



Original research article

Rage against the fossil machine: The deactivation of fossil energy production in Italy

Marco Grasso^{*}, Daniel Delatin Rodrigues

University of Milan-Bicocca, Via Bicocca degli Arcimboldi, 8, 20126, Milan, Italy



ARTICLE INFO

Keywords:

Agents of transition
Deactivation
Destabilisation
Disruption
Fossil machine
Reticular approach

ABSTRACT

The 'fossil machine' is the powerful and widespread network that supports fossil fuels and obstructs their phase-out. This article assumes that in order to advance the decarbonisation of fossil-based socio-economic systems it is first necessary to 'deactivate' the related fossil machine: to investigate how to do so we propose a new reticular approach. The article adopts this approach to investigate the deactivation of the 2019–2022 fossil machine built around a group of coal plants in Civitavecchia – the long-standing fossil energy city close to Rome, Italy – whose planned conversion to gas was eventually abandoned. The article explains the descriptive and analytical role of the reticular approach to the fossil machine. It then uses it descriptively to present, frame, and discuss the practices of destabilisation and disruption and the agents of transition that carried out these practices to deactivate Civitavecchia's fossil machine. It concludes by reflecting on the potential of the reticular approach.

1. Introduction

Current efforts to defuse the climate crisis are inadequate and/or ineffective [1]. To limit global warming to a relatively safe level, it is vital that no further investments are made in new fossil fuel projects [2]. And yet, global carbon emissions, largely boosted by those associated with fossil fuel companies' processes and, especially, products, hit a record high in 2023 [3,4].

Technical feasibility and economic efficiency are necessary but not sufficient conditions for the phasing-out of fossil fuels. This article, along with a growing literature in transition studies that focuses on the resistance of industry incumbents and their associated powers [e.g., 5–13], assumes that it is mostly the 'fossil machine' – i.e. the powerful and widespread network that revolves around fossil fuels, or to borrow the U.N. Secretary General's definition, the "fossil fuel industry and its enablers"¹ – that obstructs decarbonisation processes and supports fossil continuity, to protect its own vested interests.

Given this assumption, we propose to address the fossil-supportive and change-obstructive behaviour and actions of the fossil machine through a new broad and inclusive 'reticular approach'. We employ this

approach descriptively to present, frame (spatially and temporally), discuss, and reflect on the practices of 'destabilisation' and 'disruption' adopted by multiple 'agents of transition' in their efforts to deactivate a fossil machine. We take as a case study a group of coal-fired power plants located in Civitavecchia – the former fossil energy city near Rome, Italy – owned by Enel which had, since 2019, supported the conversion of the plants to gas. The conversion plan was eventually cancelled in 2022.²

The article first outlines the descriptive and analytical aspects of the reticular approach to the fossil machine, and then examines the practices of destabilisation and disruption used by agents of transition in the case study of Civitavecchia. The article then proceeds by applying this approach descriptively to present, to spatially and temporally frame, and to discuss these practices. It concludes by assessing the evidence that emerges from the case study in order to consider the potential of the reticular approach.

2. The reticular approach to the fossil machine

The reticular approach extends and adapts the theoretical perspectives of complexity theory [15] and systems theory [16] in political

^{*} Corresponding author.

E-mail addresses: marco.grasso@unimib.it (M. Grasso), daniel.delatinrodrigues@unimib.it (D. Delatin Rodrigues).

¹ Guterres in a speech given on 15 June 2023 referred to the "fossil fuel industry and its enablers" and claimed that they have a "special responsibility" and should "drive, not obstruct, the global move from fossil fuels to renewables" [14].

² Enel is an Italian multinational producer and distributor of electricity and gas which has, over the time, come to own and run all the fossil plants in Civitavecchia. The definitive abandonment of the plan to convert the coal plants to gas was officially announced on 7 October 2022.

science to fossil fuels phase-out. A complex system consists of a set of interdependent parts; it is delimited and distinguished from its 'environment', but it is permeable to external inputs which produce modification in the system's structure, organisation, and behaviour, and to external outputs that the environment exerts on the system [17]. In this article, the complex system which is the focus of the reticular approach includes the components of the fossil machine and agents of transition. Within this relational space, the latter, with the aim of deactivating the fossil machine, apply destabilisation and disruption practices that the former resist and obstruct to ensure fossil continuity. The fossil machine's boundaries are porous since it has a 'centripetal force' that continuously attracts and captures new components; at the same time, however, there is a chance that such components are able to withstand this force and even become agents of transition. The fossil machine and the agents of transition are embedded through multidirectional interactions in a local, national, and international environment of political, social, institutional, economic, cultural, and psychological climate change- and energy-related material and non-material elements.

The reticular approach can be employed descriptively and analytically. In descriptive terms it identifies, displays, and articulates, over a specified time period, both the active and willing components of the fossil machine and the agents of transition and the practices of destabilisation and disruption they employ. This descriptive configuration is a prerequisite for using the reticular approach analytically to identify and scrutinise the intertwined actions and interactions of those active and willing components that support fossil continuity, as well as to analyse how agents of transition attempt to erode their obstruction to the phasing-out of fossil fuels.

2.1. Descriptive use

The use of the new concept of 'fossil machine' – rather than, for example, that of 'fossil fuel bloc' [18] and 'fossil fuel historical bloc' [19] – as the object of the reticular approach to transition stems from the insight of 'actor-network theory' [20] developed in the science and technology studies literature. This perspective argues that socio-economic systems, organisations, and technological assemblages are the products of heterogeneous networks – defined as 'machines' – formed by various material and human components. As Law [20] states: "a machine is a heterogeneous network – a set of roles played by technical materials but also by such human components as operators, users and repair-persons" (p. 384). The machine concept reveals the components that define a heterogeneous network, while analytically it makes it possible to investigate how such networks generate socio-economic, institutional, and organisational effects, as well as how such effects can be reduced/eliminated. In this perspective, the heterogeneous network generated by the processes of extraction, distribution, and consumption of fossil fuels, and by the various connections of their material and human components, can be seen as a 'fossil machine'. We thus understand a fossil machine as a heterogeneous reticular structure that creates and fosters a favourable environment for fossil fuels and which enables obstruction of the urgently needed decarbonisation of socio-economic systems.

In this perspective, a fossil machine is usually set up, coordinated, and led by one or more fossil-fuel companies. It is in constant nonlinear metamorphosis [21] over a finite lifecycle and its components often shift from the foreground to the background to become almost invisible, as if 'deactivated', and vice versa. For instance, in the financial ambit, investors typically play a prominent role at the beginning of a fossil machine's lifecycle and progressively move to the background during its operation; carbon markets follow the opposite path. A fossil machine therefore has specific, yet ever-changing, boundaries and unique capacities, and it establishes, consolidates, and maintains its functional structure and continuity over time through the systemic interdependence of its components [22,23].

Drawing from the science and technology studies/social sciences

concepts of network [20,24,25], web [26], assemblage [27,28], infra-structural ecologies [29], regime complex [30], and oil complex [31], the fossil machine stretches over a specific arc of time and an explicit and dynamic relational space, otherwise unobservable, which extends far beyond the places where fossil fuels are actually extracted and processed. The concept of the fossil machine offers a lens through which to view the large-scale functional articulation of fossil fuel-related processes and of the environments [32] generated and continuously re-modulated to perpetuate fossil longevity.

The fossil machine operates in a permanently unstable equilibrium: during its lifecycle its components can move from one functional group to another (e.g. NGOs and foundations can migrate from 'culture and community' to 'governance systems' groups, if/when they engage with lobbying and advocacy); new components might enter a fossil machine, while existing components might withdraw, and even become agents of transition trying to deactivate it. This is what happened in Civitavecchia to unions and to the trade association CNA (*Confederazione Nazionale dell'Artigianato*), trapped in the health/job conundrum associated with fossil energy, as described in the case study discussed below.

A fossil machine can have *expansive* or *defensive* purposes; these purposes have different relevance and scope within the specific machine and depending on the stages of its lifecycle. A fossil machine with a predominantly expansive purpose is by and large primed to promote fossil fuels; it is usually built around a fossil infrastructure, e.g., extractive and production sites, refineries, regasification plants, fossil fuel plants, pipelines, terminals, carbon offsetting sites. A machine that is mostly defensive has the aim of protecting fossil continuity against rival low-carbon infrastructures, technologies, and materials, e.g. wind and solar farms, agrivoltaics, electric vehicles, critical minerals; to this end, the fossil machine will push 'false solutions', e.g. carbon capture technology, tree planting, net zero strategies. Defensive fossil machines usually connect with, and are largely based on, new forms of climate denial and obstruction such as discourses of delay, greenwashing, misinformation, solutionism, and technological optimism [33,34]. During their lifecycle – typically towards the end – most expansive fossil machines become defensive to preserve an environment favourable to their operational integrity.

