



# The politics of knowledge in black carbon mitigation: Policy entrepreneurship of Finnish actors and the Climate and Clean Air Coalition

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## ABSTRACT

Mitigation of black carbon (BC) is a potent short-term measure for climate and environmental policy due to the short lifetime of BC particles in the atmosphere. Fewer BC emissions would decelerate warming especially in the Arctic and bring significant co-benefits particularly in populous countries owing to BC's negative public health, food security and socio-economic effects. However, scientific knowledge on BC remains uncertain regarding the measurement, monitoring and precise effects of BC while the respective global policy framework is fragmented. To address this situation, we scrutinize the science/policy nexus in BC mitigation on the regional level where some promising openings exist. For this end, our new analytical framework focuses on policy entrepreneurs, their interests and cognitive frames, and the structural environment. Utilising content analysis of expert interviews and document data, three cases are covered with significant policy entrepreneurship on BC. First, we examine Finland's high-profile BC initiative, finding it to frame BC pollution as an Arctic climate threat. Second, Finland's research, development and innovation cluster, which has substantial expertise on air pollution, frames BC as a public health hazard, and scopes prospects for policy frameworks helping to open markets for mitigation technologies and solutions. Third, the Climate and Clean Air Coalition approaches BC with a wide multipollutant frame, driven by broad socio-economic and developmental interests. The Finnish initiative's potential is found to suffer from insufficient coordination with the RDI cluster. Both Finland's BC specific and the CCAC's wider multipollutant frame can in different ways contribute to abatement.

## 1. Introduction

This article addresses the relationship between scientific knowledge and policy in the mitigation of black carbon (BC) emissions. Here we concur with the calls to 'start developing a common understanding on BC' (Timonen et al., 2019), and for enhancing the use of scientific knowledge for mitigation ends (Yamineva et al., 2023a; cf. Khan and Kulovesi, 2018).

BC, or soot, is one of the short-lived climate pollutants (SLCPs) that also include methane, ozone and hydrofluorocarbons. BC consists of particles emitted into the atmosphere from impure combustion of fossil fuels and biomass. BC is a warming agent in the atmosphere. Although its contribution to global warming is in recent studies evaluated to be smaller than that of CO<sub>2</sub>, methane or ozone (Szopa et al., 2021), in Arctic regions its deposition into snow has significant melting and warming effects (AMAP, 2021). It moreover has negative effects on air quality, and can deposit onto lungs, provoking respiratory and heart problems, and eventually causing premature deaths (Kühn et al., 2023; Lepistö

et al., 2022). Furthermore, its effects on regional cloud-formation, precipitation and weather affect water security, flooding and crop yield (Szopa et al., 2021).

At the same time, mitigation of BC emissions is tempting since BC particles only stay in the atmosphere for days or weeks. This short-lived nature promises some rapid climate change benefits and significant socio-economic co-benefits: lower mortality rates, decreased healthcare bill and improved food security (Arif et al., 2015; UNEP, 2019b). Therefore, focusing on BC appears a 'low-risk, cost-effective and high-reward option' (Wallack and Ramanathan, 2009).

In the following sections two and three, we will consult recent literature, observing that despite progress in the scientific knowledge informing BC mitigation, several uncertainties remain; and that this uncertainty also affects mitigation in the legal and policy domains. To address this problem, we scrutinize the relationship between knowledge and policy in BC mitigation in more detail. For this end, in section four an analytical framework is developed; and in sections five to eight, applied in three case studies. In this way, we illustrate how actors form

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cognitive frames to approach the BC problem; and how in this process of sense-making, they are affected by their interests, with all this taking place in the complex structural context of BC mitigation. In the final section, we discuss the empirical findings, conceptual contributions and policy lessons learnt.

