



## Research paper

## Sociotechnical imaginaries of energy transition: The case of the Portuguese Roadmap for Carbon Neutrality 2050

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## ABSTRACT

This article analyses sociotechnical imaginaries of energy transition emerging from the Portuguese Roadmap for Carbon Neutrality 2050 (RNC2050). It expands literature on the articulations between sociotechnical imaginaries and energy transitions by introducing the Portuguese context and delving into an original and understudied case study – the RNC2050. We contend that the RNC2050 illustrates how energy transitions enable multiple – and, often times, conflicting – sociotechnical imaginaries, which, in turn, outline diverse associations between science, society and politics to address the climate crisis. By exploring how distinct actors and social groups resort to the RNC2050 to support their own understandings and pathways to carbon neutrality, we argue that this document can be interpreted as a boundary object.

We conducted nineteen semi-structured interviews and one informal conversation with members from three different stakeholder groups (the RNC2050 execution team; political entities; civil society). Drawing on our empirical data, four sociotechnical imaginaries were identified – Modernization and Techno-Economic Development; Green Economy; Energy Citizenship; Just Transition – and characterized, detailing their key features and associated stakeholders. We discuss our results highlighting six relevant aspects: the situatedness of stakeholders; the RNC2050 as a boundary object; dynamics of inclusion/exclusion, counter-hegemonic imaginaries, and power issues; the co-option of subaltern imaginaries; and the evolution of imaginaries across time. Although arising from the Portuguese context, we contend that these results are relevant for energy transitions research more broadly, as well as for energy transition policymakers. We conclude by presenting some of the policy implications of our study.

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## 1. Introduction

This article explores sociotechnical imaginaries of energy transition in Portugal, focusing on the Portuguese Roadmap for Carbon Neutrality 2050 (RNC2050, in its Portuguese abbreviation). We argue that the RNC2050 is an emblematic example to unpack how energy transitions elicit different imaginaries, allowing us to analyse how particular articulations of science, politics and society emerge to face the climate crisis, and how multiple competing understandings of carbon neutrality – and the pathways to achieve it – coexist within the same country. The article addresses two main research questions: what are the sociotechnical imaginaries of energy transition enabled by the RNC2050? How do distinct actors mobilize the RNC2050 – and the socio-political debates that followed – in an attempt to support their views – and pathways – on/to carbon neutrality?

In order to address the aforementioned questions, we carried out semi-structured interviews with three groups of stakeholders: the RNC2050 execution team; political actors; representatives from civil society. Our research design contemplated the engagement with a myriad of actors who display distinct – and, sometimes, conflicting – framings of the energy transition, resulting in the identification of four different sociotechnical imaginaries: Modernization and Techno-Economic Development; Green Economy; Energy Citizenship; Just Transition. These imaginaries reinforce the socio-political dimensions of energy transitions, showing how distinct actors and social groups lean towards specific perspectives and pathways for carbon neutrality in Portugal.

Hence, this article, informed by the concepts of “sociotechnical imaginaries” (Jasanoff and Kim, 2009) and “boundary object” (Star, 1989), contributes to burgeoning literature on sociotechnical imaginaries of energy transition, examining the original case study of Portugal – and, in particular, of the RNC2050 –, exploring how it sheds light on the multiple stakeholders,

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imaginaries and tensions underpinning energy transition in this country.<sup>1</sup>

The article is organized as follows: Section 2 presents current research on the intersections of sociotechnical imaginaries and energy transitions, stressing the article's contribution to this literature; Section 3 provides background on the RN2050 and its context; Section 4 introduces the article's methodology, as well as providing a characterization of the stakeholders engaged in this research; Section 5 unpacks four sociotechnical imaginaries of energy transition in Portugal, illustrated by interview transcripts; Section 6 elaborates on relevant topics for energy transitions research, especially from the standpoint of social sciences: the situatedness of stakeholders, the RNC2050 as a boundary object, dynamics of inclusion/exclusion, counter-hegemonic imaginaries and power issues, the co-option of subaltern imaginaries, and the evolution of imaginaries over time; the conclusion acknowledges the shortcomings of this study and opens avenues for future research.

## 2. Sociotechnical imaginaries and energy transitions: A literature review

Jasanoff and Kim (2009) initially defined “sociotechnical imaginaries” as “collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects. Imaginaries, in this sense, at once describe attainable futures and prescribe futures that states believe ought to be attained”. They progressively reformulated this definition to attend to how certain actors – “corporations, social movements and professional societies” (Jasanoff and Kim, 2008) – can articulate sociotechnical imaginaries, recognizing that these can be co-produced by multiple stakeholders, beyond nation states.

Literature on sociotechnical imaginaries initially focused on “the role that state and transnational actors play in shaping perceptions of the ‘good society’” (Smith and Tidwell, 2016), progressively shifting attention to “those produced by non-state actors” (Hess and Sovacool, 2020), recognizing the need to “map some distributed, diverse, and counter-hegemonic visions” (Longhurst and Chilvers, 2019). Consequently, scholarly work on sociotechnical imaginaries is now attending to the perceptions of a variety of actors - local communities, corporations, non-governmental organizations (NGOs) and social movements (Chilvers and Longhurst, 2016). Therefore, Jasanoff has redefined sociotechnical imaginaries as “collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology” (Jasanoff, 2018).

As Marquardt and Delina argue, “sociotechnical imaginaries not only point at the co-production of norms and social order and link visions of the future to advances in science and technology, but also shed light on the underlying assumptions and tools for social activism that often remain unproblematized” (Marquardt and Delina, 2019). Sociotechnical imaginaries illuminate the normative dimensions of science, technology and futures, illustrating the co-production of science and society, allowing us to explore how energy transitions are embedded in social, political, historical and cultural orders. As Jasanoff (2018) suggests, complex problems, such as energy transitions, demand collective actions that engage with knowledge and politics.

<sup>1</sup> Since our paper engages with the topic of energy transitions, it relates to the Sustainable Development Goal (SDG) 7 – “ensure access to affordable, reliable, sustainable and modern energy for all”. Please see Liu et al. (2021) Murshed and Tanha (2021) and Murshed (2021) for relevant literature on the articulations of SDG7 and renewable energy transition in distinct geographical contexts.

In their foundational article, Jasanoff and Kim (2009) identified a series of sociotechnical imaginaries of nuclear energy in the United States of America (USA) and South Korea. They contrasted two main imaginaries: in the USA, nuclear imaginaries were dominated by concerns with “containment”, including “not only the hazards of radiation but also the political hazards of public dissent and rejection” (Jasanoff and Kim, 2009), whereas South Korea's imaginaries were characterized by modernization and techno-economic development. Ever since this initial argument, the sociotechnical imaginaries approach has been widely mobilized to frame energy transitions in the North and Global South, reinforcing its theoretical and methodological relevance for analysing understandings and pathways to carbon neutrality.