Notwithstanding the obvious context-specificity of fossil machines, Fig. 1 provides an illustrative example of the functional groups and components of a prototype fossil machine. Their scales, weights, and mutual relations are impossible to specify abstractly, as it is not feasible to display the overall reticularity. Nevertheless, the figure shows the fossil fuel companies at the core and illustrates how the components of the fossil machine are grouped according to their role in seven archetypal functional groups: 'governance systems', 'law', 'media and communication', 'finance', 'industry', 'culture and community', and 'science and research'.

The complex system revealed by the reticular approach includes agents of transition (individuals or collective entities) that, in a context of persistently inadequate political actions to limit fossil fuels [35], challenge the fossil machine's systemic obstruction of decarbonisation efforts. Agents of transitions are 'political entrepreneurs' [36] that, based on their second-order duties – that is, the duties to ensure that first-order agents comply with their (first-order) duties – to contribute to the elimination of fossil fuels [12,p. 92–98], seek to deactivate the fossil machine's defence of fossil continuity and its obstruction of decarbonisation, through practices of destabilisation and disruption.

In sum, the descriptive application of the reticular approach to a specific fossil machine – such as the case of Civitavecchia, considered in this article – allows us to reveal and to frame, spatially and temporally, the role of agents of transition and the practices of destabilisation and disruption they carry out, and to marshal the most significant and relevant evidence.

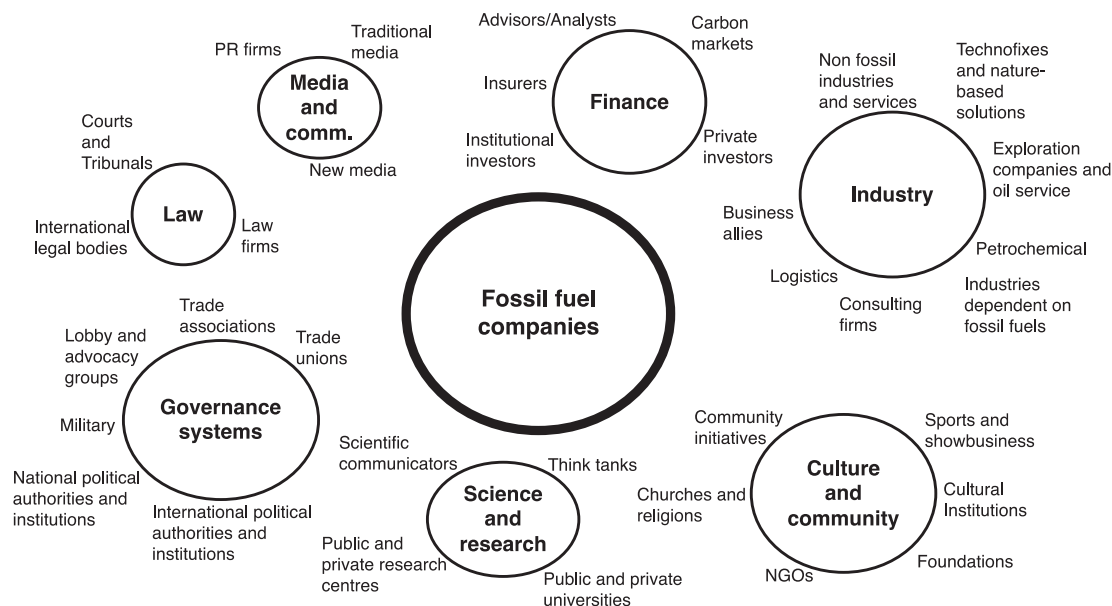


Fig. 1. Functional groups (represented by circles) and components of a prototype fossil machine. Source: Authors.

2.2. Analytical use

The dynamic relational space at the heart of the reticular approach offers an operational terrain in which to apply qualitative and quantitative methodologies to investigate analytically the deactivation of the fossil machine. The analysis of the deactivation of the fossil machine focuses mainly on three issues:

1. how the visible and active components of the fossil machine interact to support fossil continuity and obstruct the abandonment of fossil fuels;
2. how agents of transition and their interactions can neutralise components' pro-fossil behaviours and actions through practices of destabilisation and disruption;
3. the study of the positive or negative correlations between such practices and their temporally and spatially distributed deactivation potential.

Additionally, the reticular approach allows for theoretical systematisation to clarify the patterns of deactivation of the fossil machine and extend them, albeit in a 'modest' way [37]; modest here means that this extension might refer only to some functional groups or categories and/or to a certain degree, to broader sets of fossil machines – e.g., all those that refer to a fossil company, or a fossil infrastructure, or a fossil fuel – or to a specific geographic region.

To analyse the three deactivation issues mentioned above, the reticular approach adopts and 'adapts' methodologies related to 'systemic explanations' of socio-political phenomena [38], for instance 'social network analysis' [39,40] and 'detective work' [41,p. 467] to shed light on the connections and relationships between the elements of a relational structure such as that formed by the fossil machine components, agents of transition, and their actions and reactions. It also uses 'mechanism- and process-based' methodologies of explanation [38] such as 'process tracing' [42], a causal inference methodology that reconstructs causal mechanisms and processes. The extension of the outcomes of the deactivation analysis can be carried out through a 'grounded theory' methodology [43] to identify and conceptualise latent social patterns and structures through a process of constant comparison between destabilisation and disruption practices, to create subcategories and general theoretical properties of the deactivation of

fossil machines.

By looking at the fossil machine through the lens of the reticular approach, differences in the scope, temporality, and logic of destabilisation and disruption carried out by agents of transition become evident. This is in contrast to most of the existing literature which tends to use these two terms – and others such as 'exnovation' [44,45] – interchangeably or to treat them as indistinguishable, usually without providing clear definitions [e.g. 46–53].

Destabilisation practices target and engage the fossil machine's visible and active components over a specific period in order to spread, foster, and reinforce social norms, values, principles, perceptions, imaginaries, actions, and provisions that denaturalise the use of fossil fuels [54]. The main goal of destabilisation is to deconstruct the norm-basis of the 'hegemonic ideas' of fossil continuity and endless growth that cement – to borrow a Gramscian term – the dominant 'historical bloc' [19,55,56], which in this context is the bloc that coalesces around the necessity and inevitability of fossil fuel use. Destabilisation aims to increase awareness of the imperative to move to a safer, low-carbon world and to undermine the social licence to operate of the current fossil-centric model. It does this by, for example, advancing acknowledgment of the harmfulness of fossil fuels, emphasizing the reckless behaviour of fossil fuel companies, highlighting their causal and moral responsibility for the climate crisis, and more generally by claiming the centrality of justice issues [57], discouraging high-carbon lifestyles, delegitimising financial institutions that invest in fossil fuels, etc.

Disruption, on the other hand, preferably carried out on a terrain already fertilised by destabilisation, targets the visible and active components of the fossil machine through practices to transform [58] the fossil model and its overall functioning, fruition, and longevity. These practices include, for instance, policy and administrative provisions, lawsuits, divestment initiatives, shareholder resolutions, etc. [12].

Destabilisation and disruption may also be non-oppositional or proactive and comprise the proposal and introduction of alternatives to fossil-centric socio-economic systems, as happened with the renewable energy projects in Civitavecchia. Additionally, while destabilisation and disruption are context-specific, destabilisation generally applies to components of a fossil machine that can be more readily detached from the operational sites of fossil fuels and relate to its discursive and institutional power, while disruption is by and large associated with the instrumental and material power of expansive fossil machines [59].

The reticular approach's clear-cut distinction between destabilisation and disruption helps us to analytically clarify the role of agents of transition. Here we refer to agents of transition that carry out (mostly) destabilisation practices as 'primary'. This family of agents is basically involved in spreading anti-fossil fuel norms to denaturalise the continued use of such fuels. Investigating the role of these primary agents is essential when it comes to exploring the other agents involved in the deactivation of fossil machines, termed here 'operational'; these are the agents who mainly carry out disruption activities through regulations, markets, legal actions, and/or financial means to reduce the operational space of the fossil machine. As noted above, disruption practices are more feasible when the socio-cultural context is 'ripe', that is, when destabilisation has increased public recognition of the urgent need to end the dangerous relationship with fossil fuels. To achieve its full deactivation potential, disruption must therefore be rooted in destabilisation: in other words, the effectiveness of primary agents of transition has a knock-on effect on operational agents. It is important to note, however, that agents can be simultaneously both primary and operational, and can switch repeatedly from one grouping to the other.

The three categories – purposive, descriptive, and analytical – of the reticular approach to the fossil machine are summarised in the Table 1.