## 2. Scientific knowledge on BC emissions

The basic scientific facts relevant for BC mitigation are well-known. The sources of BC particles include the combustion of biomass for agricultural land use, for cooking or for energy purposes, the flaring of associated gases in fossil fuel production and use of fossil fuels in the power, transport, building and industrial sectors (Kühn et al., 2023; UNEP, 2019b). BC is a typical environmental problem as it is caused by the externalities of human economic behaviour and has cross-border effects (DeSombre, 2018), since the particles can travel afar (AMAP, 2021). The warming effects of BC are thought to be the gravest in the flat areas of the Arctic. By contrast, in mountainous areas close to the Equator, the effect can differ notably. In such locations, BC does not add to the surface's absorbing capacities and can be co-emitted with cooling agents or otherwise be rapidly removed from the atmosphere to the ground by wet deposition or gravitational force (Kühn et al., 2023).

However, several uncertainties remain. Data gaps persist for many low-income regions despite improving global emission inventories (Xu et al., 2021), and rapidly accumulating knowledge for example on the transport sector (e.g. Aakko-Saksa et al., 2023; Brewer, 2019; Comer et al., 2017; Frey, 2018; Pirjola et al., 2019; Yumashev et al., 2017; Zhang et al., 2019). Uncertainties also persist on the precise climatic effects of BC emissions and on technical questions of modelling (Yamineva et al., 2023a). The measuring of direct effects is convoluted by BC being co-emitted with other pollutants such as organic carbon (OC) and nitrogen oxides (NO<sub>x</sub>) that are treated as cooling agents. The ability of BC to deposit onto other aerosols further impairs analysis. The measurement technologies and practices remain subject to scientific and policy debate (Blanco et al., 2014, pp. 360–363; Saarikoski et al., 2021; Szopa et al., 2021). The indirect effects of BC are particularly uncertain as they depend on aerosol-cloud interactions, properties and formation of clouds, atmospheric temperature, and albedo effects of the surface. Furthermore, the local, regional and global effects of BC particles depend on wind patterns (Kühn et al., 2023; Timonen et al., 2019).

Although the body of knowledge relevant for BC mitigation remains incomplete, Yamineva et al. (2023a) deem it firm enough to constitute an epistemic community. By epistemic community, it is referred to an international 'network of professionals with recognized expertise and competence in a particular domain and an authoritative claim to policy-relevant knowledge within that domain', with shared normative and causal beliefs, notions of validity and common policy enterprise (Haas, 1992). However, in the case of BC, we suggest that the claim to policy-relevant knowledge is less well-consolidated when compared to the epistemic community on CO<sub>2</sub> that has formed around the work of the International Panel on Climate Change (IPCC) (Corbera et al., 2016; Yarime and Li, 2018). A crucial problem here is that BC emissions originate from multiple but regionally differentiated sources, with unevenly distributed effects. In other words, it remains difficult to assign responsibility and identify the owners of the problem. This hampers the use of knowledge for policy purposes.

## 3. Legal and policy efforts for BC mitigation

Legal scholarship has pointed out how international law on air pollution in general is 'inadequate' and 'fragmented' (Yamineva and Romppanen, 2017). Mitigation efforts regarding SLCP and BC emissions are dispersed on various governance and jurisdiction levels (Yamineva et al., 2023b). Simultaneously, legal studies deem the global level law and policy framework – based on the United Nations Framework Convention on Climate Change (UNFCCC), the Paris agreement and the

follow-up mechanisms informed by the IPCC's knowledge-based work – as largely inappropriate for BC abatement. This heavily CO<sub>2</sub> focused framework acknowledges SLCPs, but its metrics for measuring and reporting on them remain under development. Although countries can report on SLCPs, including BC emissions as part of their nationally determined contributions, by autumn 2022, only a dozen countries did so (Yamineva and Pekkarinen, 2023).

Many regional level legal and policy frameworks more appropriately address SLCPs including BC. However, these remain largely inconclusive. The 2012 amendments to the Gothenburg Declaration, made under the Convention on Long-Range Transboundary Air Pollution (CLRTAP), convey a regulatory process to reduce BC emissions as part of fine particle matter (PM<sub>2.5</sub>). However, the CLRTAP regime mostly covers northern hemispheric countries. Whether it represents binding regulation or soft law, remains debated (Byrne, 2023). In the EU, the road transport sector features relative success in mitigation, and in the USA even more so (Frey, 2018). The EU is exceptional here with its binding regulation of air pollution, but its targets fall short of the guidelines of the World Health Organization (WHO). Moreover, implementation problems exist throughout Europe both nationally and municipally (Viana et al., 2020; Yamineva and Romppanen, 2017).