Regarding the European context, Genus et al. (2021) contrasted two energy policy imaginaries, delving into the role of social sciences and humanities research in tackling challenges related to energy transitions and climate change. They identified a dominant imaginary characterized by technological and behavioural change, and an alternative imaginary focused on practices and cultural change, emphasizing “novel ways of seeing research objects, subjects and relations among them, with citizens, policy-makers, industry actors and researchers as partners in the co-production of knowledge about everyday practices in energy systems”. The latter, by highlighting social practices connected to energy use, overcomes the techno-economic-centrism of the hegemonic imaginary, underlining the bottom-up ethos of a multiplicity of stakeholders, crucial to reflect upon carbon neutral futures, different scales and actors. Engels et al. (2020) discussed energy futures in Germany, focusing on business stakeholders, identifying three aspects pertaining to these imaginaries: a story of an old energy world, characterized by fossil-fuels and nuclear energy; the importance of the Paris Climate Conference in 2015 as a turning point towards decarbonization; the story of a new energy-world where alternatives to the carbon path are legitimate, necessary, and imperative.

In their study of smart grids in Europe, Vesnic-Alujevic et al. (2016) argue that “the socio-technical imaginaries that are being privileged come from the industry and are then echoed by policy makers”, and seem to reproduce standard innovation imaginaries, presenting smart grids as drivers of modernization, development, and citizens' empowerment, with little discussion of potential risks. Similarly, Ballo's (2015) research on smart grids imaginaries in Norway suggests that these are “described as a necessity for technological progress, enabling increased automation and control of the grid”. Mutter (2019) drew on Jasanoff and Kim's (2009) work to analyse sociotechnical imaginaries of fossil-free futures in Linköping, Sweden, focusing on public transport, identifying two conflicting stances: a dominant one, centred on biogas, and the electricity imaginary, articulated with “new developments in electric vehicle technology suggesting that electricity is the ideal fuel in inner city bus traffic”.

The sociotechnical imaginaries approach has also been mobilized to examine energy transitions in the Global South. Delina (2018) examined the co-production of energy sociotechnical imaginaries in Thailand, identifying three core imaginaries: an imaginary entwined with “energy security, development, and connectivity”, linked to economic growth and competitiveness; a second imaginary tied with “sustainability of energy source, less-risky technologies, and domestic energy reliability”; and a third imaginary characterized by “energy affordability and reliability, democracy, and self-sufficiency”. Simmet (2018) carried out research on imaginaries of energy transition in Senegal, distinguishing two competing imaginaries of development: one focused on technologies – specifically solar panels – that “are expected to transform society in accordance with presumed universal models of development”, and another imaginary that rejects universalizing assumptions, aiming to begin with society, bringing in “only

those technological or material necessities that will enable a nation's or region's desired futures to connect to its past".

Beyond "sociotechnical imaginaries", other notions have emerged in the literature on energy transitions – "scenarios" (Söderholm et al., 2011), "energy futures" (Miller et al., 2015), "mental models" (Schmid et al., 2017), "storylines" (Tozer and Klenk, 2018), "energy visions" and "sociotechnical visions" (Longhurst and Chilvers, 2019). However, we have adopted the "sociotechnical imaginaries" approach because it will allow us to: identify multiple conflicting visions of technological development; examine how imaginaries are differently produced, mobilized and justified by diverse stakeholders (nation states, social movements, corporations, NGOs and lay citizens); analyse how societies, expectations, technologies and futures are co-produced.

To the best of our knowledge, the sociotechnical imaginaries approach has only been deployed once in the Portuguese context: focusing on parliamentary debates between 1945 and 2013, Santos Pereira et al. (2017) argued that, although initially nuclear energy imaginaries were entwined with notions of modernity, economic development and technological prowess, after the democratic revolution of 1974 they were progressively characterized by concerns with the environment, potential risks and geopolitics. Hence, this article contributes to the scarce literature on sociotechnical imaginaries in the context of the Portuguese energy transition, exploring an original case study – the RNC2050.

### 3. The roadmap for carbon neutrality 2050

In 2016, at the 22nd Conference of the Parties, the Portuguese Government committed itself to the goal of achieving carbon neutrality by 2050. This pledge followed the signature and ratification of the Paris Agreement, which invited all ratifying Parties to formulate and communicate long-term low greenhouse gases (GHG) development strategies until the end of 2020. Portugal complied with this recommendation and, in September 2019, submitted its national strategy – the RNC2050 – to the United Nations Framework Convention on Climate Change.

The RNC2050 outlines technologically viable and cost-effective trajectories to reach carbon neutrality by 2050, which requires a rapid transition from fossil fuels to renewable energies (see Fig. 1). Underlying this goal is a strategic vision that perceives the decarbonization process and the energy transition "as an opportunity for the country, based on a democratic and fair model of national cohesion that enhances the generation of wealth and the efficient use of resources" (Governo Português, 2019). The pathway drawn by the RNC2050 assumes that the transition to carbon neutrality will be socially fair, fostering economic competitiveness and job creation, promoting co-benefits associated with air quality and human health, valuing the territory (Governo Português, 2019).

The accomplishment of this strategic vision is anchored in eight premises, corresponding to the main sections of the RNC2050: (1) transition to a competitive, circular, resilient and carbon neutral economy; (2) decarbonization vectors and lines of action; (3) resilience and climate change adaptation; (4) research and innovation; (5) financing conditions; (6) fair and cohesive transition; (7) effective conditions for governance and integration of carbon neutrality objectives in all sectors; (8) engage society, focus on education, information and awareness, increasing individual and collective action (Governo Português, 2019).

At the core of the RNC2050 is the delineation of GHG emission trajectories to attain carbon neutrality by 2050, derived from modelling exercises encompassing all relevant economic sectors: the energy system, comprising power generation, mobility and transport, industry, and buildings; agriculture, forests, and other land uses; waste and wastewater.

Alongside the electrification of the economy, complementary decarbonization vectors include: energy efficiency; decentralization and democratization of energy production; building renovation; sustainable agriculture; carbon sequestration; circular economy; prevent waste generation; enhance the role of cities and local governments; research and innovation; green taxation; align the financial system with carbon neutrality; promote the involvement of society; encourage a new economy linked to energy transition and decarbonization; guarantee a fair and cohesive transition (Governo Português, 2019).

From a methodological standpoint, the RNC2050 relies on the development of three socioeconomic scenarios – "Off-Track", "Peloton", and "Yellow Jersey" –, subsequently guiding modelling exercises. Each one offers a plausible narrative for the transformation of the Portuguese society, exhibiting varying degrees of success in achieving carbon neutrality, according to the evolution of selected macroeconomic and demographic indicators. The completion of the RNC2050 involved a multidisciplinary team of Portuguese experts, aided by contributions from external consultants.

