have at least two reasons to explain that reaction of local actors.

First, although this study engaged local actors in steps one, two and three of the Integrative Approach to the Energy-Poverty Nexus, the results of the future views in form of clusters of scenarios and pathways of development were not previously discussed with local actors. Thus, they did not have the opportunity to argue in favour of or against the research findings or to provide additional information to the findings. Also, as presented above, step four of the Integrative Approach was performed without the participation of local actors. In a further study, it is highly recommended the engagement of local actors in all the steps of the Integrative Approach. In that sense, the proposal suggested by Schmidt-Scheele et al. (2019) may be useful by integrating in a systematic way the position and role of local actors in the pathways of development.

The second reason may be associated with the fact that local people often dislike recognizing that the surrounding environment is not going in an expected way, in particular when they are active actors in shaping the local environment. Such behaviour was reported by Freire (2003) in an educational circle with poor people in the United States in which a picture showing the garbage and poor buildings from the surrounding area was presented to the participants. The first reaction of the participants was that the picture was from a poor country but not from their country and the place where they live. That way, it is important to deconstruct images that people may have in mind. In the case of this study, after reflecting and discussing the results of this research with the local actors in Ceará, those few actors that did not agree at the beginning at the end also agreed that Ceará is following or is at least close to the cluster "S1-Conservative". Other actors also suggested that Ceará is trapped in "S1-Conservative" due to the historical formation of Brazilian society and external forces, such as national policies focusing on agribusiness and the role that modern society plays in promoting economic models that increase wealth concentration. However, it was also argued that many rural communities in Ceará seem to be following the cluster "S4-Transition through contextualized education" in which local families critically reflect their situation and join efforts to grasp new opportunities to improve living conditions and reduce poverty in their communities.

The possibility of having rural Ceará trapped in "S1-Conservative" (and consequently trapped in the first pathway of development) is worthy of further study. For that, the work of Unruh (2002, 2000) can be useful, in which the author discusses how systems can get locked in dominant structures and the necessary forces to make the system escape from lock-in. This study has identified that at least a change in education and capacity building is necessary to lead the energy-poverty nexus in rural Ceará to escape from the first pathways of development, which effects can be maximized by another change in governance. However, there may have other potential forces that can contribute to moving the energy-poverty nexus in the rural areas of Ceará (see below).

6.4.2 External changes affecting the energy-poverty nexus in rural Ceará

Besides the changes analysed in sub-sections 6.3.3 and 6.3.4, the energy-poverty nexus in rural Ceará can suffer disturbances from outside of the framework considered in this study, which can lead the nexus to adapt itself (or be transformed) to conditions that could not be identified in this research. Such disturbances are related to panarchy, i.e. cross-scale influences on the system analysed (Walker et al., 2004), that can influence the resilience of the system under analysis. One can also say that such disturbances are related to uncertainties not included into the system analysed in this study (see below).

For instance, one disturbance can be the reduction in the number of poor families benefiting from the conditional cash-transfer programme *Bolsa Família* or even the suspension of the programme. The *Bolsa Família* was created in 2003 by the national government with the aim to contribute to poverty reduction (MDS, 2015). As described in the element "*Income source and asset accumulation*" (see sub-section 4.4.2, chapter four), the *Bolsa Família* plays an important role in the financial situation of many poor rural families in Ceará. Currently (early 2021), more than one million families and 3.2 million people in Ceará (about 35% of the total population) are beneficiaries of the programme (CGU, 2021). Thus, a reduction in the number of families benefiting or the suspension of the programme without the adoption of compensatory measures can increase monetary poverty in Ceará. For the energy-poverty nexus, more people living in monetary poverty might conduct the nexus to trajectories different from those identified in this study. For instance, the basin of attraction "S1-Conservative" might become deeper in Figure 6.8, meaning that more efforts are needed to move the nexus outside the cluster. In an extreme reflection, the increment of monetary poverty in rural areas might be a driver for the migration of poor people (as it was in the past in Ceará), making the nexus move to and reshape the cluster of scenarios "S2-Migration".