3. The Civitavecchia fossil machine through the reticular approach

3.1. Methodology of empirical investigation

This article carried out the empirical investigation from February 2022 to March 2023. We first conducted semi-structured and structured interviews with primary and operational agents of transition, who were identified and contacted as a result of information provided by an activist from Civitavecchia. Between April and June 2022, eight non-structured interviews were carried out with agents of transition, as reported in Table 2, to discover which functional group(s) they were

Table 1
The categories of the reticular approach to the fossil machine.

Purposive category	Expansive	Fossil machine primed to expand reliance on fossil fuels and built around a fossil fuel infrastructure	
	Defensive	Fossil machine aimed at protecting fossil continuity against rival low-carbon infrastructures/ technologies/materials and obstructing such infrastructures/technologies/materials	
Descriptive category	Components	Active and willing parts of the fossil machine in a specific time period	
	Functional groups	Groupings of the fossil machine's components based on their main function in a specific time period	
	Agents of transition	Entities that seek to deactivate the fossil machine	Entities that seek to deactivate the fossil machine
Analytical category	Primary	Use mostly destabilisation practices to 'prepare the ground' to deactivate the fossil machine	Use mostly disruption practices to deactivate the fossil machine
		Practices carried out by agents of transition to stigmatise, delegitimise, weaken, erode, and/or halt the visible and active support of the fossil machine's components to fossil continuity and obstruction of decarbonisation in a specific time period	Practices that limit/ stop the reproduction of the fossil model and its functioning, fruition, and longevity
	Operational	Practices aimed at promoting social/moral norms and provisions that denaturalise use of fossil fuels	Practices that limit/ stop the reproduction of the fossil model and its functioning, fruition, and longevity
	Extension	Systematisation and modest generalization of the outcomes of a deactivation analysis	

Source: authors.

Table 2
Agents of transition interviewed, functional groups targeted, and practices of destabilisation and disruption adopted.

Agents of transition (in alphabetical order)	Functional group*	Practices of destabilisation/ disruption
1. <i>Città Futura</i> (environmental group)	Culture and community, Media and communication	Meetings; research; cultural events; educational events; information through social media and various other channels
2. <i>Comitato Sole</i> (environmental group)	Culture and community, Media and communication	Meetings; research; cultural events; educational events; information through social media and various other channels Support to organising the diffusion and introduction of non-fossil alternatives
3. <i>Confederazione Nazionale dell'Artigianato</i> (CNA) (the Civitavecchia section of the National Confederation of Crafts and Small and Medium-sized Enterprises)	Industry, Governance systems	Lobbying; participation in institutional and political processes
4. <i>Forum Ambientalista</i> (environmental group)	Culture and community, Media and communication	Meetings; cultural events; educational events; information through social media and various other channels; demonstrations; citizen science
5. Fridays for Future (social movement)	Culture and community, Media and communication	Meetings; cultural events; educational events; information through social media and various other channels; demonstrations
6. <i>No al Fossile</i> (social movement)	Culture and community, Media and communication	Meetings; cultural events; educational events; information through social media and various other channels; demonstrations; protests
7. <i>Unione Sindacale di Base</i> (labour union)	Industry, Governance systems	Participation in institutional and political processes; strikes; 'state of agitation'; blockades
8. Technical committees (professionals, firms, and agencies to support the 'Porto Bene Comune' and offshore wind farm projects)**	Fossil fuel plants	Non-oppositional/proactive destabilisation and disruption Scientific dissemination of the advantages of the renewable alternative compared to Enel's conversion plan Technical support to developing and introducing non-fossil alternatives

Source: authors.

* Agents of transition 1–7 targeted Enel and the fossil fuel plants, as well as targeting certain functional groups.

** These agents of transition did not target the Civitavecchia fossil machine's functional groups, but rather worked proactively for the introduction of renewable projects as an alternative to Enel's fossil fuel plants.

predominantly targeting through their destabilisation and disruption practices, and to learn about such practices. Via digital media [60], we also collected information related to Civitavecchia's fossil machine, the agents of transition involved, and other stakeholders, to complement the information obtained through the interviews.

In November 2022, two additional structured interviews were conducted with the two agents of transition with the most comprehensive knowledge of the issues at stake and of the role of all the other agents involved.³ The objective was to get a more general perspective on destabilisation and disruption, also in light of the October 2022 cancellation of the proposed conversion of the power plants to gas.

To complement these interviews, we used digital ethnography [61] in the period up to May 2023 to follow the interviewed agents of transition and their networks in online spaces (social networks, news portals, etc.). The digital infrastructure allowed access to different sources of information – articles published in magazines, online newspapers, discussion forums, corporate advertising, archives, blogs, posts, etc. – in different formats and languages. We also widened the perspective with insights from various other stakeholders in the local environment, gathered by accessing publicly available documents in digital form from public institutions and in the archives of Enel. Enel itself, however, did not agree to give interviews for this research.

The purpose of the interviews and the digital information gathered was to obtain data enabling us to describe, to frame spatially and temporally, and to scrutinise and discuss: i) the components of the Civitavecchia fossil machine; ii) the agents of transition involved; and iii) the destabilisation and disruption practices they employed to target the components of the fossil machine. To address these issues more thoroughly we also considered the connections that link the Civitavecchia fossil machine to the national and international environment such as, for example, the Italian energy policy and the international coal market. This meant tracing information in external circuits and re-situating it within the local dynamics.

The descriptive analysis conducted required the (re)combination of various data sources and types of information to reach a clear picture of the practices used by the agents of transition to reduce the spaces occupied by the fossil machine, and the modalities they used to shape new socio-material and cultural arrangements as alternatives to those dominated by the use of fossil fuels.

3.2. The Civitavecchia fossil machine

Civitavecchia is a municipality and major port on the Tyrrhenian Sea 60 km from Rome, Italy. Its fossil machine was built around a number of fossil fuel-fired power stations in the Torrevaldaliga Nord and Torrevaldaliga Sud areas of the city; this research focuses on the final years of these plants (2019–2022), when the fossil machine created for their installation and management exercised a predominantly expansive purpose to ensure their fossil-to-fossil conversion from coal to gas.⁴ This temporal choice, as detailed below, drove the research to focus mostly on the components of the fossil machine belonging to its 'governance' functional group, such as trade unions and associations, and policy makers, as well as the 'culture and the community' group.

In May 2019, Enel submitted its conversion plan for the Civitavecchia plants to the then Ministry of the Environment. It was driven by the requirement to abandon coal for energy production introduced by the National Integrated Energy and Climate Plan (*Piano Nazionale Integrato per l'Energia e il Clima – PNIEC*), which was eventually adopted in

January 2020.

Beyond the plants themselves, the boundaries of the Civitavecchia fossil machine are difficult to determine given its 'camouflage capacity' and its continuous transformations, as it sought to maintain its functional continuity through the constant inclusion and expulsion of different components over the period observed. Enel and the power plants were the main foci of destabilisation and disruption practices; other important components were the political groups and trade unions that aligned and realigned their positions for or against fossil continuity. Their shifting roles – as already mentioned, they repeatedly switched their status from components of the fossil machine to agents of transition and vice versa – depended mostly on their ever-changing sensitivity to the health/job conundrum, explained in more detail below. Fig. 2 shows the fossil machine of the Civitavecchia plants in the study period: the sizes of the circles of the functional groups are approximately proportional to their relevance.

It can be observed that some of the functional groups and components of the reticular approach represented in Fig. 1 do not feature in Fig. 2, including the financial constellation that supported it, insurance companies that our empirical investigation could not identify, actors along the plants' global fossil supply chain, maintenance and consulting companies, and the international coal supply market.⁵ They are not included because they did not play a major role in the Civitavecchia fossil machine at the time of the research. For instance, although the importance of the 'finance' functional group in fossil blocs is increasingly acknowledged [62], our analysis shows that during the period of investigation of the Civitavecchia fossil machine, this group featured only in the background. To be clear, the components of this functional group – by and large banks and other financial institutions – were present, but they were almost invisible, effectively 'inactive', and therefore not relevant to our analysis.⁶ No practices of destabilisation or disruption targeted them and none of the agents of transition interviewed referred to the machine's financial components. This is not surprising, given that 'finance' functional groups tend to be most prominent and active when fossil machines are under construction or new, especially when they are serving an expansive purpose and revolving around a fossil infrastructure. For example, in the fossil machine of the East Africa Crude Oil Pipeline (EACOP) – a pipeline under construction, supported by the international oil company TotalEnergies (France) and by the state owned-enterprises Uganda National Oil Company, Tanzania Petroleum Development Corporation, and China National Offshore Oil Corporation, to transport crude oil from the oilfields on the Ugandan side of Lake Albert to the marine storage terminal at Port Tanga, Tanzania – the

⁵ For instance, the coal used in the Torrevaldaliga Nord plant over time came from different coal fields around the world (Poland, South Africa, the United States, Venezuela, Colombia, Indonesia, China, and Australia). See: <https://va.mite.gov.it/File/Documento/274296>.