The technical work was accompanied by a process of public participation, namely a cycle of technical workshops on the role of circular economy in the future of mobility, forestry activities, agri-food, construction, cities, energy, and waste and wastewater, engaging various stakeholders from each economic sector. Simultaneously, a cycle of thematic events focusing on decarbonization also took place. The preliminary version of the RNC2050 was later submitted to public consultation and it was presented in six Portuguese cities.

The RNC2050 is a forward-looking instrument, characterized by concepts such as "scenarios", "trajectories", and "narratives", envisioning how a carbon neutral Portugal might look by 2050, advancing possible pathways to achieve it. Nevertheless, these pathways are not univocal, nor indisputable. In fact, the RNC2050 can be considered a "boundary object", objects that

"are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. (...) They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" (Star, 1989)

"Boundary objects", while intersecting different social worlds, also manage to satisfy the specific requirements and practices of each group, which means they are both "ambiguous and constant" (Bowker and Star, 2000). We argue that the RNC2050 is a "boundary object" due to its flexibility, as it is differently enacted by multiple – and often competing – stakeholders: members of academia, representatives of corporations, public officers, and social movements.

The RNC2050 will allow us to identify various – and conflicting – imaginaries of energy transition in Portugal. Although the RNC2050 represents the "official" national imaginary of energy transition, it results from a broader process of public engagement, illustrating how this "official" imaginary has been co-produced. Moreover, the RNC2050 highlights how certain sociotechnical interventions regarding energy transition are entwined with a number of normative claims underpinning "Modernization", "Techno-Economic Development", "Green Economy", "Energy Citizenship" and "Just Transition". Finally, this document is particularly emblematic to analyse the co-production of science and society, and how visions of future societies are enrolled to support energy transitions.

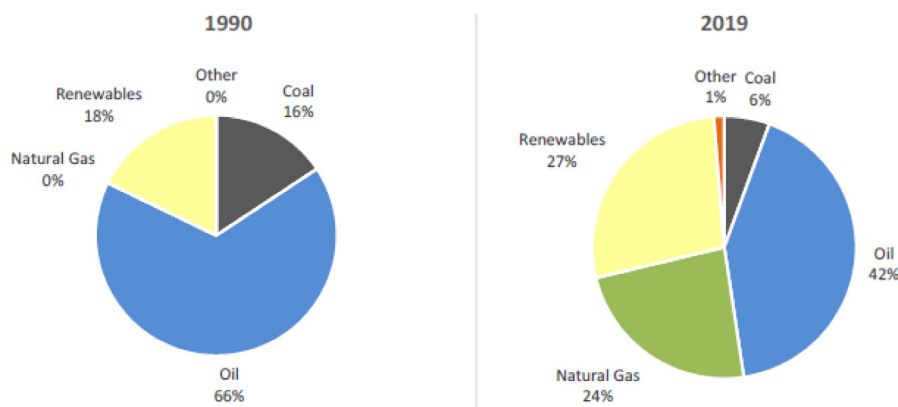


Fig. 1. Primary energy consumption by energy source in Portugal, Portuguese Environment Agency (2021).

#### 4. Methodology

We conducted nineteen semi-structured interviews, and one informal conversation, in person and online, between November 2019 and March 2021, with actors from three stakeholder groups: (1) the RNC2050 execution team (nine interviews); (2) political actors of high-level state institutions in charge of the energy transition (three interviews); (3) members of civil society (seven interviews). While groups one and two were directly implicated in the elaboration and monitoring of the RNC2050, group three is usually underrepresented in decision-making processes. By acknowledging this diversity of actors and interest groups, we were able to grasp the multiplicity of sociotechnical imaginaries of energy transition in Portugal (beyond the RNC2050), providing a more comprehensive analysis of this phenomenon. Moreover, this allowed us to recognize the power dynamics embedded in energy transitions, namely: co-production and co-optation, where distinct sociotechnical imaginaries gradually converge and blend, becoming dominant; and exclusion, dismissing counter-hegemonic sociotechnical imaginaries and preventing their advocates from actively engaging in climate and energy policies.

The RNC2050 execution team (group one) was composed of twenty-nine people, representing five different institutions: Get2C, a consulting company in the field of climate finance and sustainable development; the NOVA School of Science and Technology (FCT NOVA); AGRO.GES, a society of studies and project management for the agricultural transition in Portugal; Lasting Values, a strategic consulting firm in the areas of green, resilient and circular economies; J. Walter Thompson, a marketing communications company. Of these, we interviewed nine stakeholders from four institutions: one of the partners of Get2C; five FCT NOVA researchers, including the team coordinator, the supervisor of the public participation process, and members of the working groups on energy and mobility and transport; the founder and scientific coordinator of AGRO.GES, responsible for leading the working group on agriculture, forests and other land uses; one of the co-founders of Lasting Values and its managing-partner, in charge, respectively, of the working groups on circular economy and on waste and wastewater.

The main political entities involved in the decision-making process, as well as in the evaluation cycle of the RCN2050 (group two), include: the Ministry for the Environment and Climate Action; the Secretary of State for Energy; the Directorate-General for Energy and Geology (DGEG); the National Council of the Environment and Sustainable Development; and the Portuguese Environment Agency (APA, in its Portuguese abbreviation). We interviewed three high-ranked representatives from the Secretary of State for Energy, the Portuguese Environment Agency and the

National Council of the Environment and Sustainable Development. Our attempts to interview actors from the Ministry and APA were unsuccessful, thus resulting in a disparity between the number of interviewees in each group.

The third stakeholder group corresponds to members of civil society, heterogeneous in itself (academics, mainstream environmental NGO's and climate justice movements, non-profit associations, renewable energy cooperatives, and private companies). We interviewed at least one representative of each domain. Although not directly involved in the elaboration of the RNC2050, their contribution was deemed valuable, as they represent historically concealed and marginalized voices in the Portuguese climate and energy landscapes, allowing us to identify and compare various sociotechnical imaginaries of energy transition. We interviewed seven people: a member of the directive board of ZERO – a non-profit environmental association; an associate of ZERO and campaigner for “Empregos para o Clima” (literally, “Climate Jobs”), a just energy transition campaign; a co-founder of Coopérnico – the only renewable energy cooperative in Portugal – and member of the directive board of ZERO; a coordinator of Coopérnico and member of the general council of ZERO; a member of the directive board of “Just a Change” – a non-profit association focused on rebuilding energy-efficient houses; a legal scholar working on energy cooperatives, specifically on Coopérnico; a climate justice activist at Climáximo; a member of the directive board of the Portuguese Renewable Energy Association; and we had an informal conversation with a high-representative of a leading energy company.