Other significant changes in the system that were not considered in this study refer to the occurrence of extreme events and developments. This study understands extreme events as those that occur suddenly and without the intentional participation of human beings in triggering such events. Example of an extreme event can be the current COVID-19 pandemic. But extreme developments are possible to track and count on the intentional participation of society to trigger such developments. Example of an extreme development can be the implementation of a dictatorship in Brazil. Since 2015 and in particular in 2020, anti-democratic acts and ideas pro-military intervention have gained increased support from Brazilian society (BBC, 2020c; Folha de São Paulo, 2015; Paduan, 2020). Both examples of extreme events and developments can cause significant changes in the energy-poverty nexus in rural Ceará. Thus, additional research including the occurrence of possible extreme events and developments is recommended.

6.4.3 Refining the current system in additional research

In future works, not only additional events and developments (extreme or not) could be analysed but also the elements considered in this research can be refined. One example of refinement that can be done in the future refers to the trends of the element "*Costs of electricity and cooking fuels*" defined in this research as "*High*" or "*Low*" (detail in chapter four, sub-section 4.4.4). Often, the affordability of modern energy services is related to a certain amount of family income expended with energy (e.g. Boardman, 2010; Chester and Morris, 2011; Foster et al., 2000; Hills, 2011; Schuessler, 2014). However, the element "*Income source and asset accumulation*" describes a context in which informal economy is still playing an important role in rural Ceará (detail in sub-section 4.4.2). Therefore, at the present time, it would be inadequate to set the trends of "*Costs of electricity and cooking fuels*" according to a certain amount of family income. Further scholars also observed the importance of considering informal economy in studies related to energy and poverty (e.g. Bazilian et al., 2010; Pachauri et al., 2004; Pereira et al., 2011). Nevertheless, approaches based on purchasing power are interesting as soon as rural economies become more formal, which is not the current situation in rural Ceará.

Also, it should be highlighted that refining the current system and strategies adopted to achieve better results is part of step six of the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, sub-section 3.2.6). However, this step was not conducted in this research (see below).

6.4.4 Partial application of the Integrative Approach in rural Ceará

As mentioned in the description of the Integrative Approach to the Energy-Poverty Nexus (detail in chapter three, section 3.2), steps five and six were not performed in the case of rural Ceará. Step five refers to the design and adoption of strategies for actions while step six aims to evaluate results, redesign strategies (if necessary) and celebrate the results achieved.

Throughout this dissertation, possible strategies were suggested (detail in the storylines of the clusters “S4-Transition through contextualized education” and “S5-Overcoming poverty in rural Ceará” in chapter five, sub-sections 5.4.4 and 5.4.5) that could lead the energy-poverty nexus into the direction of the second pathway of development related to the reduction of poverty with the support of modern and renewable energies. Nevertheless, the application of such strategies were not implemented in large scale in Ceará. Therefore, the effectiveness of such strategies cannot be measured. Also, the implementation of the strategies suggested in sub-sections 5.4.4 and 5.4.5 would require the participation of local actors, including community members, NGOs, electricity utilities and the governments from Ceará and Brazil.

It should be highlighted, however, that some strategies at the community level suggested in “S4-Transition through contextualized education” have been adopted in some rural communities in Ceará, in which the families join efforts (e.g. in form of cooperatives and associations) to create and strengthen opportunities to increase income generation and the quality of life in the communities.

The full application of the Integrative Approach to the Energy-Poverty Nexus should take place in another project in a rural community located in an island on the Brazilian Amazon, a project in which the author of this dissertation is engaged (ITAS, 2020). The project will be fully managed by the community members with the support of a research team from Brazil and abroad and intends to increase food sovereignty of 50 riverbank families living in the community through the adoption and use of solar power generation. It is worth noting that in this case, the use of CIB for the identification and design of future views may be not the best approach to be adopted because it may be too academic to be carried out together with the community members.

6.5 Concluding remarks

Through the partially application of the Integrative Approach to the Energy-Poverty Nexus in rural Ceará, four central arguments constructed throughout this study can be synthetized as the main conclusions of this research.

First, the Integrative Approach to the Energy-Poverty Nexus can represent a promising advance in the sectors of energy access and socioeconomic development because it allows for a better understanding of the dynamics of rural areas in relation to energy and the causes of poverty. Another advantage of the Integrative Approach is that not only the current situation is analysed but also future views of how the energy-poverty nexus may unfold in the future in a community, region or country. All this allows for the design of better strategies aiming to strengthen people's capabilities to take more advantage of modern energy services to improve their quality of life and reduce poverty. The approach can, therefore, maximize energy as a mechanism for poverty reduction while minimizing the risks of undesirable side effects for poor people. Thus, its application in other cases in developing countries can prove an interesting and innovative approach in the energy access sector to reduce poverty in rural communities.