A particularly noteworthy regional level framework is found in Arctic cooperation which comprises an influential scientific knowledge base on SLCPs (AMAP, 2015; 2021). This helped the Arctic Council to adopt the Framework on Action for Enhanced Black Carbon and Methane Emissions (2015), including follow-up inventory and monitoring. Although this includes ambitious, quantitative reduction targets, legally speaking, they remain political commitments (Koivuova et al., 2023). The knowledge accumulation together with the framework agreement nevertheless feature relative success. This can be explained by how the largest BC emitter countries to the Arctic have a strong self-interest in mitigation, due to the potential savings in public health costs and other co-benefits. Collective benefits also exist on climate change mitigation (Aakre et al., 2018).

Nevertheless, a crucial stumbling block here remains Russia. Although Russia is not a major BC polluter globally, it is the second largest BC emitter in the Arctic region (after the USA) and the second largest contributor to Arctic BC burdens (after East and South Asia) (AMAP, 2015). Russia's impact on Arctic BC burdens, and Arctic warming, is amplified due to the travelling, concentration and deposition patterns of emissions originating within or close to the Arctic (Kühn et al., 2020; AMAP, 2015); and emission sources with high temperature response per unit emitted mass (AMAP, 2015). Russia has commended the Arctic Council's scientific work but politically displayed ambiguous abatement commitments. After first reporting its BC emissions to the Council's Expert Group on Black Carbon and Methane (Arctic Council, 2017), Russia failed to follow up. This contributed to the hesitations of the USA regarding Arctic cooperation under President Trump. Since Russia's full-scale invasion of Ukraine in February 2022, the rest of the Arctic Council Member States discontinued Arctic cooperation with Russia (Koivuova et al., 2023). The Russian domestic debates also turned sour on emission reductions (Aalto et al., 2023) and Arctic cooperation overall.

Another major regional level interface linking scientific knowledge and policy is the Climate and Clean Air Coalition (CCAC), established under the UN Environmental Programme (UNEP). It is a state-led voluntary partnership mandated until 2030. As of February 2024, it covers 86 states, alongside intergovernmental organizations, businesses, scientific institutions and NGOs. With sector-specific recommendations on SLCP and BC mitigation, it has enhanced technical expertise and supported grassroots capacity-building (Unger, 2020), and fostered North-South cooperation, including awareness-raising in Asia (UNEP, 2019b). Like the AC, the CCAC features voluntary cooperation.

Since the Arctic and CCAC feature the most prominent contexts of using scientific knowledge on BC for policy ends, we will inspect these more closely. Noting that BC mitigation within the Arctic Council as

such is well covered (e.g. Khan and Kulovesi, 2018; Koivurova et al., 2023; Romppanen, 2018), we will (i) focus on Finland's BC initiative, a little examined and rare high-politics endeavour in this area, culminating in the country's Arctic Council (2015–2017) (CCAC, 2023; Eerola, 2020; cf. Government of Finland, 2017). We then (ii) extend the analysis to Finland's strong research, development and innovation (RDI) cluster: an interlinked, albeit informal group of private and public sector professionals and experts representing the state-of-the-art on emission measurement and mitigation technologies. Some of these experts contribute to the Arctic Council's scientific work, while some participate in standardization and lobbying activities in the EU context. No studies exist on this cluster's role; while we know that expert level environmental and technological cooperation is traditionally a subtle part of Finland's regional cooperation and foreign policy (Tynkkynen, 2008). Third, we (iii) contrast these analyses to the CCAC's advocacy which also builds strongly on scientific knowledge but has a more North-South policy angle.

These three cases have not yet been examined in parallel. They comprise actor groups that can each shape emission mitigation: activist state pushing a pollutant onto the science diplomacy agenda (e.g. Rosendal et al., 2020; Rottem, 2017); RDI actors in that state with respective technological capacities; and transnational coalition for knowledge dissemination and further advocacy (Unger, 2020). By focusing on how these actor groups approach the BC problem, we can scope the prospects for enhanced collective action, and hence respond to the calls for more detailed studies of how scientific knowledge can be used to abate BC emissions (e.g. Yamineva et al., 2023a; b; Qi et al., 2024a). We will next build an analytical framework for our study.