A semi-structured interview script was prepared for each group. This format was flexible and adaptable enough to understand stakeholders' perspectives on the RNC2050 and energy transitions more broadly. The interview script of group one assessed general information regarding the elaboration of the RNC2050 and its *ex post* monitoring and implementation, identifying the sectorial trajectories for carbon neutrality of each working group. For group two, the main goal was to understand the strategic vision and the fundamental priorities regarding energy and climate action, with a special focus on the energy transition. The interview script for group three assessed different civil society's actors' perspectives on the potentialities and limitations of the RNC2050, encompassing alternative non-state-centric sociotechnical imaginaries.

All interviews were fully recorded, transcribed, and anonymized, and all interviewees provided us with either written or verbal consent according to the guidelines of our research institution. Table 1 outlines the stakeholders that were interviewed and the interview date. Following a process of thematic analysis conducted by the three co-authors, we identified four sociotechnical imaginaries of energy transition in Portugal: (1)

**Table 1**  
List of interviewed stakeholders according to group and interview date.

Stakeholders	Participant's name	Interview date
Group 1 RNC2050 Team	BPM	November 2019
	SJ	November 2019
	FF	January 2020
	LR	February 2020
	FP	June 2020
	BJE	June 2020
	TH	July 2020
	AF	July 2020
	MS	July 2020
Group 2 Political Actors	SFD	January 2021
	BJC	February 2021
	GJ	March 2021
Group 3 Civil Society	PA	December 2019
	CJ	January 2020
	MD	May 2020
	ARA	June 2020
	BA	July 2020
	FS	May 2020
	JPA	March 2021

Modernization and Techno-economic Development; (2) Green Economy; (3) Energy Citizenship; (4) Just Transition. In Section 5, we will describe and analyse each one of these imaginaries.

## 5. Sociotechnical imaginaries of energy transition in the Portuguese context

### 5.1. Imaginary one – modernization and techno-economic development

The first imaginary frames the energy transition as a driver of modernization and techno-economic development, leading to economic – and geopolitical – leadership. This is the dominant imaginary displayed by political officials, and, to a lesser extent, by academics and the private sector. Imaginary one conceives the energy transition as: an opportunity to modernize Portugal; generating positive overflows that impact manifold socioeconomic spheres; allowing Portugal to converge with the European Union (EU) and with the Paris Agreement; potentially becoming a disruptive force that will reverse North/South inequalities within the EU, bringing Portugal into a leadership position in achieving carbon neutrality. Imaginary one frames the energy transition – and the RNC2050 – as embedded in a path of infrastructural and technological modernization that is inevitable and urgent due to the threat of climate change:

The content of the Roadmap is of relative common sense, and it is linked to a natural modernization of our country. (MS, 07-2020)

We must undertake this transition, because it is urgent, and it has to be achieved in a democratic and universal fashion. The energy transition towards decarbonization should be supported by available and evolving technologies. (BJC, 02-2021)

The energy transition is envisaged as an “opportunity” and not merely as a requirement under EU’s energy and climate frameworks. Portugal is thought to reap numerous socioeconomic gains, illustrating how the country can benefit from the reconfiguration of sociotechnical regimes:

The imperative and obligation of carbon neutrality should be presented not as a problem, but as an opportunity. (GJ, 03-2021)

[The transition to carbon neutrality] is a great opportunity for our country: it will create the opportunity for a wide range of companies and universities to work on innovation for energy transition as a tool to fight climate change. It also generates an opportunity for job creation in Portugal, for economic growth, for an increase in tax revenues to reduce the deficit and public debt, to generate funds for social security for citizens’ retirement pensions. (JPA, 03-2021)

If this problem is not solved at the global scale, living conditions in Portugal and Southern Europe will become more difficult. If we do not follow the Paris Agreement, there are very high risks of desertification (...) there is a real risk of losing well-being, economic prosperity and quality of life. (SFD, 01-2021)

Interviewees recognized that the transition to carbon neutrality is not only an opportunity for Portugal – promoting job creation, economic growth, budgetary balance and overall well-being and prosperity –, but it is also a way of mitigating climate change and restoring the Earth System. Energy transition and the RNC2050 are understood as allowing Portugal to keep up with a wider global trend towards sustainability and carbon neutrality, aligning itself with the recommendations from the IPCC and the goals established by the European Commission. Moreover, the deactivation of the coal power plants of Sines and Pego are interpreted as signs that reinforce the national commitment towards decarbonization. Beyond the calibration of national policies with broader European and global trends, Imaginary one also places Portugal at the forefront of the energy transition, with some interviewees, namely from group two, arguing that the country – due to its climate, natural resources, and political vision – could become a leader in the transition to carbon neutrality, reverting systemic North/South unbalances within the European context:

The first impact of renewables is geopolitical: Southern Europe, historically, was poor in terms of resources and Northern Europe had plenty of resources... This scenario is reversed... Or at least becomes more balanced, because Portugal and Spain are the richest European countries in terms of sun, and Portugal is the third country with more wind resources. So, we have here a huge potential regarding renewables. (GJ, 03-2021)

We must make these goods [natural resources] available to humankind. Portugal has the largest lithium reserves known in Europe. And it is probably the 6th or 7th in the world. So, it has a huge responsibility when it comes to exploring these resources – it should have been exploring them for the past six or seven years –, we are already late. Portugal must make these resources available to the population as soon as possible. (BJC, 02-2021)

I think it [carbon neutrality] will depend on certain technologies, but it would be very interesting to anticipate that goal [of 2050] to try to avoid the devastating impacts of climate change. In the Portuguese case it was great to set 2050 as a goal, we were one of the first countries to make that commitment, but it would even be possible to anticipate that goal! We are seeing signs of energy transition happening much faster than we anticipated. (BPM, 11-2019)

The country’s capacity for [green] hydrogen production is significant, compared to other European countries. We are moving from a paradigm where we import everything and depend on foreign countries and on oil producers, to a logic where we just need to find ways to control the fluctuation of renewable energy. (TH, 07-2020)

According to imaginary one, Portugal is a potential leader in the energy transition, due to its climate and natural resources, embracing a new renewable energy paradigm that will be able to reverse the long-standing dependence on fossil fuels and foreign countries. This imaginary is entwined with principles of leadership and frames the energy transition as a driver of technological modernization and economic growth.

## 5.2. Imaginary two – Green economy

Imaginary two conceptualizes the decarbonization process as benefiting the Portuguese economy, embedded in a wider paradigm of “green economy” where economic growth is coupled with sustainability and climate change mitigation and adaptation. This imaginary perceives the RNC2050 as foregrounding a future where the Portuguese economy undergoes profound socio-economic changes to meet the challenges of decarbonization. Imaginary two entails four main tenets: new market, business, and job creation opportunities within the carbon neutral economy; the coupling of economic growth and sustainability; the adoption of principles of sustainability by existing companies, particularly in the energy sector; the consolidation of emerging economic paradigms, namely circular economy.