Second, modern and renewable energies can be used to increase or reduce poverty, depending on the context in which they are used in society. This can be observed in Ceará through the two main pathways of developments designed through the partial application of the Integrative Approach to the Energy-Poverty Nexus, one indicating the continuance and the other the reduction of poverty with the support of modern and renewable energies.

Third, although this study suggests that rural Ceará is following (or seems to be trapped in) the trajectory of the cluster "S1-Conservative", it does not mean that Ceará is set to remain in this trajectory. The future visions presented in the clusters "S4-Transition through contextualized education" and "S5-Overcoming poverty in rural Ceará" indicate possible social and political conditions in which the use of decentralized energy systems and clean means of cooking can significantly contribute to reducing poverty in the rural areas of Ceará. To move the energy-poverty nexus from its current state to the pathway of development of the two last clusters mentioned above, a contextualized education and capacity building is essential, followed by adequate governance. This pathway of development is not easy to follow because it contradicts the historical and unequal man-made conjuncture that excludes and oppresses poor people in Brazil in general and in Ceará in particular. Nevertheless, as presented throughout this study, it is a possible pathway to be followed with promising results towards a less unequal society with no poverty. That way, this thesis argues that, besides access to adequate energy services, poor people need to have adequate social and political conditions to allow them to develop capabilities that will enable them to take more advantage of modern energies to get out of poverty.

Finally, Brazilian society in general and the local people in Ceará in particular represent the main actors able to cause significant changes in the status quo of the energy-poverty nexus to move it from the first to the second pathway of development, representing the reduction of poverty with the use of modern and renewable energies. One should highlight, however, that if the energy-poverty nexus moves to the second pathway, there is no guarantee that it will remain ad infinitum in this pathway of development. History shows counter-developments in which advances achieved can be lost. This can also occur to the energy-poverty nexus in rural Ceará. To avoid that, constant monitoring and the reinforcement of strategies to maintain the energy-poverty nexus in a desired pathway are essential.

Chapter seven

Towards an integrative and inclusive energy access

This chapter closes this dissertation by providing additional reflections on the findings and conclusions of this research and extending such reflections to the energy access sector at the global level. In that sense, this chapter represents the outlook of this research and aims to contribute to the scientific knowledge towards an integrative and inclusive energy access.

The chapter is organized as follows: Section 7.1 discusses the need for systematic and participatory approaches in energy access to maximize positive impacts towards poverty reduction and sustainable societies. Sections 7.2 and 7.3 discus the importance of a contextualized education and adequate governance in the energy access sector, respectively. Then, section 7.4 provides some insights that seek to contribute to a better understanding of why poverty and the lack of modern energy access are still a reality in modern societies. Finally, section 7.5 provides some recommendations towards an integrative and inclusive energy access. The author of this study recognizes that the arguments and insights presented in this chapter need to be further studied in order to increase and improve the scientific knowledge on the energy-poverty nexus.

7.1 The need for systematic and participatory approaches in energy access

Access to modern and affordable energy has the potential to bring several opportunities for social and economic advances in poor rural communities. However, the arrival of energy can also bring negative impacts on people's lives. Potential positive and negative impacts of energy access were discussed in this study in the literature review (chapter two) and in the clusters of scenarios that compose the two pathways of development identified for the case of rural Ceará (chapters five and six).

That way, the context in which energy services are provided is of high relevance for planning energy access and for anticipating and preventing possible negative impacts. This context, which is multifaceted, is also important because it exercises a great influence on the socialization process of each person, which makes that different people (with different life experiences and opportunities) use energy differently once they have access to it. Often, strategies and actions to provide energy access do not pay attention to such a multifaceted context and its range of possible effects while assuming that energy will bring only benefits on poor rural communities. This can lead to unsuitable approaches when dealing with energy and poverty reduction in rural areas.

The outcomes of this research suggest that contextualized factors and conditions interacting with each other determine whether energy becomes, in the best case, a mechanism that contributes to reduce poverty or, in the worst case, a mechanism that contributes to generate poverty. Thus, this study shows that energy per se cannot be blamed as the cause of negative impacts on rural communities as well as it cannot be glorified as the source of positive impacts on people's lives. Energy is a means used by human beings to foster development, which does not necessarily mean less unequal societies or the reduction of poverty. A country can be a global power and have marginalized social groups living in conditions similar or worse than poor people in developing countries, as is the case of many Black, Latinx and Indigenous people in the United States (Brosemer et al., 2020; Sen, 1999).