⁶ To give a glimpse of the complexity of the financial affairs of Enel, it is useful to note that in 2009, the company's 2010–2016 investment prospectus lists shareholders holding more than 2 % of shares as the Ministry of Economy and Finance with a direct control of 13.88 %, Cassa Depositi e Prestiti with 17.3 % and Blackrock Inc. indirectly through Blackrock Investment Management (UK) Limited with 3.02 %. In 2009 Enel entered into a €8 billion financial agreement with the following institutions: Banco Bilbao Vizcaya Argentaria, S. A., Banco Santander Central Hispano S.A., BNP Paribas S.A., Caixa d'Estalvis i Pensions de Barcelona "la Caixa", Caja de Ahorros y Monte de Piedad de Madrid, Calyon S.A. Milan Branch, Intesa SanPaolo S.p.A, Mediobanca, Natixis S.A. Milan Branch, The Bank of Tokyo Mitsubishi UFJ Ltd. Milan Branch, The Royal Bank of Scotland Plc, Unicredit Market Investment Banking through Bayerische Hypo Und Vereinsbank Ag, UniCredit Bank AG, Milan Branch (*Prospetto Enel relativo all'offerta pubblica di sottoscrizione e alla contestuale ammissione a quotazione sul mercato telematico delle obbligazioni delle obbligazioni del prestito denominato "Enel tf 2010–2016" e delle obbligazioni del prestito denominato "Enel tv 2010–2016"*): <https://www.deutsche-bank.it/files/documenti/sezione-prospetti/offerte-pubbliche-di-scambio/ProspettoEnel.pdf>.

³ To avoid possible conflicts, we cannot disclose the identity of the two agents of transition interviewed in this second round since they were asked to consider and evaluate destabilisation and disruption practices of all other agents of transition.

⁴ In 2003 Enel carried out a first fossil to fossil – from oil to coal – conversion of the same power plants.

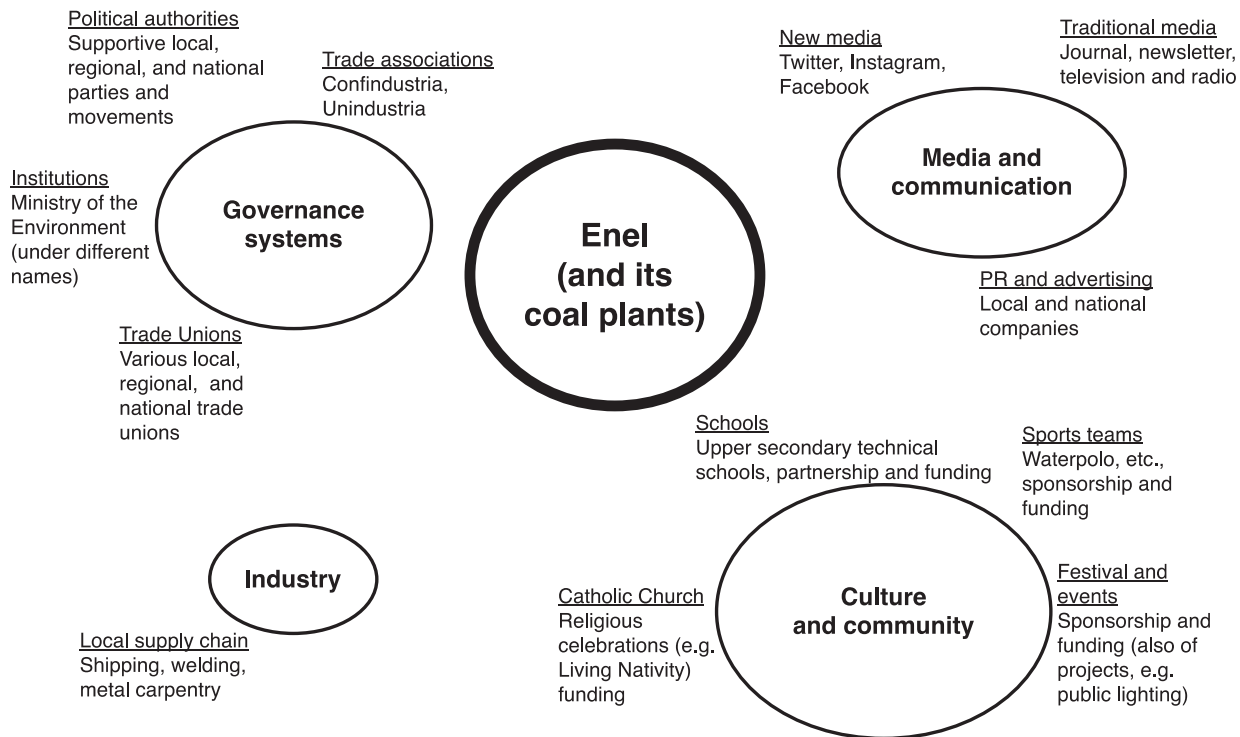


Fig. 2. The Civitavecchia fossil machine, 2019–2022.
Source: Authors.

‘finance’ group is currently the most important and visible of all the groups, with four active major financial advisors, three institutional investors, 39 commercial banks and financial institutions, and 29 insurance companies involved. Furthermore, this group is a clear target for destabilisation and disruption practices, as the core of the EACOP fossil machine – TotalEnergies and the other fossil fuel companies – are still seeking funding and backing for the project.

On the other hand, Civitavecchia is a well-established fossil machine; the ‘finance’ group was not prominent at the time of our research, whereas the ‘Culture and community’ functional group, typically not significant in fossil machines that are recent and or/under construction, was visible and active. The information gathered on this group is diffuse and shows the capillary presence of its components in the different manifestations of the city’s collective life; it also shows that agents of transition engaged with this group on a regular basis.

4. Descriptive application of the reticular approach to the Civitavecchia fossil machine

The prominent role assumed by Enel in Civitavecchia emerged in the reconstruction of the city after it was reduced to rubble during the Second World War. The company’s narrative of progress revolved around the fossil fuel plants, portrayed as the main drivers of innovation and modernisation in the area. By generating direct and indirect jobs, providing vocational training for residents, and promoting activities of interest in the social and cultural life of the town, Enel could present itself as a pillar of local development and the enabler of a better future for the community. However, rising levels of damage to the environment and harm to human health – cardiorespiratory diseases, cancer, and allergies [63] – increasingly led to intense confrontations and protests in the community.⁷ The collective interpretation of the harm was

⁷ According to agents of transition, there is no family in Civitavecchia that has not suffered health issues directly associated with the carbon emissions from the power plants.

continuously re-modulated, from strictly local harm to broader notions involving the impact on the climate and ecological systems. The practices of destabilisation and disruption carried out followed the trajectory of the Civitavecchia fossil machine’s lifecycle, adapting and changing over time, articulating the problems of energy production within the ever-changing socio-political contexts through new interpretative frames, such as those offered by the IPCC reports, international agreements, protests in other areas, national and international political issues, etc.

During the period observed, destabilisation and disruption practices targeted the fossil machine’s visible and active functional groups, as was to be expected. Some examples of the practices carried out by agents of transition in that period are reported in Table 3. In the remainder of this section we first reconstruct the environment that favoured the emergence of such practices, then offer examples of activities that were most significant for the deactivation of Civitavecchia’s fossil machine in 2019–2022, identifying the agents of transition involved and their role.

4.1. The road to deactivation

According to an agent of transition of the *Città Futura* group, protests and mobilisations against the activities of the thermoelectric plants began to gain in intensity in the 1980s, with protesters demanding the right to health and environmental protection and the creation of jobs not linked to fossil fuels. Besides directly confronting Enel, protests and mobilisations also targeted political groups and parties, trade unions, and industrial and commercial associations that supported fossil fuel energy production in the area. The context for these practices was the opposition between advocates for the environment and advocates for jobs. In the words of an agent of transition of the *No al fossile* group, in 2003 the authorisation to the mentioned conversion from oil to coal generated great tension in Civitavecchia, causing a split between parties, unions, associations, and even families:

Many people took part in protests and mobilisations; the Civitavecchia town council was occupied for several days. We also

Table 3

Functional groups and examples of practices of destabilisation and disruption targeting Civitavecchia's fossil machine (2019–2022).

Functional groups	Practice
Enel (and its fossil fuel plants)	Strikes and blockades at the plants and in several other locations
Media and communication	Promotion of counter-narratives through local TV and social media
Governance systems	Regulations against fossil fuels at various levels Awareness and campaigns by trade unions and trade associations towards environmental concerns
Industry	Strikes and blockades along the supply chain
Culture and community	Communitarian meetings, assemblies, and demonstrations Civic science programme in epidemiology Expert citizen disclosures

Source: authors.

occupied the Rome-Genoa-Ventimiglia railway line, interrupting the service. There were conflicts, but we couldn't merge the fight for health to the that for good jobs. The historical context was different and the immature technologies we had meant that the adoption of any alternatives was unlikely in the short term. [64, authors' translation].