Various interviewees believed that the energy transition would be a driver of new market, business, and job opportunities, bolstering economic growth:

If there is an increase in the generation of renewable electricity, there will be an increase in related jobs. Then, there are also the services, [such as] car sharing. Smart grids will also generate a series of applications and related services. So, there is a whole world that can emerge of new opportunities there. (FP, 06-2020)

There is a whole range of new opportunities. Perhaps we can assess the negative impacts of transition, but we cannot fathom the potential benefits and opportunities that will emerge. A new market will open for these industries, new businesses, not only what we can conceive at the moment, but what will emerge and we cannot really account for now. Having a policy and a strategy to help us with transition and how to obtain future gains is essential. (LR, 02-2020)

The industries will necessarily need to reconvert and adapt to a new economic paradigm. They will have to try and profit from all the new businesses around the production of renewable, clean energy, etc. This will be absolutely decisive within the next years. The truth is, we will lose some jobs, but many more will be created! (TH, 07-2020)

The idea that carbon neutrality will foster new opportunities was recurrent in political, academic, and corporate stakeholders, arguing that the energy transition would open plentiful possibilities for businesses. Imaginary two postulates that the energy transition allows for a virtuous coupling between economic growth and sustainability, suggesting that, in a carbon neutral world, corporations will only be able to prosper if they actively address environmental and climate concerns. As mentioned by a top representative of a leading energy company, nowadays the market devalues strategies that are not consistent with the energy transition, and stakeholders from the State and the private sector recognized that sustainability goals and targets must be actively incorporated by companies in order to thrive in the carbon neutral world:

We will [at the European level] start funding projects that are concerned with sustainability, in terms of raw material exploitation, production, processing and recycling. There is a strong orientation, from the European point of view, to make sure that funded projects are aligned with these guidelines. (BJC, 02-2021)

Many companies have already realized the impact that climate change can have on their businesses; so, the issue of carbon neutrality emerges as a necessary step to continue their business. (FS, 5-2020)

Interviewees emphasized that numerous Portuguese companies – even from the fossil fuel industry – were adapting to this new scenario, building their energy futures around renewables and carbon neutral technologies, in order to meet the decarbonization goals. By aligning their strategic plans and investments with carbon neutrality targets, these companies will be able to benefit from this emerging green economy:

These are large companies that are integrated in European networks, so they conduct that kind of analysis and studies and keep adapting. For example, Navigator,<sup>2</sup> in September, presented their own roadmap for carbon neutrality in 2030. So, they conduct that exercise themselves, and make investment decisions based on that future. Companies such as *Energias de Portugal* (EDP, in its Portuguese abbreviation)<sup>3</sup> have been thinking like that for a long time. Galp<sup>4</sup> has environmental concerns, regarding their activities. It has sustainability indexes... These companies [have] a set of concerns applied to their operations. (SJ, 11-2019)

We think that if an oil company, for example, becomes a 100% green company, that is not bad. It is positive. (GJ, 03-2021)

Energy companies, such as EDP, Galp, Endesa,<sup>5</sup> Iberdrola,<sup>6</sup> etc., know that in that sector a huge energy transition is underway, they have known it for five or ten years, so their response is quite sophisticated, it is not just marketing. (BPM, 11-2019)

The companies themselves understand already that they cannot be competitive if they do not modernize, if they do not meet sustainability standards, environmentally sustainable standards. (BJC, 02-2021)

The Green Economy imaginary frames energy transitions as potentially benefiting those companies which have the ability to adapt – and profit – from a carbon neutral future. There is also an emphasis on economic paradigms able to meet the challenges of climate change and sustainability, reconfiguring sociotechnical and economic structures towards carbon neutrality. The RNC2050 is informed by principles of circular economy, considered a “regenerative growth model” (European Commission, 2020) characterized by: sustainable products designed for reuse, repair, and recycling; high quality, efficient and affordable products; sustainable services and business models; waste prevention and reduction; valorization of secondary raw materials (European Commission, 2020). The majority of interviewees delved into the importance of this economic model to reach carbon neutrality:

<sup>2</sup> The Navigator Company is an integrated forest producer, whose end products are pulp & paper, tissue, and energy.

<sup>3</sup> One of the leading energy companies in Portugal.

<sup>4</sup> One of the leading energy companies in Portugal.

<sup>5</sup> One of the leading energy companies in Spain.

<sup>6</sup> One of the leading energy companies in Spain.

Regarding circular economy, I can even produce less but the question is to produce with a higher added value. Every time I reduce consumables in the process, I reduce the energy consumption. That is circular economy – reducing material consumption, to reduce the intensity of consumption throughout the productive process, thus reducing costs. (MS, 07-2020)

Circular economy is a huge challenge. In practical terms it means that, instead of using concrete, [we will] use a replacement that has the same function and requires less carbon. It also means a transformation in logistics, a change in behaviours, and an important driver – the price. The logic is to ensure that resources entering the system have a small carbon footprint, both in their origin, circuit, and life cycle. So, they do not compromise the decarbonization process. (FF, 01-2020)

These quotes indicate that energy transitions pave the way for the emergence of economic paradigms suitable to respond to the challenges of climate change, highlighting a co-production between science, technology, economy, and society. This suggests that the Green Economy imaginary is at odds with the linear economy paradigm, implying that energy transitions can not only provide new opportunities for businesses, but also substantially reshape production and consumption systems.

### 5.3. Imaginary three – Energy citizenship

The third imaginary frames energy transition as leading to a new type of citizenship where individuals and communities become active agents of socioecological transitions. While imaginaries one and two favour the top-down action of the State and private companies, this imaginary is eminently bottom-up, emphasizing the key role of citizens in driving energy transitions, which, in turn, will be supported by individual behaviours, lifestyle changes, and the dissemination of prosumers and renewable energy communities – an emblematic example of Energy Citizenship.