#### 4. The politics of knowledge framework

We will approach the knowledge/policy nexus in BC mitigation by referring to the *politics of knowledge*. With this concept, we imply how actors in environmental policy frequently operate with imperfect information in conditions of uncertainty and complexity (Ascher et al., 2010; Roe, 1994). The actors must choose which information to use, how to interpret it and what policy options to favour. In such conditions, use of knowledge is partial, selective and context-dependent, and can have profound political implications (Turnhout, 2018). Consequently, we conceptualize the actors as *policy entrepreneurs*. More precisely, we propose that in such capacities, actors (i) are driven by their *interests* in selecting information; and (ii) utilize *cognitive frames* to arrange the information into meaningful sets enabling policy; while (iii) the information they seek to process concerns the *structure* of which they are part. We will next explain each of these concepts.

(i) *Policy entrepreneurs*: this concept is often invoked to explain (transformational) change but can as well refer to agency impeding it (Boasson, 2018). It refers to skilful actors who can shape an issue area more than their occupation or position might suggest. In our cases, such actors include governmental and municipal experts on air quality and/or climate issues; and scientists and representatives of RDI companies engaged in policy advice or lobbying for technologies and solutions. Research on policy entrepreneurs initially focused on their individual skills and strategies through which they advance their preferred problem framings and solutions. Although this research has increasingly turned towards the institutional embeddedness shaping the agency of policy entrepreneurs (see e.g. Bakir and Jarvis, 2017; Boasson and Huitema, 2017), a recurring theme remains the 'policy windows' their efforts can open (Rose et al., 2020). This turn towards the institutional context directs us to study the interests the actors espouse as a key indicator of how the institutional context can shape their activity.

(ii) *Interests*: because policy entrepreneurs are goal-oriented, we must develop an idea of what they want. For this end, we draw upon institutionalist literature (Hughes and Lipsky, 2013). Policy entrepreneurs may be driven by single causes, but usually several interests shape their agency. In either case, in interaction with others, policy entrepreneurs

unavoidably encounter multiple interests needing to be reconciled with each other for any mitigation solution to emerge and become adopted. At the same time, the perseverance of some interests can incur strong lock-ins and path-dependence impairing progress (Moe, 2015). The range of interests is as wide as the range of institutional contexts that can influence policy entrepreneurs: promotion of climate neutrality; combating health problems caused by pollution; managing the socio-economic effects of air pollution; developing RDI solutions and competences for abatement; potential profits in respective technology and device business; and the consequent fiscal benefits to the public sector from the profits, in addition to prospects of technology exports and contribution of science and RDI to foreign policy influence (cf. Kotilainen et al., 2019; Aalto et al., 2021; see Fig. 4.1; Table 6.2).

(iii) *Cognitive frames*: since policy entrepreneurs have multiple information sources and operate in conditions of uncertainty and complexity, they resort to using frames. These are cognitive devices helping them to select, make sense of and interpret that information; and ultimately, treat the thus distilled information as knowledge (Linner and Wibeck, 2019; Sovacool and Brown, 2015). Actors can use frames to pinpoint certain problems as warranting more attention than others. This can facilitate policy change (Baka et al., 2018) or alternatively, hamper progress or induce polarization (Roe, 1994). In sum, frames function as devices with which actors differentiate problems and (part-) solutions from another and hence form 'mental maps' of the structural context of which they unavoidably are part. This context is the final step in our analytical framework.

(iv) *Structure*: the structural context comprises the overall operating environment of the actors and as such denotes a wider space than their institutional contexts. The structure has both enabling and constraining qualities. We conceptualize the structure to comprise three analytically separable dimensions: (i) resources, technologies and infrastructure; (ii) financial dimension including markets, costs and business models; and (iii) institutional dimension of policies and regulation alongside the associated informal institutions (cf. Aalto et al., 2021). These structural dimensions are in empirical practice interrelated. Importantly, they are not fully known as such by the actors. Rather, they are analytical devices constructed for the purposes of scholarly analysis. Even though the actors' knowledge of the structural context remains partial, they nevertheless must make choices, and in this are instructed by the frames they develop (see Fig. 4.1).