The understanding that the context is important when analysing and planning energy access for poverty reduction enables the construction of two arguments that can be useful for the energy access sector at the global level. First, achieving SDG7 will not mean that poor people will have real opportunities to benefit from energy services to get out of poverty. Second, if the provision of modern energies in poor rural communities does not necessarily imply positive benefits towards the reduction of poverty, other approaches that contemplate in a participatory way the context and the dynamics of rural areas in relation to energy and poverty are urgent and necessary, such as the Integrative Approach to the Energy-Poverty Nexus. This is so because systematic and participatory approaches in the energy access sector can lead to create deep interrelationships between SDG7 and SDG1 (as well as other SDGs) in a way to actively promote energy access towards sustainable and inclusive societies.

7.2 The importance of a contextualized education

A contextualized education starts the educational process from the learners' knowledge and reality, discussing and problematizing their knowledge and perceptions about a determined topic (Freire, 2005). When addressing energy and poverty in rural communities, a contextualized education encourages and empowers people to think critically of the matter while enlarging their knowledge and awareness of the reasons for poverty. Ultimately, a contextualized education in the energy access sector has the potential to enable people to setting better strategies aiming to break down cycles of poverty with the support of modern energies.

An interesting approach related to a contextualized education was developed by the Brazilian educator Paulo Freire in the 1960s and 1970s and has been adopted on a small and medium scale (when compared to national educational systems) in Brazil and other Latin

American countries regarding the education of adults to break cycles of social oppression and poverty while increasing their social, civil and political organization (Freire, 2005). According to Freire (2005), once poor people are aware of their social and political situation, they know quite well their needs and challenges to move out of poverty. In the context of the energy-poverty nexus, this is the main reason why community members and their representatives have to participate in the energy planning of their communities, discussing and addressing their needs and challenges while setting strategies to reduce poverty through the access and use of modern energies. Finally, a contextualized education can prove invaluable to the socialization process of poor people by discussing with them new ways of thinking about the socio-cultural, political and economic environment they live in.

Nevertheless, the author of this dissertation recognizes that the adoption of a contextualized education in the energy access sector on a large scale does not represent an easy task. To the author's knowledge, there are no examples from the past or present of the large adoption of a contextualized education and capacity building in the energy access sector as it is visualized in the cluster of scenarios "S5-Overcomming poverty in rural Ceará". In that sense, the adoption of a contextualized education in the energy access sector at a broad level (in Ceará or in other similar cases around the world) may support and challenge the findings and conclusions of this research while providing additional insights from its applicability on a large scale.

7.3 The importance of adequate governance

Adequate governance in the context of the energy-poverty nexus can provide means to protect and promote poor people, ensuring that they have adequate opportunities to participate in and take advantage of activities and services that can be boosted by modern energy services. If no or limited mechanisms and policies are adopted to foster adequate opportunities, people that are already in a better social and economic position, or those politically well represented, can take more advantage of energy than poor people, as discussed in the three clusters of scenarios that compose the first pathway of development identified in this study (chapter five). Consequently, non-adequate governance can lead to the increment of poverty instead of its reduction.

One example of non-adequate governance through the adoption of inefficient energy policies relating to the energy access sector seems to be the case of global fossil-fuels subsidies. In a broad sense, these subsidies are intended to facilitate the extraction, conversion and consumption of fossil fuels as well as to foster development and energy access for poor people (IEA, 2011; Koplow, 2014). A common measure adopted by governments to forward energy access through subsidies bears on price regulation. This measure could contribute to reduce poverty by facilitating, for example, access to LPG for poor people.

However, under inadequate policy measures and inadequate socio-political and economic structures to promote adequate opportunities, the most beneficiaries of fossil-fuels subsidies are high-income social groups and industries that increase their consumption, as well as intermediaries and companies that extract, convert and commercialize fossil fuels. Indeed, an estimation made by IEA (2011) revealed that in 2010 only 8% of the total global fossil-fuel subsidies reached the poorest 20% of the population. In addition, Koplow (2014) argues that fossil-fuel subsidies misrepresent relative energy prices and do not contribute to reducing poverty or energy poverty, but contribute to uphold the problem.