According to Imaginary three, citizens are active agents of change, conceptualizing energy transitions as a bottom-up endeavour that illustrates the transformative power of individual options:

They [citizens] are the agents of change. It is impossible to undergo an energy transition without society, without citizens. Not just at the technological level, but also at the behavioural level. Many of the premises that we used in our scenarios [of the RNC2050] assume that there will be changes in societal patterns, such as circular economy, including car sharing, for example. (FP, 06-2020)

There must be a profound change in public policies... And for that to occur we need a profound change in how individual citizens think, which then leads to changes in collective thinking. (ARA, 06-2020)

We cannot expect the message to come from above... This requires a change in behaviour, and that change depends on us! (MD, 05-2020)

Imaginary three emphasizes the role of individual behaviours, and it is pervasive in representatives of NGOs, social movements, and academia. The RNC2050 includes a wide range of changes in consumption patterns in its scenarios, underlining how individual behaviours must shift to face the challenges of the energy transition. The Energy Citizenship imaginary understands citizens as consumers, and it is through particular consumption changes, forms of education and awareness that transition can be enacted:

With the introduction of scooters and bicycles over the past three years, mobility in Lisbon has changed radically. Six years ago, this was unthinkable. So, consumer behaviour is extremely important. (LR, 02-2020)

There will be a natural evolution of diets, due to human health and due to the need to make land use more sustainable, favouring diets that consume less animal protein. (AF, 07-2020)

Much more energy literacy is needed in order for this transformation to occur. (ARA, 06-2020)

This work of education must be carried out. Right now, we must work with young people. The DGE has several projects targeting youth. This emphasis on education is very important to allow for a more rational society from the sustainability point of view. (BJC, 02-2021)

This imaginary conceptualizes energy citizenship as entailing a myriad of fields, including individual diets and mobility, and understands education, energy literacy and environmental awareness as key aspects for behavioural change. Within this imaginary, citizens are empowered as consumers and producers – they become prosumers with an active role in sociotechnical change. According to a high representative of a leading energy company, citizens have the potential to become a crucial actor in the energy transition as soon as different technologies become widespread (e.g., electric cars, batteries, solar panels, etc.). This stance was echoed by other stakeholders:

Portugal has recently implemented the directive that reinforces the role of citizens: from passive consumers of energy into active agents of energy transition.<sup>7</sup> (GJ, 03-2021)

We will have consumers with an active role in the electric system, not only because they will be able to buy and sell electricity whenever they want, but because they will be able to offer what is called *demand response*, i.e., flexibility services. (...) Beyond their consumption patterns, beyond being able to buy cheaper electricity, [prosumers will] be able to participate in the energy market. (JPA, 03-2021)

Imaginary three conceives citizens as active prosumers in a new energy scenario characterized by flexibility and decentralization. This imaginary is eminently bottom-up, decentralized and distributed, supported by a new model of energy consumption and production – the *renewable energy community*.<sup>8</sup> Stakeholders frequently referred to renewable energy communities as an emblematic model to imagine decarbonized energy futures, where individual citizens – and communities – play an active role:

Renewable energy communities are much more complex energy ecosystems... We are preparing regulation and conducting the first pilot tests, because they imply not only production and consumption, but also other aspects, such as providing energy services, energy efficiency, electric mobility, storage, consumption aggregate and production aggregate. So, they imply a set of aspects and here many actors can participate, including residents of social housing (...) who otherwise

<sup>7</sup> The Decree-Law No. 162/2019 establishes the legal scheme applicable to self-consumption of renewable energy, individual, collective or by renewable energy communities.

<sup>8</sup> The Decree-Law No. 162/2019 defines “renewable energy communities” as legal entities for the production, consumption, sharing, storage and sale of renewable energy.

would never have the money to buy solar panels... These new mechanisms of collective self-consumption and of renewable energy communities allow for the participation of those with lower incomes. We hope that, throughout this decade, we will achieve a higher participation of producers at lower costs to join this system. (BJC, 02-2021)

This legislative change has to do with collective self-consumption. But we need much more: we cannot have energy communities in every neighbourhood without providing training, explaining them how it will work. At Coopérnico, every week we receive an email from someone asking us how they can do it, but collective self-consumption is under DGE's control. I am not sure if they will ever have the ability to help citizens who want to do so. It is not enough to change legislation... We need much more than that: we need energy literacy for this transformation to occur, so that we can have more prosumers. (ARA, 06-2020)

[Energy communities] are an instrument that contributes to territorial cohesion. (SJ, 11-2019)

Stakeholders from the State, the private sector and academia highlighted the benefits of energy communities. However, as we can see from the second quote, the representative of the energy cooperative believed that the State would not be able to properly inform citizens on how to embrace this new model of energy production and consumption, suggesting that energy communities are a boundary object differently imagined – and enacted – according to particular agendas, interests and situationalities. Although Energy Citizenship is a recurring imaginary among various stakeholders, in practice it carries different meanings, strategies and processes. Despite being entwined with a broader political ecology that emphasizes the power of individual – and community – changes to enforce energy transitions, it is an ambivalent imaginary.

#### 5.4. Imaginary four – Just transition

Imaginary four entails a set of social, political, and ethical concerns inherent to energy transitions, highlighting the need for an inclusive and fair reconfiguration of sociotechnical and socioeconomic systems. Just transition is the dominant imaginary among interviewees belonging to the climate justice movement; civil society stakeholders from environmental NGOs and academia also share this imaginary. It is an ambivalent imaginary, assuming multiple socio-political configurations - from public policies aiming at attenuating market failures to a blunt critique of capitalism. Imaginary four encompasses the following trends: the need for strong public policies and State intervention; the protection – and retraining – of fossil fuel workers; energy transition as an opportunity to develop alternatives to the dominant socioeconomic system.

The first tenet of this imaginary is the recognition that, in order to avoid the asymmetrical social costs of energy transitions, the State must implement robust social policies. Although just transition is not explicitly mentioned in the RNC2050, it was often acknowledged by researchers involved in its preparation, who argued that it was up to the government to safeguard this aspect:

Regarding just transition, that is a discourse that obviously was taken into account by those who prepared the RNC2050, but it is something that is not part of the model. The model did not look at social justice, but obviously each one of us (all the team members) assumed that the transition had to be socially just. But that responsibility... it is an option of the government, not ours. (FF, 01-2020)

Just transition is a public policy framework and we need to anticipate how low-income families will transition towards carbon neutrality. This is one of the most important aspects of public policy: how can low-income families invest in energy efficiency, namely in their homes, with a direct impact on thermal comfort. This is called energy poverty. We need fiscal policies because if we do not do so carbon neutrality will lead to more social inequalities. (SJ, 11-2019)

The Just Transition imaginary frames the government as directly responsible for ensuring that no one – especially low-income families – is harmed by the decarbonization process, highlighting the need for socially-oriented public policies – such as taxes and other fiscal instruments – to avoid the deepening of social inequalities. Moreover, the first quote also emphasizes that, since the RNC2050 did not explicitly mention “just transition”, it is up to the government to assure the fairness of the energy transition, through the implementation of robust social policies. Another matter of concern while discussing just transition is the loss of jobs linked to fossil fuel industries. The Coal Power Plant of Sines was deactivated in early 2021 and Pego is expected to close down by the end of 2021, potentially leaving dozens of workers unemployed. Stakeholders from climate justice groups and NGOs were especially concerned with this, stressing the need to requalify these workers, reintegrating them in other sectors:

[Just transition] is a transition that opens possibilities for the training of those who are forced to change jobs, due to the energy transition. So, it is the possibility of developing programs that allow those people to continue to have a role in society and to have a job. When a coal power plant such as Sines or Pego is closed down, some of the workers will eventually lose their jobs, so we must have training programs to ensure that they have opportunities... (SFD, 01-2021)