#### 5. Case studies, methods and materials

Our empirical case studies concern the policy entrepreneurship in the Finnish BC initiative, the work of Finnish RDI cluster and the CCAC. The primary material includes: 1) official documents recording the diplomatic activities supporting Finland's initiative; 2) expert interviews with representatives of the Finnish RDI cluster; and 3) documents from the CCAC and its parent body UNEP together with background discussions (see Table 5.1). Existing studies were also used. Overall, the body of the material is selected to ensure that the input from both policy and RDI actors is well covered.

All material was systematically coded and content analysed with the Atlas.ti software and fed to MS Excel (for analysis, see Table 5.2). The research questions guiding the empirical analysis were: 1) which interests and cognitive frames shape the policy entrepreneurship of the Finnish BC initiative, the country's RDI cluster, and the CCAC? 2) what are the lessons learned for environmental governance, and particularly, the policy lessons for the global mitigation of BC emissions? With our tripartite case selection, we expected to identify different actor types with varying frames and interests, and sought to examine how their diverse postures and efforts could be combined in order to propose ways of strengthening the fragmented global governance of BC mitigation.

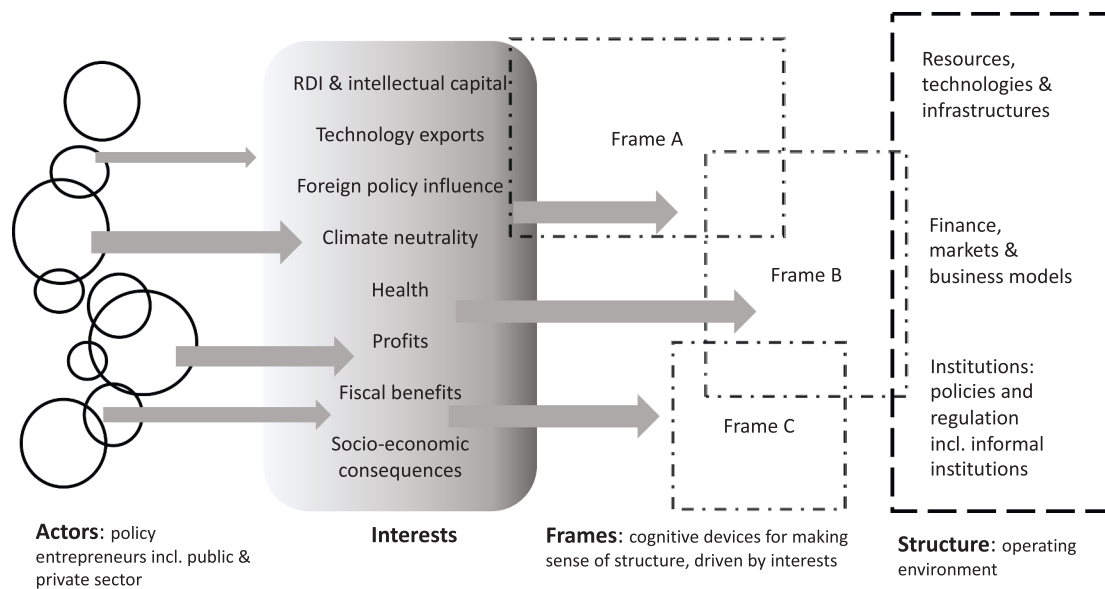


Fig. 4.1. Policy entrepreneurs, interests, frames and structural context.

## 6. Case study I: Finland's official BC initiative

The policy entrepreneurship in Finland's official initiative predominantly focuses on BC rather than wider categories such as SLCPs, particulate matter or air pollution (see Table 6.1).

The most significant interest driving this initiative is concern for climate change. A third of the identified references to interests in the material were on climate (32 out of 97; see Table 6.2), followed by related concerns for nature and the environment (10/97); alongside socio-economic development (9/97), health and safety (8/97), and peace and security (8/97).