This juxtaposition between environment/health and economy/employment was weaponised by Enel and by various components of the local fossil machine to justify their pro-fossil choices and try to secure the support of citizens, trade unions, and political groups. According to an agent of transition from the *Forum Ambientalista* group (and former member of the communist party, *Rifondazione Comunista*): “Enel has polluted not only the environment, but also people's consciences”. According to several interviewees, one of the reasons for the limited success in slowing down or blocking fossil energy production was that the local community remained trapped in this narrative of juxtaposition to which no credible alternatives existed. Many stakeholders were unable to see beyond the environment/job dichotomy, which limited the relationships that could be established with other stakeholders in the area.

An agent of transition from Fridays for Future claimed that, starting from the 2000s, the main issue was “to give young people in Civitavecchia the chance to imagine a different future. Instead of leaving the city and looking for jobs in Rome, we're fighting to be able to stay. But to stay in a place that offers not only jobs, but also quality of life”. In fact, various agents of transition engaged the community, starting from the more vulnerable workers, through the narrative of a different, better choice of occupation.

When Enel presented its second fossil-to-fossil conversion plan in 2019, a *No al fossile* agent of transition remarked that “switching from coal to gas would not guarantee jobs for those living in polluted areas, nor would it further environmental protection or public health”. It was in this situation of entrenched conflict that the construction of an alternative – the renewable energy projects outlined below – became a solid basis for the elaboration of socio-technical imaginaries beyond fossil fuels. These projects acted as a powerful magnet for activists, professionals, workers, trade unions, and employers' associations: around them the human, communitarian, technical, and economic resources necessary for the design and effective political and social articulation required for the projects coalesced. They became the terrain on which non-oppositional/pro-active practices of destabilisation – “to neutralise Enel's narrative” – and disruption – “to leave fossil fuels behind” – developed, as an agent of transition put it.

The first alternative project, *Porto Bene Comune*, envisioned the

conversion to renewables of the port of Civitavecchia and was presented by the local committee *SOLE*⁸ to the Italian Ministry of Economic Development (*Ministero dello Sviluppo Economico – MISE*) as part of the EU-ERC Horizon 2020 call. According to the agents of transition interviewed, the port project represented a critical turning point and became a platform for the development of socio-technical alternatives that brought together various actors which had previously belonged to the fossil machine, in a significant process of social and environmental transformation. Through the port project it was possible to move from protests (destabilisation) to proposals (disruption), and stakeholders could discuss and elaborate technical issues and diverse socio-technical imaginaries [65].

The second alternative project was an offshore wind farm. With a total capacity of 270 MW and an annual production potential of approximately 935 GWh, its implementation would provide between 300 and 1000 jobs in Civitavecchia. This project was submitted in March 2022 to the (then) Ministry of Ecological Transition for the environmental impact assessment procedure (*valutazione di impatto ambientale – VIA*) which was finalized, with positive results, in April 2024. This is an inclusive and comprehensive project that pays special attention to job creation.

In the interviews, several agents of transition emphasised that the existence of a context favourable to the energy transition, both internationally and nationally (e.g., the EU Green Deal and the 2020 Italian PNIEC⁹), increased the credibility and viability of alternatives to fossil fuels. It should be noted that the national context was perceived as favourable despite the emerging nationalist and sovereigntist approach [66] to energy and climate issues. This approach, permeated by elements of fossil fascism [67] and rooted in the Italian historical legacy of climate denialism and obstruction [68,69], was openly promoted by the right-wing coalition that won the 25 September 2022 snap election. For instance, the use of regulatory procedures at different levels – two recent (May and June 2024) decrees that make it extremely difficult to install photovoltaic panels due to increased costs and legal uncertainties – as a strategy to obstruct the expansion of renewables is consistent with the traditional Italian far-right approach to environmental issues [70].

In our analysis, we took into account these interactive articulations between local and external dimensions related to political and institutional constraints, with the aim of observing how they became an additional lever through which agents of transition could act.

4.2. Destabilisation, disruption, and agents of transition

The crucial moment for the deployment of the practices of destabilisation and disruption against Civitavecchia's fossil machine, and the development of alternatives, occurred at the delicate juncture of the Covid-19 health emergency when public meetings and gatherings were banned.

The local media, and especially the local radio and television network TRC, widely recognised as a credible vehicle for information of community relevance, provided ample space to the different agents of transition to put forward ideas and projects, and to discuss an exit from fossil fuels and the proposition of a new local and regional development model. In addition to TRC and other traditional local media, agents of transition also made strategic use of the social networks Facebook and Instagram, through which they could promote counter-narratives, share documents, images, activities, and relevant information about ongoing processes as well as establish interactive channels with broad sectors of

⁸ https://asvis.it/public/asvis2/files/Porto_Bene_Comune_un_capolavoro_tutto_italiano.pdf.

⁹ When, in January 2020, the Italian ‘National Integrated Energy and Climate Plan’ (*Piano Nazionale Integrato per l'Energia e il Clima – PNIEC*) set 2025 as the year of exit from coal, demands for the complete cessation of fossil energy production became more explicit.

the local community.¹⁰

Even before reaching this stage, the agents of transition interviewed reported that the first step in challenging the Civitavecchia fossil machine was to raise awareness about the wrong choices that it “made and was still making in relation to the development model and social life of Civitavecchia”. The local media allowed agents of transition to present new stories and narratives that framed the local historical trajectory in the broader context of post-war development policies and emphasised the obvious need – due to the climate, ecological, and energy crises – to shift that trajectory in favour of new socio-technical and communitarian arrangements.

Their involvement in developing alternative projects required agents of transition to learn about complex technical issues and problems and to closely familiarise themselves with Enel's energy transition plan. To this end a working group was set up, including associations, citizens, experts, and scientists. It found that the conversion to gas would reduce jobs by up to 90 %. As described in the newspaper *Il Manifesto*:

The mobilisation started from the initiative of a small group of workers, with the help of some experts, then widened to include various other stakeholders, first across the city and then across the country. First came *Fiom, Uilm* [both national unions that used to be components of the Civitavecchia fossil machine] and some grassroots unions present in the plants, which successfully called two strikes to demand the realisation of the project. This was followed by the involvement of various committees and associations, both inside and outside the city, including the *Laudato si'* association, an alliance for climate, the planet, and social justice inspired by Pope Francis's 2015 encyclical *Laudato Si'*, then parishes, the diocese, the city administration, local businesses, and the office of the regional environmental councillor. All these stakeholders organised or took part in various conferences and events in the city in support of the project [the offshore wind farm]. A project that has already found planners and investors ready to operationalise it. [71, authors' translation].

In March 2021, the Lazio Region created the Department for Ecological and Digital Transition (*Assessorato alla Transizione Ecologica e alla Trasformazione Digitale*, ATETD), which according to all the agents of transition interviewed, played a fundamental role in deactivating Civitavecchia's fossil machine, especially the head of the organisation, the Five Stars politician Roberta Lombardi. According to a CNA agent of transition: “If it hadn't been for the political momentum given by ATETD and two regional councillors, our success would have been very unlikely”. In October 2021, ATETD organised a conference on new technologies for the energy transition in Civitavecchia, thus creating a space where agents of transition, besides declaring that in Civitavecchia “no-body wanted a future linked to fossil fuels”,¹¹ could publicly present the feasibility of simultaneously phasing out fossil fuels and creating new jobs. Afterwards, ATETD accelerated its work on wind energy projects and started a working relationship with the (then) Ministry for the Ecological Transition.

The perspective of the reticular approach offers the insight that the rejection of fossil continuity in Civitavecchia must be seen as a process in which new alliances are woven and new collective subjects can surface. The emergence of alternative projects was the result of a collective trajectory in which the practices of destabilisation that had been undertaken over the past 40 years eventually created conditions that were favourable to disruption.

The compound forms of destabilisation and disruption that took place in Civitavecchia can be described by examining the functional

¹⁰ TRC broadcast debates between the different agents of transition that could also reach an audience that did not use social media networks or online platforms.

¹¹ See: https://www.facebook.com/watch/live/?ref=watch_permalink&v=2175019059344879.

groups of the local fossil machine, as well as its core (Enel and its plants) that were targeted by agents of transition. For example, both destabilisation and disruption practices targeted the ‘governance’ functional group at different levels. Destabilisation included numerous parliamentary discussions and investigations at local and regional level; trade unions and industrial and commercial associations hosted discussions and debates about the critical aspects of fossil continuity and the potential of new production models that were patently at odds with the positions of regional and national representatives who defended the continuation of fossil energy production. Practices of destabilisation also involved numerous agents of transition in the definition of a shared perspective on the future of the city and of new, inclusive models of governance, with the active participation of citizens, workers, and entrepreneurs.