First of all, what will happen to those workers [of the fossil fuel industry]? If we cut down on those industries, there will be plenty of people starving. When we talk about just transition, we need mechanisms to allow those people to transition towards the carbon neutrality market, to find job alternatives, because they will probably struggle to find another job using those same technical skills. (BA, 07-2020)

The coal power plants represent about 20% of emissions in Portugal... Their dismantling and conversion... That space can be used for other activities. Those workers, according to the talks we had with the union, most of them are in pre-retirement, so probably a significant number will retire by 2023. There are plenty of workers, perhaps about 30%, in a precarious situation. So, it would be interesting to develop activities where those workers can have more stable conditions. For instance, in Sines, we have power lines with a large capacity for energy transmission. Solar and wind energy are forms of electricity produced intermittently, so they need some form of storage. Those sites, since they have a great capacity for energy transmission, can be used to store energy through hydrogen. (PA, 12-2019)

Within Imaginary four, the priority is to ensure that energy transitions protect the future of the working class; therefore, the government must intervene to ensure the retraining of fossil fuel workers and the conversion of coal power plants into renewable energy related infrastructure. Within this imaginary, we also identified strong critiques of the capitalist world-ecology, especially from actors linked to climate action groups and/or climate justice movements, who interpret “Just Transition” as an opportunity to develop socioeconomic alternatives. In one case, the interviewee explicitly criticizes the RNC2050 for not considering the power relations underpinning the climate crisis:



The RNC2050 identifies some sectors where some things can be done, but it is a vision totally detached from society. It assumes that it is possible to decarbonize the economy without changing power relations. It is a technocratic view of the energy transition. It ignores the fact that the system allows for the social structure we have today. Transitioning requires a much higher pace than the one envisioned by the RNC2050. We consider that waiting for private actors – and believing that private agents, due to some miracle, will suddenly stop responding to market logics and investing, when there are still incentives for other catastrophic investments – is a mistake. (CJ, 01-2020)

This interviewee views the RNC2050 as an expression of technocracy, detached from social struggles and failing to address the major cause of climate change – “neoliberal capitalism”, as they told us –, indicating that imaginary four is contested by social movements that believe that it is not possible to attain carbon neutrality without addressing the deep-rooted causes of the climate crisis. This reiterates the argument that the RNC2050 can be understood as a “boundary object” that, in this case, is mobilized to criticize the “hegemonic” version of the energy transition, calling for alternatives to the capitalist world-ecology. Some members of NGOs and social movements named some of these alternatives – degrowth, energy democracy and cooperatives:

We need to stop talking about growth and start talking about degrowth ... If the goal is the wellbeing of the population, then perhaps wellbeing in the future is not achieved through economic growth, but through other indicators that favour a higher quality of life. (ARA 06-2020)

One of the concrete measures we propose is a 32-hour work-week. We even think it can be more reduced, but that implies a logic that totally collides with the RNC2050, which is the logic of a stationary economy, whose goal is not economic growth as this document clearly predicts. (PA, 12-2019)

I believe cooperatives are the best model to achieve a fair energy system. Most private companies have forgotten what their primary goal is – to provide energy for citizens. (...) Access to energy is a fundamental good for every citizen, everywhere in the world, so it must come with a fair price, it must be accessible to everyone. This is why energy cooperatives are better equipped to achieve this fairness. (...) Cooperatives are the best model to achieve what we call “energy democracy”. (MD, 05-2020)

In this Section, we have outlined the main characteristics of each sociotechnical imaginary, resorting to excerpts from interview transcripts. Table 2 summarizes our findings, presenting imaginaries’ key features and associated stakeholders. The contested nature of these sociotechnical imaginaries reinforces the assumption that the RNC2050 encompasses a multitude of agendas, interests, socioeconomic aspirations, and political ecologies. It is a “boundary object” unpacking some of the contradictions of the political, technological, and socioeconomic responses to the climate crisis, as we will suggest in the discussion.

## 6. Discussion

In this section, we highlight and further discuss six relevant aspects deriving from our findings: the situatedness of stakeholders; the RNC2050 as a boundary object; dynamics of inclusion/exclusion and counter-hegemonic imaginaries; power dynamics and the alliance between incumbent energy companies and political actors; the co-option of subaltern imaginaries;

the dynamic co-construction of imaginaries throughout time. Although arising from the Portuguese context, we contend that these aspects are relevant for energy transitions research more broadly.

The four sociotechnical imaginaries suggest that stakeholders (the Portuguese Government, climate justice movements, environmental NGOs, private companies, and members of academia), convey various – and often competing – interests, aspirations, and agendas regarding energy transition. Although all interviewees support carbon neutrality, their sociotechnical imaginaries are decisively shaped by the situatedness of the stakeholder group they belong to.

Therefore, the RNC2050 can be viewed as a boundary object, displaying different meanings according to the specific stakeholders that were interviewed and/or involved in its preparation. The plasticity of the RNC2050, i.e., its adaptability to multiple interests, agendas, and aspirations, allows for the emergence of diverse imaginaries and pathways to carbon neutrality aligned with goals such as modernization, new economic models, energy citizenship and greater social justice. Stakeholders imagined how certain economic sectors could be adjusted to, support and benefit from carbon neutrality, drawing on the RNC2050 to bring to the fore renewed versions of socioeconomic systems, technologies, climate and energy policies and lifestyles. This also extends to the distinct political ecologies displayed by interviewees, involving numerous strategies such as top-down public policies, green capitalism, grassroots initiatives, circular economy, degrowth and confrontational/agonistic politics. Arguably, the pathway to carbon neutrality, far from being consensual, can elicit distinct sociotechnical imaginaries of energy transition and a wide range of socioeconomic proposals.

By engaging with often marginalized and excluded voices (such as climate justice activists and NGOs representatives), we recognized their agency in energy transitions, attending to the multiplicity of visions that go beyond the nation-state and frequently compete with dominant sociotechnical imaginaries. By considering which actors are included or excluded from decisions on the energy transition, we highlighted the ideological competition between numerous visions of a carbon-neutral future for Portugal.

These actors brought to the fore a multitude of bottom-up, local, community-based approaches to carbon neutrality, led by citizens, activists, cooperatives and/or local entrepreneurs. By highlighting the ethical, socioeconomic, and political challenges underlying the energy transition and the climate crisis, they advanced proposals aimed at fostering climate and social justice, based on counter-hegemonic economic models such as degrowth, or alternative organizational structures, such as cooperatives, which were not a priority for the RNC2050.

The majority of members of social movements criticized the green economy model proposed by the RNC2050 and argued for a systemic socioeconomic change, contending that the document fails to address the root cause of the climate crisis – capitalism. These visions portrayed the energy transition as an opportunity to imagine alternatives to current power structures, promoting a more democratic transition to carbon neutrality, challenging the assumption that the RNC2050 is an apolitical document.