The climate interest revolves on the Arctic but does not forget the global implications. Niinistö repeatedly refers to BC's effects regarding the melting of Arctic Sea ice and glaciers, rising sea levels, and links it to global warming (e.g. Niinistö, 2017a; 2017b). The warming is a global 'threat multiplier', causing famine, water scarcity, flooding and forced displacement (Niinistö, 2017a; 2018a). In short, we find an Arctic climate threat frame wherein tackling BC emissions in this region becomes a similar low-hanging fruit in climate policy as in the IPCC's fifth assessment report (Blanco et al., 2014). However, in the Finnish version of the Arctic climate threat frame Russia is heavily present. This is not unexpected since Finland has long-standing climate, environmental and foreign policy interests regarding the Arctic and the North in general, while relations with Russia are pivotal in both instances (Väätänen, 2021; Heininen et al., 2020; cf. Etzold and Haukkala, 2011). Consequently, Niinistö champions the BC initiative in many bilateral Finnish-Russian meetings, Arctic Council meetings and in other multi-lateral contexts (Table 6.3). Less expected, however, are the references to Russia as an emission source considering the initiative's 'global Arctic' framing and the actual breakdown of BC emissions to the Arctic wherein Chinese and Indian sources also figure strongly (Aakre et al., 2018).

As for Russia, Niinistö mentions the BC emissions from Russia's fossil fuel industry: in 2010, flaring of natural gas was estimated to account for 33 % of overall Arctic BC emissions north of 60°N and 66 % north of 66°N (AMAP, 2015, p. 33). Following Russia's full-scale invasion of Ukraine, flaring multiplied from Russia's LNG plant in Portovaya, close to St. Petersburg and the Finnish-Russian border, with additional 9000 million tonnes of CO<sub>2</sub> equivalent a day released. Allegedly, this was gas originally intended for exports to European markets before Gazprom halted its supplies to the EU area, reacting to the EU's 2022 sanctions. For a while, these leaks, widely debated in Finland, constituted the

largest single source of BC emissions to the Arctic (McGrath, 2022). Second, Niinistö mentions BC emissions from maritime traffic. Russian vessels accounted for 51 % of BC emissions in 2015 in the 'Arctic waters' as defined by the International Maritime Organization (IMO) (Comer et al., 2017). Third, Russian forest fires were noted that often in the summer bring emissions to Finland.

Niinistö also underlines the benefits available from emission abatement when viewed along the financial dimension and hints at several solutions Finnish actors can offer to that effect (Fig. 4.1; Table 6.3). As for the institutional dimension, two observations are important. Arctic institutions appear preferred for both mitigation and Russia's engagement. This may be motivated by the experience of how northern Europe's environmental cooperation has involved Russia since the 1990s, also via Finland's Northern Dimension initiative and its Environmental Partnership (Tynkkynen, 2008), and Russia's reporting of BC emissions to the AC in 2015 (Ministry of Natural Resources and the Environment of the Russian Federation, 2015), despite lack of follow-up. By contrast, in the IPCC context, Russia has never reported on BC.

Yet somewhat extraordinarily, EU institutions are missing. The omission of this otherwise crucial pivot of Finnish foreign policy is partly explainable by referring to the freezing of EU-Russia relations since Russia's annexation of the Crimea in 2014. Moreover, Finland's political system also delegates EU affairs to the prime minister (Raunio and Sedelius, 2020). However, that the Arctic and the EU remain separate goes against proposals made at the time in legal scholarship for extending EU governance to the region. This would require the Union to first widen its problem-definition of BC from an air quality and health problem towards climate policy concerns (Romppanen, 2018). More damagingly, that the EU remains absent, also disregards how this direction is key to the Finnish RDI cluster since it is the main source of regulatory and market considerations that also influence the science on BC (see Section 7 below). Hence the politics of knowledge this frame conveys comprises gaps that leave the epistemic community's potential underutilized.

## 7. Case study II: the Finnish RDI cluster's health hazard & sectoral technologies business frame

Whereas Finland's official initiative focuses on BC as such, actors in the Finnish RDI cluster take a wider and more nuanced view. They treat BC as part of the larger group of aerosols and particle matter emissions (Table 6.1), which they know to have complex interconnections.