Practices of disruption occurred through various political decisions taken at municipal and regional level against the conversion of Enel's coal plants to gas, including Civitavecchia City Council resolution 130 of 24 October 2019, and the 2021 regional provision banning fossil production in the city. Workers of the power plants carried out disruption through ‘states of agitation’ (*stati di agitazione*)¹² and strikes against specific components of the fossil machine, targeting the power plants and their supply chains (for example, transport companies). Political parties along the entire spectrum which were initially “part of the fossil machine”,¹³ as emphasised by an agent of transition of *Città Futura*, became fully fledged agents of transition that concurred with destabilising the local fossil machine through the creation of permanent negotiation spaces that ensured political representation at the institutional level.¹⁴

It should be noted that at the time of writing, unions, spurred on by the imminent closure of the coal-fired power station in 2025 imposed by the 2020 *PNIEC*, have returned to a state of agitation and strikes due to the unwillingness (people in Civitavecchia say “the immobility”) of the business community and the political authorities to implement an industrial plan based on the alternative projects described above.

With regard to the functional group ‘culture and community’, agents of transition used different practices, by and large falling into the category of ‘contentious repertoires’ [72], and including demonstrations in the city streets, occupation of public buildings, obstruction of railways and highways, and hunger strikes. Attacks and direct confrontations with public authorities, identified as components of the local fossil machine, and with Enel leaders were also common: one such case involved the throwing of vegetables at Enel executives who were visiting the power plants. Agents of transition in this functional group also carried out destabilisation by creating content – songs, shows, music concerts, art exhibitions – to influence the public perception of the harmful implications of fossil fuels, propagating alternative visions, and criticising and denaturalising local dependence on the fossil energy monoculture. In addition, groups of health professionals and citizens

¹² The state of agitation was proclaimed to protest the possible approval of a decree simplifying the licensing procedures for high-impact activities that directly affected Civitavecchia (<https://www.fiomromalazio.it/2021/05/di-semplificazioni-stato-di-agitazione-appalti-tvn/?fbclid=IwAR0xQtKfrpod7asda5w6Pz9N2dWI-XzZndXdcNDE1TAUzFdpXlA3qcYOK3to>).

¹³ It was this use of the term “*macchina fossile*” by the agent of transition that first led us to consider this network of disparate actors a ‘fossil machine’; this serendipitous input was then theoretically pondered, elaborated, and justified within the tradition of science and technology studies, as explained in the Introduction.

¹⁴ In 2021 a ‘permanent table’ was created with the objective to build a low-carbon future. The document was signed by the mayor of Civitavecchia, Ernesto Tedesco, councillor Brunella Franceschini, the representative of Allumiere, the mayor of Tolfa, Landi, the political parties PD, M5S, Fratelli d'Italia, Lega, Rifondazione Comunista, and Verdi, and included most of the agents of transition reported in Table 2.

engaged in practices of destabilisation through popular epidemiology, carrying out continuous monitoring of the area's environmental and health conditions to uncover and expose fossil fuel pollution and the associated harms.

To engage the 'media and communication' functional group, data on the environmental and health impacts in the area were strategically used as a counter-narrative to Enel's. To give citizens the possibility to voice their opinions, the local branch of Fridays for Future launched an 'open microphone', inviting them to share their experiences and positions on the power plants and on the future of Civitavecchia. Table 4 categorises some of the most important practices of destabilisation and disruption against the Civitavecchia fossil machine.

5. Findings and reflections

The descriptive account provided here falls short of giving a full explanation of the convoluted process of deactivation of the fossil machine that took place in Civitavecchia: this would need to be integrated with a future analytical use of the reticular approach. However, the

Table 4
Destabilisation and disruption in relation to the Civitavecchia fossil machine.

Functional group targeted	Destabilisation	Disruption
Enel (and its fossil fuel plants)	Various kind of protests	States of agitation, strikes, blockades
Media and communication	Formation of narratives (e.g. on job creation/destruction). Careful use of social media (Facebook, WhatsApp, Instagram)	Reduction of narrative spaces for the reproduction of fossil fuels and increased space for alternative renewable projects
Governance systems	Bottom-up and top-down initiatives; meetings of parliamentary groups and sector representatives; demonstrations and protests at the plants and along their supply chain; alliances between groups which united the local community with political representatives at various levels, especially the regional level, by introducing an alternative that protected jobs	Approval of laws that slowed down or blocked the continuation of fossil fuel production in the territory Establishment of permanent political and technical discussion board to promote a non-fossil fuel alternative Strikes
Industry	Various kind of protests	Blockades
Culture and community	Communitarian meetings, assemblies, and other initiatives (tour of the power plants, songs, banners, online graphics) to strengthen local protests and communities by connecting them to similar cases at regional and national levels Awareness campaigns (e.g., on the possibility of overcoming the job/health dichotomy) Self-education programmes Citizen science epidemiology, physics, chemistry	Job creation through alternative projects

Source: authors.

descriptive use of the approach does provide some insights into the 'sensitive intervention points' of Civitavecchia's fossil machine and allows us to make some significant observations and advance more general considerations.

Borrowing from Farmer et al. [73], sensitive intervention points can be understood as nodes of the fossil machine in which initial changes triggered by destabilisation and/or disruption produce disproportionately large outputs in terms of deactivation, mainly through various feedback effects. In this regard, a major insight that emerges from the research is that primary agents of transition mostly employed destabilisation to lay the fundamental groundwork. This foundation provided a bottom-up way to prepare the Civitavecchia community to acknowledge and endorse the unacceptability and future impossibility of fossil fuel production in the area. They did so by activating sensitive intervention points that could 'shift' the internal and external dynamics of the components of the local fossil machine by substantially changing its rules (e.g. key values and concepts, and behaviours in the socio-economic-political context). Operational agents of transition, on the other hand, were able to 'kick' Civitavecchia's socio-energy systems onto novel trajectories beyond fossil fuels, thanks to the changed underlying system dynamics; they could do so mainly through practices of disruption targeted at sensitive intervention points of the Civitavecchia fossil machine that could materially create room for non-fossil futures.

Although an accurate analysis of the 'amplification potential' of specific sensitive intervention points to deactivate a fossil machine would demand the analytical application of the reticular approach, even the descriptive application carried out here gives rise to some interesting findings. Job creation and/or destruction seems to have been a common denominator and a catalyst both to 'shift' and 'kick' the components of the Civitavecchia fossil machine through destabilisation and disruption practices, in particular those belonging to the functional groups 'governance', 'culture and community', and 'media and communication'. A crucial sensitive intervention point, acted upon in different ways in all the different functional groups, is the creation of renewable alternatives.

A further finding is that the deactivation of a fossil machine requires multiple agents of transition to operate at different levels on its components and at different points in time. The analysis carried out in the case study confirms that the same agent of transition can be both primary and operational and that it can play both roles within the same functional group, not necessarily at different times; there is also a potential revolving door between the status of agent of transition and component of the fossil machine.

While an emerging perspective in the phase-out literature claims that sustainability transitions are not compatible with current capitalist political-economic systems [e.g. 51], in Civitavecchia the successful coalition of agents of transition includes both anti-capitalist and capitalist components that alternate the use of practices that can be considered antagonistic and anti-system (for example, workers' strikes and blockades) as well as others that are an integral part of the capitalist system of the Global North (for example, the services of engineering and legal firms to deliver alternative projects and legal initiatives). At the same time, the resonance between the fossil machine's components and the agents of transition, on the one hand, and Latour's conflictual categories of 'extracteurs' (extractors) and 'ravaudeurs' (repairers) [74] on the other hand, echoes the extractivist ferocity of the former (here the components of the Civitavecchia fossil machine) in the 'Capitalocene' and the efforts of the latter (here the agents of transition) to 'repair such wounds'.

Our work further suggests that an effective deactivation entails bottom-up practices that involve the largest possible number of agents of transition. In our case study, destabilisation and disruption practices occurred without being spearheaded by charismatic leaders, in contrast to what part of the sustainability transitions literature [e.g., 49] seems to postulate. While this same literature generally suggests that efforts to phase out fossil fuels are extremely onerous, in our case study

destabilisation and disruption are not excessively knowledge-, resource-, or people-intensive: as long as these practices are sufficiently widespread, the deactivation of a fossil machine can be triggered with relatively limited technological, financial, and human input.

In the empirical case presented here, the distinction between destabilisation and disruption shows how these practices can be further differentiated due to an important characteristic: if destabilisation can be successfully carried out by a single agent of transition, disruption requires the collaboration of multiple agents. Because disruption aims to obstruct and occupy the various spaces for fossil reproduction, it needs to be enacted on different components of the fossil machine, in a variety of forms, and for prolonged periods.