The promotion of poor people, however, does not necessarily represent a priority for those who hold the political and economic power in many countries and regions, especially in those with high social and economic inequalities, such as in Brazil. Such a promotion can threaten current unequal-social, political and economic structures because poor people can start to participate in sectors monopolized by dominant social groups (Freire, 2005, 2003, 1994; Souza, 2019, 2018, 2016). The findings of this research seem to support the arguments presented above. Perhaps this is also one of the reasons why universal energy access, even just to meet clean means of cooking and access to electricity for basic human needs, is still not a reality worldwide and is not expected to be a reality by 2030, although studies have demonstrated that this achievement is completely feasible (e.g. in Birol, 2014, 2007; IEA, 2017, 2010).

Indeed, from an estimated average of USD 423 billion per year on global fossil-fuels subsidies provided from 2010 to 2019 (IEA, 2020e), this value represents more than 12 times the USD 35 billion per year estimated by IEA (2020a) in the Sustainable Development Scenario to universalize access to electricity in the world by 2030. Regarding access to clean means of cooking, the reality is even worse because the investment estimated to provide clean cooking facilities around the world by 2030, an investment of USD 5 billion per year (IEA et al., 2020), is a very low value compared to the USD 423 billion spent every year in average in fossil-fuel subsidies. Ultimately, one can say that adequate policies to deal with energy access require significant changes in the political agenda.

That way, one can argue that one of the main challenges to universalize the access to modern energies around the world is not a financial one but to achieve a fairer distribution of wealth, or the social and economic opportunities resulting from this wealth, among different social groups, seeking to reduce high disparities among them. Through the findings of this research, one can argue that the matter in rural Ceará is no different. Finally, one can say that measures to promote equitable opportunities, including the opportunity of universal energy access, can be promoted through adequate governance.

7.4 The normalization of poverty and the lack of modern energy access

What makes inadequate policies such as the fossil-fuels subsidies, that contribute to concentrating wealth among few people and companies, to be accepted in modern societies, while 2.6 billion people have no access to clean means of cooking and 770 million have no access to electricity? What makes the access to these basic energy needs to be neglected for so many people in a globalized and high-technological world? These questions are similar to others focusing on the context of this study: what makes Brazil one of the most unequal countries in the world? What makes the six richest people in Brazil concentrate the same wealth amount as the poorest 100 million people? How are such socioeconomic paradoxes possible in modern societies, especially in developing countries which suffer from socio and economic inequalities the most? Such questions are important because according to the literature review presented in the first and second chapters of this dissertation, poverty is morally and ethically unacceptable in modern societies.

Answers to questions as the above are not simple to give and can be related to the legitimization process of privileges over time among different social groups, since it contributes to normalize poverty and high inequality in modern societies. One reason for this legitimization is because all the people, whatever their social group, do not only want to live their lives, they want and need to justify for the others that they have the right to live the life they may have reasons to value, even if such a right means the oppression and exclusion of other people (Souza, 2018).

According to Souza (2018), one mechanism used to legalize privileges and inequalities in modern societies can be attributed to the principle of meritocracy. By using this principle, societies have an instrument to argue that they distribute resources according to the merit of each person, hiding the pre-conditions available (or not) for people to succeed or fail in a globalized and competitive world. This is different than to say that resources are distributed in an equitable way. In that sense, the principle of meritocracy contributes to providing a frame to justify that modern societies are "fair" with their citizens, because if a person produces much more than another one, it is also fair that this person should receive much more than the other who does not produce that much. Consequently, the principle allows societies to neglect or pay less attention to equitable policies. One should also note that the main indicator to measure the merit of people in modern societies is their capacity to produce something useful and valuable. Valuable in this sense means something with economic value, since money is the universal mediator in modern societies.

The lack of access to modern energy services among poor people can be accepted and understood as "normal" in modern societies under the lens discussed above. That way, societies can "justify" that it is "better" or more productive to provide fossil-fuel subsidies for some groups, because these groups will produce even more wealth, instead of driving a small part of these subsidies to solve a global problem for poor people that do not produce that much economically. In addition, the social groups that most take advantage of fossil-fuel subsidies have much more voice and power to complain against the reduction of subsidies than poor people have to complain about the miseries they face in their daily life (the lack of access or limited access to energy, basic sanitation, education, healthcare, employment, shelter, etc.). This can be observed not only in the energy sector but in other sectors, as the barriers that inhibit the taxation of big fortunes in Brazil (OXFAM, 2020) and the barriers that inhibit to reduce extreme inequalities at the global level (Coffey et al., 2020).