**Table 5.1**  
Primary material.

Case	Type of data	Years covered	Material selection process
Finland's official BC initiative	19 speeches and statements of President Sauli Niinistö	2013–2021	(i) preliminary analysis of 33 documents with substantial information on the Finnish BC initiative; documents with mere mention discarded; (ii) selection of 19 documents for final analysis by the Finnish presidency owing to its strong powers of foreign policy initiative (Raunio and Sedelius, 2020) and the heavy personification of Finland's BC initiative on Niinistö's activity. Most of the 19 documents coincide with Finland's chairship of the AC (2017–2019)
	A video by the Ministry of Foreign Affairs	2018	Included as additional material due to its coincidence with the intensification of Finnish BC initiative
Finnish RDI cluster	12 Interviews with 22 experts from 8 firms and 2 major cities (average interview length 1.5hrs)	Oct 2019–Feb 2020	On grounds of examination of publicly available material from the RDI sector, judgemental selection of expert interviews with representatives from (i) companies profiled in emission measurement, control technologies and services, and targeting stronger market entry in these areas; (ii) municipal air quality monitoring services, looking to enhance their work; and (iii) experts from high-emitting industries intending to decrease BC emissions
CCAC and UNEP	46 documents by the CCAC	2013–2019	(i) preliminary analysis of 60 documents (co) authored by the CCAC, and other material available on the CCAC website; (ii) selection of 46 documents for final analysis, incl. lengthy reports with substantial RDI expert input, covering BC specifically and SLCPs in general, and representing the CCAC's wide scope of work
	13 documents by the CCAC's parent body UNEP	2011–2019	On grounds of the CCAC's close relationship with UNEP, 13 documents selected, covering BC specifically and SLCPs in general, including lengthy reports with substantial RDI expert input; three of these documents were co-authored with the CCAC
	Background discussions		Experts approached who were associated with the CCAC

**Table 5.2**  
Material analysis.

Phase of analysis	Description
Preparation	Full transcription of interview data; upload to Atlas.ti software for coding and analysis
Four-step coding procedure for content analysis	(i) systematic calculation of references to BC and other pollutants, including classification of how actors refer to them; (ii) thematization techniques utilized to analyse the underpinning interests; (iii) examination of the information actors convey on the BC problem in order to interpret the frames guiding their activity; (iv) analysis of how the actor's frames comprehend the structural environment, in order to understand how they relate the problem to potential solutions
Validation phase	Two coders used to validate findings

**Table 6.1**  
References calculated to BC and other pollutant agents.

Referent	Finland/ president	Finland/ RDI cluster	CCAC	UNEP	Total
Air pollution/ air quality	2	23	931	1324	2280
Black carbon	33	212	904	446	1595
Particle/ aerosol*	1	131	78	137	347
Particulate matter	1	62	283	410	756
SLCP/ SLCF	0	0	762	514	1276
Total	37	428	2958	2831	6254

The most forcefully emerging interests in the RDI cluster's material concern health (63/175 instances), which closely relate to air quality interests (16/175). Climate policy interests occur less frequently than in the official initiative (20/175) (Table 6.2). This concept of BC as more of a public health and air quality hazard than a first-order climate change agent builds on the IPCC's understanding in its sixth assessment report (Szopa et al., 2021), as opposed to the fifth report's take on BC as a strong climate forcer (Blanco et al., 2014). Interests in costs and resource efficiency (20/175), commercial profits (18/175), image (10/175) and RDI (9/175) also appear.

Despite the multiple interests, the baseline of the RDI cluster's frame is clear. It seeks to achieve a policy and business environment wherein the cluster's knowledge and various sectoral technological solutions its companies possess on the measurement and mitigation of air pollution can make a difference for addressing public health. That profit interests appear relatively modest (18/175), can be traced to acute awareness of how the air quality sector's business opportunities do not compare to those in CO<sub>2</sub> mitigation, circular economy and climate change as reported in the interviews.