Finally, consistent with the systemic perspective demanded by the more recent transition literature [45,49,51], the reticular approach to the fossil machine shows how in Civitavecchia deactivation blurred the usual distinction between sectoral and systemic levels, and demonstrates that a process only targeted at decarbonising the local energy system could involve an entire community/socio-economic structure and could thus be part of a broader systemic effort towards a sustainable future. By the same token, within a systemic perspective in which communitarian involvement is crucial, the local context seems to be more decisive than extra-local factors in resisting the fossil machine: most of the deactivation practices in Civitavecchia took place within a national socio-political milieu that brought to power a right-wing coalition whose aversion to the energy transition had been long known and openly touted.

This evidence prompts five major reflections on the potential of the reticular approach. First, in order to be successful, practices of destabilisation and disruption need to operate relationally and are likely to be accelerated by the multiple mutual connections and interactions that agents of transition establish, as well as by the convergence of their actions and objectives. Second, the larger the number of the components of the fossil machine targeted by practices of destabilisation and disruption, the greater the chance to successfully deactivate it. Third, to deactivate a fossil machine, the existence of feasible renewable alternatives is a fundamental requirement. Fourth, practices of destabilisation and disruption have a sort of 'expiry date', since they tend to progressively lose their effectiveness; they eventually reach a point at which they cannot exert any more meaningful deactivation pressure on a fossil machine, as the current union protests in Civitavecchia testify. Fifth, while the fossil machine can be effectively used as a subject for the reticular approach to frame and analyse practices of destabilisation and disruption, it is at the same time a powerful metaphor to support transition narratives.

6. Conclusion

This article presents and tests a new approach to investigate how to overcome resistance against the exit from fossil fuels by the vested interests that support them and obstruct decarbonisation processes. To this end the article develops a reticular approach to describe and analyse how agents of transition can deactivate a fossil machine through practices of destabilisation and disruption. Here, this approach is used descriptively to display, frame (temporally and spatially), and discuss the practices of destabilisation and disruption that several groups of agents of transition carried out in the period 2019–2022 to successfully deactivate the Civitavecchia fossil machine.

We believe that the Civitavecchia fossil machine's case study has a sufficient paradigmatic epistemological reliability [75] to provide an encouragingly solid justification of our reticular approach, showing its broader strengths and weaknesses and its overall potential, scope, and limits.

Applying the categories of the reticular approach to a complex case study like the conversion of Civitavecchia's fossil fuel plants demonstrates that these categories are fit for purpose in helping to illuminate and disentangle the multi-layered intricacies of a fossil machine and in

clarifying how to address its resistance to moving towards a low-carbon future. It therefore appears that the reticular approach can be usefully applied to carbon-centric systems to understand how to promote the exit from fossil fuels.

The reticular approach offers a wealth of information and knowledge on the dynamics, means, logic, and rationales of the deactivation of a fossil machine and provides insights both for future research and activism/praxis in phasing out fossil fuels. At the same time, future work must inevitably address the methodological challenges raised, especially, by the analytical use of the reticular approach. Besides the choice of the most appropriate methodologies – such as systemic methods and, in certain cases, mechanism- and process-based tools – and their adaptation to the multilayered complexity of the fossil machine, another important issue is their calibration to case studies. It is vital that they are appropriate for and consistent with the context and environment under scrutiny. For example, where social protest is criminalized, access to data on destabilisation and disruption by agents of transitions will be very different from contexts where they are not criminalized: in the latter case social media might be an extremely useful source, whereas in the former context agents of transition will avoid them.

CRedit authorship contribution statement

Marco Grasso: Writing – review & editing, Investigation, Formal analysis, Data curation, Conceptualization. **Daniel Delatin Rodrigues:** Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

References

- [1] UNEP – United Nations Environment Programme, Emissions Gap Report 2023: Broken Record – Temperatures Hit New Highs, Yet World Fails to Cut Emissions (Again). Nairobi. <https://www.unep.org/resources/emissions-gap-report-2023>, 2023.
- [2] IEA – International Energy Agency, Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach, in: Update 2023, IEA, Paris, 2023.
- [3] P. Friedlingstein, et al., Global carbon budget 2023, *Earth Syst. Sci. Data* 15 (12) (2023) 5301–5369.
- [4] IEA – International Energy Agency, CO₂ Emissions in 2023. A New Record High, but Is There Light at the End of the Tunnel? IEA, Paris, 2024.
- [5] D.L. Levy, P.J. Newell, Business strategy and international environmental governance: toward a neo-Gramscian synthesis, *Global Environ. Polit.* 2b(4) (2002) 84–101.
- [6] J. Meadowcroft, What about the politics? Sustainable development, transition management, and long-term energy transitions, *Policy. Sci.* 42 (2009) 323–340.
- [7] F.W. Geels, Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective, *Theory Cult. Soc.* 31 (5) (2014) 21–40.
- [8] M. Lockwood, C. Kuzemko, C. Mitchell, R. Hoggett, Historical institutionalism and the politics of sustainable energy transitions: a research agenda, *Environ. Plann. C: Politics Space* 35 (2) (2017) 312–333.
- [9] J. Köhler, et al., An agenda for sustainability transitions research: state of the art and future directions, *Environ. Innov. Soc. Trans.* 31 (2019) 1–32.
- [10] B.K. Sovacool, M.C. Brisbois, Elite power in low-carbon transitions: a critical and interdisciplinary review, *Energy Res. Soc. Sci.* 57 (2019) 101242.
- [11] P. Newell, The business of rapid transition, *WIREs Clim. Change* 11 (2020) e670.
- [12] M. Grasso, From Big Oil to Big Green. Holding the Oil Industry to Account for the Climate Crisis, MIT Press, Cambridge, Ma, 2022.
- [13] T. de Geus, F. Avelino, M. Strumińska-Kutra, M. Pitzer, J.M. Wittmayer, L. Hendrikx, K. Rogge, Making sense of power through transdisciplinary sustainability research: insights from a transformative power lab, *Sustain. Sci.* 18 (3) (2023) 1311–1327.
- [14] UN – United Nations, Press Conference by Secretary-General António Guterres at United Nations Headquarters. <https://press.un.org/en/2023/sgsm21840.doc.htm>, 2023.
- [15] P. Cairney, Complexity theory in political science and public policy, *Polit. Stud. Rev.* 10 (3) (2012) 346–358.