The competing sociotechnical imaginaries are not equal, and their ability to succeed is associated with the power of their advocates in the Portuguese energy landscape. One could argue that Imaginaries one (Modernization and Techno-Economic Development) and two (Green Economy) – the most commonly shared by participants, reflecting an alignment between political actors, incumbent energy companies and the RNC2050 execution team – are more likely to become dominant. The harmonization between the discourses of political actors and energy operators

**Table 2**  
Brief characterization of the four sociotechnical imaginaries.

Imaginaries	Characteristics	Stakeholders
Modernization and Techno-Economic Development	<ul style="list-style-type: none"> <li>• Technological prowess.</li> <li>• Economic and geopolitical leadership.</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholders from <b>group one and two.</b></li> <li>• Specific stakeholders from <b>group three</b>, notably representatives from private companies.</li> </ul>
Green Economy	<ul style="list-style-type: none"> <li>• Positive economic impact.</li> <li>• Coupling between economic growth, sustainability and climate change mitigation and adaptation.</li> <li>• Energy transition as an opportunity for the emergence of new business models.</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholders from <b>group two.</b></li> <li>• Specific stakeholders from <b>group three</b>, notably representatives from private companies.</li> </ul>
Energy Citizenship	<ul style="list-style-type: none"> <li>• Citizens as active agents of socioecological transitions.</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholders from <b>group one and three.</b></li> </ul>
Just Transition	<ul style="list-style-type: none"> <li>• Opportunity to rethink dominant social, political and economic systems.</li> <li>• Social, political and ethical concerns.</li> </ul>	<ul style="list-style-type: none"> <li>• Stakeholders from <b>group three</b>, notably climate justice activists, representatives of NGOs and cooperatives.</li> </ul>

was patent in the interviews, and even in the RCN2050 itself, as it attributes a central role to the private sector in the energy transition.

Imaginary four (Just Transition) is absent from the RNC2050, but it has been progressively absorbed and co-opted by Portuguese and European institutional discourses and climate neutrality policies. Here, we can see how the situatedness of different stakeholders influences the enactment of Just Transition: although stakeholders from groups one and two recognize the need to safeguard jobs and requalify workers, their optimistic take on energy transition already presupposes that all citizens – not only economic and political elites – will benefit from this new sociotechnical scenario. In contrast, the perspective of civil society stakeholders is critical, arguing that lower-income families and fossil fuel workers, as well as the socioeconomic fabric of some regions, will be unfairly hit by carbon neutrality. Therefore, our data set suggests that the concept of “just transition” may have been co-opted by dominant imaginaries (Imaginary one and two), as its meaning significantly differed depending on whether we were interviewing stakeholders from the State (and private companies) or from climate justice movements.

Since we conducted interviews over the course of a year and a half, we were able to grasp how the different sociotechnical imaginaries evolved over time and beyond the RNC2050. During this period, the approval of the National Energy and Climate Plan 2021–2030, the closure of the Sines power plant or the development of the National Hydrogen Strategy influenced stakeholders’ perspectives on the RNC2050. Sociotechnical imaginaries are constantly being co-constructed according to societal and technological transformations, illustrating the co-production of science and society, specifically how energy transition imaginaries are embedded in broader social, political, and economic orders.

The RNC2050 depicts how energy transitions are a proxy to discuss political, socioeconomic, technological, and environmental issues, bringing to the fore matters of power and ideology. Carbon neutrality became a trope that allowed stakeholders to convey their visions for Portugal in the 2050 horizon, encompassing issues of techno-economic development, the reconfiguration of markets and economic systems, social justice, and individual behaviours. In that sense, energy transition became a metanarrative that allowed for the imagination of how specific behaviours, socioeconomic systems and technologies could be marshalled to achieve carbon neutrality and to address the climate crisis.

## 7. Conclusion

This article analysed sociotechnical imaginaries of energy transition in Portugal, delving into the case study of the Portuguese RNC2050. Drawing on semi-structured interviews with stakeholders belonging to three distinct groups, we identified four sociotechnical imaginaries that illustrate different ways of enforcing and imagining carbon neutrality, highlighting how the RNC2050 can be understood as a driver to unfold some of the socio-political tensions related to carbon neutrality transitions, and to the climate crisis more broadly. Our article contributed to current scholarship on sociotechnical imaginaries of energy transitions, exploring an original case study – the Portuguese RNC2050.

As we have argued, the RNC2050 – alongside the energy transition – can be understood as a boundary object that is differently mobilized and enacted by distinct actors and social groups. This further exposes the issues of power embedded in energy transitions: in fact, as we have discussed in the previous section, there are currently two dominant imaginaries stemming from the RNC2050 – Modernization and Techno-Economic Development and Green Economy. Although there was a consensus regarding the urgency of energy transition, the debate concerning its materialization is deeply political, and can articulate manifold socioeconomic stances, as well as various technological and energy options.

Some of the shortcomings of the article include the following: the four imaginaries are deeply dependent on our data set – by engaging with other stakeholders, one could eventually identify other imaginaries; the research was conducted over a period of one year and a half, and some of the information – and proposals – mentioned by interviewees were dynamic, evolving over time (for instance, aspects such as lithium mining or green hydrogen were not explicitly mentioned in the RNC2050); since the RNC2050 is not a binding document, it allows for a wide range of stances, projections and aspirations in fields such as agriculture, transportation, energy and waste; the RNC2050’s flexibility, alongside the fact that some of the interviews with members of the preparation team were centred on their specific fields, often prevented us from grasping their imaginaries as a whole, beyond their areas of expertise.

As directions for future research, we believe it will be necessary to study the evolution of sociotechnical imaginaries of

energy transition in Portugal from a longitudinal perspective, analysing how these different imaginaries interact, how new imaginaries – and stakeholders – emerge, as well as the power dynamics that will be established, in order to assess which imaginaries will become dominant – thus shaping energy transitions – and which ones will be marginalized, excluded and co-opted.

In terms of policy implications, we contend that Portuguese political authorities should take into account the diverse ecologies and meanings of energy transition conveyed by different actors. In practice, this could be achieved by dialoguing with stakeholders from the civil society that are often absent from decision-making processes, such as unions, local communities, small business owners, cooperatives, environmental organizations, and climate justice groups. Failure to do so may undermine public acceptance and commitment towards carbon neutrality, while also failing to ensure a just and inclusive energy transition.

### CRedit authorship contribution statement

**António Carvalho:** Collection and analysis of empirical data, The preparation of the research protocol, Writing of this manuscript. **Mariana Riquito:** Collection and analysis of empirical data, The preparation of the research protocol, Writing of this manuscript. **Vera Ferreira:** Collection and analysis of empirical data, The preparation of the research protocol, Writing of this manuscript.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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