For those countries who already achieved (or are close to) universal energy access, such as Brazil, the framework discussed above provides the legal basis to blame poor people for their own poverty, diminishing the responsibility of society in the process of poverty generation. Similar thoughts are presented by Alston (2020) in relation to the simple way that policymakers frequently deal with poverty as if poor people were mainly responsible for their poverty, ignoring systematic factors.

That way, the results of this research contribute to deconstructing beliefs in society regarding the causes of poverty in rural Ceará, which may be similar to other regions around the world. Above all, the belief that poverty is something “normal” in modern society when, in fact, there is a man-made conjuncture that generates this poverty. For the energy access sector, deconstructing beliefs can contribute to the design of better policies and measures towards the reduction of poverty with the support of modern energies.

7.5 Closing remarks

The reflections presented above are synthetized below in five recommendations for further projects, programmes and initiatives seeking for an integrative and inclusive energy access sector that can maximize the access and use of modern energies to reduce poverty in rural communities.

(i) Systematic energy access: the impact of energy access in rural areas towards human well-being and sustainable development with less inequalities and no poverty can be maximized if projects, programmes and initiatives in the energy access sector address energy and the multifaceted context (e.g. socio-cultural, political, economic, technological and environmental) in which people live and communities exist. That way, the dynamics of rural areas in relation to energy and the context in which energy is provided can be better addressed in a systematic way. This can lead to the design of better strategies to maximize benefits and reduce risks and negative impacts of energy access and use on poor rural families and communities.

(ii) Time: the implementation of integrative and inclusive energy access projects in rural communities is expected to take more time to be realized than business as usual approaches focusing in techno-economic aspects and efficiency. This is so because the conduction of projects on energy access *with* and not *for* poor people requires more time to engage with poor people in a participatory and active way in all project phases (e.g. design, implementation, monitoring and maintenance). Also, some impacts of energy access on rural communities may occur after some years of project implementation. Thus, it is important, in particular to fund agencies in the energy access sector, to consider having more time to execute integrative and inclusive energy access projects and measure their impacts on rural communities.

(iii) Participation and inclusivity: Poor rural people that get access to modern energy services are much more than "end users" or "beneficiaries", as they are frequently treated in the literature. Poor people are transformation agents in their communities and of the reality that they face every day. Thus, they are essential in energy access projects for the problematization, systematization and analysis of energy and local problems and challenges. Also, marginalized people can be found inside communities, which can be excluded and oppressed by other community members. That way, inclusivity is key to address the needs of marginalized social groups, seeking more equity inside and outside rural communities.

(iv) More than energy access: besides addressing energy access in poor rural communities, integrative and inclusive energy projects should address strategies at the social and political levels to ensure that once poor rural people have access to adequate energy services, they also have access to adequate opportunities to increase their capabilities to benefit from energy to reduce poverty in their communities.

(v) Contextualized education: since a contextualized education and capacity building is described as the main condition to trigger modern and renewable energies in rural Ceará as a mechanism for poverty reduction, which benefits can be maximized through an adequate governance, this study suggests the adoption of a contextualized education and capacity building also for the execution of further projects, programmes and initiatives in the energy access sector. As discussed throughout this study, a contextualized education can lead local actors to critically reflect on the energy-poverty nexus in rural communities, regions and countries. Ultimately, a contextualized education represents a means to empower marginalized and poor people to overcome, or at least to minimize, the causes of poverty.

Following the recommendations presented above, projects, programmes and initiatives in the energy access sector in developing countries are expected to increase the access and use of modern energies in rural communities towards the reduction of poverty in an integrative and inclusive way. In that sense, the recommendations above can contribute to deepen and expand the principles to foster a culture of inclusivity in energy access proposed by Mbungu et al. (2020). Also, it is worth highlighting that the recommendations presented above consider local people as the main actors of energy interventions in local communities.

Finally, for the rural areas of Ceará, since the State already enjoys universal electricity access, the recommendations presented above may contribute to move the energy-poverty nexus from its current pathway of development to the second pathway designed in this research, in which the use of modern and renewable energies can be maximized towards the reduction of poverty in rural communities.

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