- [16] M.A. Kaplan, Systems theory and political science, *Soc. Res.* 35 (1) (1968) 30–47.
- [17] A. Pickel, Systems theory, in: C.J. Jarvie, J. Zamora-Bonilla (Eds.), *The SAGE Handbook of the Philosophy of Social Sciences*, Sage, Thousand Oaks, CA, 2011, pp. 240–251.
- [18] M. Paterson, The end of the fossil fuel age? Discourse politics and climate change political economy, *New Polit. Econ.* 26 (2021) 923–936, <https://doi.org/10.1080/13563467.2020.1810218>.
- [19] A. Heras, Supply-side climate policy and fossil fuels in developing countries: a neo-Gramscian perspective, *Int. Environ. Agree.: Politics Law Econ.* 24 (2024) 49–74, <https://doi.org/10.1007/s10784-024-09627-z>.
- [20] J. Law, Notes on the theory of the actor-network: ordering, strategy, and heterogeneity, *Syst. Pract.* 5 (1992) 379–393.
- [21] G. Macdonald, Containing oil: The pipeline in petroculture, in: S. Wilson, A. Carlson, I. Szeman (Eds.), *Petrocultures: Oil, Politics, Culture*, McGill-Queen's University Press, Montreal and London, 2017.
- [22] N. Luhmann, *Social Systems*, Stanford University Press, Stanford, Ca, 1995.
- [23] D. Byrne, G. Callaghan, *Complexity Theory and the Social Sciences. The State of the Art*, Routledge, Abingdon, 2014.
- [24] A. Barry, Technological zones, *Eur. J. Soc. Theory* 9 (2006) 239–253.
- [25] T. Mitchell, *Carbon Democracy: Political Power in the Age of Oil*, Verso, London, 2011.
- [26] J. Marriott, M. Minio-Paluello, *The Oil Road: Journeys from the Caspian Sea to the City of London*, Verso, London and New York, 2013.
- [27] J. Stewart, Making globalization visible? The oil assemblage, the work of sociology and the work of art, *Cult. Sociol.* 7 (2012) 368–384.
- [28] M.J. Watts, A tale of two gulfs: life, death, and dispossession along two oil frontiers, *Am. Q.* 64 (2012) 437–467.
- [29] D. Banoub, S.J. Martin, Storing value: the infrastructural ecologies of commodity storage, *Environ. Plann. D Soc. Space* 2020 (38) (2020) 1101–1119.
- [30] R.O. Keohane, D.G. Victor, The regime complex for climate change, *Perspect. Polit.* 9 (2011) 7–23.
- [31] M.J. Watts, Righteous oil? Human rights, the oil complex, and corporate social responsibility, *Annu. Rev. Env. Resour.* 30 (2005) 373–407.
- [32] G. Simondon, *On the Mode of Existence of Technical Objects*, University of Minnesota Press, Minneapolis and London, 2016.
- [33] W.F. Lamb, G. Mattioli, S. Levi, J.T. Roberts, S. Capstick, F. Creutzig, J. Steinberger, Discourses of climate delay, *Glob. Sustain.* 3 (2020) e17.
- [34] R. Brulle, J.T. Roberts, M. Spencer (Eds.), *Climate Obstruction in Europe*, Oxford University Press, Oxford, 2024.
- [35] G. Piggot, The influence of social movements on policies that constrain fossil fuel supply, *Clim. Pol.* 18 (7) (2018) 942–954.
- [36] C. Tilly, Political identities in changing polities, *Soc. Res.: Int. Q.* 70 (2) (2003) 605–619.
- [37] C.C. Ragin, *The Comparative Method: Moving beyond Qualitative and Quantitative*, University of California Press, Berkeley: CA, 1987.
- [38] C. Tilly, Mechanisms in political processes, *Annu. Rev. Polit. Sci.* 4 (1) (2001) 21–41.
- [39] M.D. Ward, K. Stovel, A. Sacks, Network analysis and political science, *Annu. Rev. Polit. Sci.* 14 (2011) 245–264.
- [40] M. Caiani, Social network analysis, in: D. della Porta (Ed.), *Methodological Practices in Social Movement Research*, Oxford University Press, Oxford, 2014, pp. 368–396.
- [41] J.H. Fowler, M.T. Heaney, D.W. Nickerson, J.F. Padgett, B. Sinclair, Causality in political networks, *Am. Politics Res.* 39 (2) (2011) 437–480.
- [42] A. Bennett, J.T. Checkel (Eds.), *Process Tracing*, Cambridge University Press, Cambridge, 2015.
- [43] B.G. Glaser, A.L. Strauss, *Discovery of Grounded Theory: Strategies for Qualitative Research*, Routledge, Abingdon, 2017.
- [44] M. David, Moving beyond the heuristic of creative destruction: targeting exnovation with policy mixes for energy transitions, *Energy Res. Soc. Sci.* 33 (2017) 138–146.
- [45] D.J. Davidson, Exnovating for a renewable energy transition, *Nat. Energy* 4 (4) (2019) 254–256.
- [46] B. Turnheim, F.W. Geels, Regime destabilisation as the flipside of energy transitions: lessons from the history of the British coal industry (1913–1997), *Energy Policy* 50 (2012) 35–49.
- [47] B. Turnheim, F.W. Geels, The destabilisation of existing regimes: confronting a multi-dimensional framework with a case study of the British coal industry (1913–1967), *Res. Policy* 42 (10) (2013) 1749–1767.
- [48] P. Johnstone, K.S. Rogge, P. Kivimaa, C.F. Fratini, E. Primmer, A. Stirling, Waves of disruption in clean energy transitions: sociotechnical dimensions of system disruption in Germany and the United Kingdom, *Energy Res. Soc. Sci.* 101287 (2020).
- [49] P. Kivimaa, S. Laakso, A. Lonkila, M. Kaljonen, Moving beyond disruptive innovation: a review of disruption in sustainability transitions, *Environ. Innov. Soc. Trans.* 38 (2021) 110–126.
- [50] A. Rinscheid, D. Rosenbloom, J. Markard, B. Turnheim, From terminating to transforming: the role of phase-out in sustainability transitions, *Environ. Innov. Soc. Trans.* 41 (2021) 27–31.
- [51] L. Van Oers, G. Feola, E. Moors, H. Runhaar, The politics of deliberate destabilisation for sustainability transitions, *Environ. Innov. Soc. Trans.* 40 (2021) 159–171.
- [52] L. Frank, H. Schanz, Three perspectives on regime destabilisation governance: a metatheoretical analysis of German pesticide policy, *Environ. Innov. Soc. Trans.* 44 (2022) 245–264.
- [53] B. Turnheim, The historical dismantling of tramways as a case of destabilisation and phase-out of established system, *Proc. Natl. Acad. Sci.* 120 (47) (2023) e2206227120.
- [54] D. Jamieson, Slavery, carbon, and moral progress, *Ethical Theory Moral Pract* 20 (2017) 169–183.
- [55] H. Winkler, Towards a theory of just transition: a neo-Gramscian understanding of how to shift development pathways to zero poverty and zero carbon, *Energy Res. Soc. Sci.* 70 (2020) 101789.
- [56] M. Blondeel, Toward a neo-Gramscian interpretation of “social licence”. The case of fossil fuel divestment, in: *The Palgrave Handbook of Social License to Operate and Energy Transitions*, Springer International Publishing, Cham, 2022, pp. 1–24.
- [57] T. Kalt, Jobs vs. climate justice? Contentious narratives of labor and climate movements in the coal transition in Germany, *Environ. Polit.* 30 (7) (2021) 1135–1154.
- [58] S. Spatan, D. Peter, G. Thiele, M. Wolfram, F. Ehnert, S. Scherbaum, C. Surrey, Epistemic outsiders: unpacking and utilising the epistemic dimension of disruptive agency in sustainability transformations, *PLOS Sustain. Transform.* 3 (2) (2024) e0000097.
- [59] M. Grasso, Rodrigues D. Delatin, Disrupting to decarbonise socio-energy systems: the ‘carbon transformation axes’ framework, *Energy Res. Soc. Sci.* 90 (2022) 102657.
- [60] A. Caliendo, A. Gandini, *I Metodi Digitali nella Ricerca Sociale*, Carocci, Roma, 2019.
- [61] N. Marres, *Digital Sociology: The Reinvention of Social Research*, Polity, Cambridge, 2017.
- [62] H. Shue, Reckless complicity: International banks and future climate, in: M. Kiener (Ed.), *The Routledge Handbook of Philosophy of Responsibility*, Routledge, Abingdon, 2024, pp. 431–441.
- [63] V. Fano, F. Forastiere, P. Papini, V. Tancioni, A. Di Napoli, C.A. Perucci, Mortalità e ricoveri ospedalieri nell'area industriale di Civitavecchia, anni 1997–2004, *Epidemiol. Prev.* 30 (4–5) (2006) 221–226.
- [64] De Girolamo G. and Pezzopane F. (2022) *Una comunità contro il fossile. Jacobin Italia*. Available at: <https://jacobinitalia.it/una-comunita-contro-il-fossile/>.
- [65] S. Jasanoff, Future imperfect: Science, technology, and the imagination of modernity, in: S. Jasanoff, S.-H. Kim (Eds.), *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power*, University of Chicago Press, Chicago, IL, 2015, pp. 1–33.
- [66] D. Conversi, *Cambiamenti Climatici. Antropocene e Politica*, Mondadori Education, Milano, 2022.
- [67] A. Malm, Zetkin Collective, *White Skin, Black Fuel: On the Danger of Fossil Fascism*, Verso Books, London, 2021.
- [68] S. Caserini, *A Qualcuno Piace Caldo*, Edizioni Ambiente, Milano, 2008.
- [69] M. Grasso, S. Levantesi, S. Beqja, Climate obstruction in Italy: From institutional indifference to widespread climate delay, in: R. Brulle, J.T. Roberts, M. Spencer (Eds.), *Climate Obstruction in Europe*, Oxford University Press, Oxford, 2024, pp. 265–290.
- [70] D. Conversi, Eco-fascism: an oxymoron? Far-right nationalism, history, and the climate emergency, *Front. Hum. Dyn.* 6 (2024) 1373872.
- [71] Viale G. (2021) *Civitavecchia e Gkn, esperienze apripista della transizione. Il Manifesto*, 19 November 2021. Available at: <https://ilmanifesto.it/civitavecchia-e-gkn-esperienze-apripista-della-transizione>.
- [72] C. Tilly, *Contentious Performances*, Cambridge University Press, New York and Cambridge, 2008.
- [73] J.D. Farmer, C. Hepburn, M.C. Ives, T. Hale, T. Wetzler, P. Mealy, R. Way, Sensitive intervention points in the post-carbon transition, *Science* 364 (6436) (2019) 132–134.
- [74] B. Latour, *Où Suis-Je?: Leçons du Confinement à l'Usage des Terrestres*, La Découverte, Paris, 2021.
- [75] B. Flyvbjerg, Five misunderstandings about case-study research, *Qual. Inq.* 12 (2006) 219–245.