The focus on climate, 'global Arctic' and Russia in Finland's official initiative is off target for the RDI cluster. According to the interviews, the cluster's companies do not foresee much demand for their solutions in Russia or the Arctic but rather seek to shape regulatory development and markets in the EU along with assessing Asia's potential. The solutions they offer range from the transport sector (e.g. diesel particulate filters); to emission monitoring devices, cleaner burning engines, and heating and recreational combustion devices (e.g. fireplaces, stoves). The business is, however, hampered by the persistence of long lifespan, high-emitting devices.

The RDI cluster's view of the structural environment is more nuanced when compared to Finland's official initiative. Regarding the resources, technologies, and infrastructure dimension, the cluster discerns several gaps and solutions. For example, emission inventories are inadequately resourced. Moreover, it is difficult to identify mitigation targets since competing definitions, measurement protocols, and air quality indicators exist for BC (e.g. elemental carbon, ultra-fine

**Table 6.2**  
Interests identified vis-à-vis BC and SCLP mitigation.

Interest	Finland/ president	Finland/ RDI cluster	CCAC	UNEP	TOTAL
Health and safety	8	63	229	164	464
Climate	32	20	148	108	308
Food security	3	0	61	54	118
Nature/ environment	10	0	26	32	68
Sustainable development	1	4	31	30	66
Cost & resource efficiency	0	20	20	25	65
Socio-economic development	9	3	20	18	50
Ecosystem	0	0	13	10	23
Air quality	3	16	0	0	19
Commercial/profit	0	18	0	0	18
Security of energy supply	1	0	14	2	17
Social factors (other)	0	0	8	8	16
Energy efficiency RDI	0	1	6	5	12
Image/ attractiveness	1	9	0	0	10
Security & peace	0	10	0	0	10
Competitiveness	8	0	0	0	8
Cost factors	4	0	2	1	7
Biodiversity	2	4	0	0	6
Urban/city development	0	0	1	4	5
Well-being	0	0	3	1	4
Human rights	3	0	0	0	3
Cooperation	3	0	0	0	3
Export	1	2	0	0	3
Cost savings	0	2	0	0	2
Quality products	0	0	2	0	2
Buildings, other materials	0	0	0	2	2
Livelihood, employment	2	0	0	0	2
Clean water	2	0	0	0	2
Weather	0	2	0	0	2
Cultural heritage	0	0	0	1	1
Natural resources	0	0	1	0	1
(Forced) migration	1	0	0	0	1
Standard of living	0	1	0	0	1
Total	97	175	585	465	1322

particles, and particulate number). Enhanced standardization and more BC-specific regulation would enable more efficient data compilation and the development and commercialization of appropriate technologies. In other words, technological gaps can be amended by actions of the institutional dimension, which for their part can feed into market development (Table 7.1).

For example, the EU’s 2013 introduced Clean Air policy package including the 2016 adopted National Emission Ceilings (NEC) directive is viewed too permissive for countries with established air quality policies. Based on the 2019 Fitness check, the European Commission has proposed a revision of the Ambient Air Quality Directives and Annexes in 2022. Such a revision would better align the EU annual limit values with the WHO air quality guidelines, and with respect to PM<sub>2.5</sub>, halve the limit values. BC-specific regulation, for example guideline values for concentrations in ambient air, would help assigning responsibility for measurement and costs of mitigation, and facilitate the market entry of BC-labelled technologies and services. Medium-priced, durable and reliable measurement technologies would also be needed to supplement already existing standard high-cost monitoring equipment and low-cost sensors used for short-term measurements.

For the cluster, another area requiring institutional improvements is work safety. Enhanced regulation concerning working environments with high pollution concentrations (harbours, airports, etc.) could pave

**Table 6.3**  
The structural context in the Arctic climate security frame.

Structural dimension	Example(s)
<i>Resources, technologies and infrastructure dimension</i>	‘For a lay man [flaring of natural gas] is almost impossible to understand. In 2015 flaring amounted to almost 150 billion cubic meters of wasted gas. To put this into a perspective: this is almost 40 times as much as Finland uses natural gas annually’ (Niinistö 2017a)
	‘[...] and we know that black carbon sources are a lot of them in Russia. They are old-fashioned energy plants producing heating. The other problem is flaring. (Niinistö, 2017b)
<i>Financial dimension incl. markets, costs and business models</i>	‘[The flaring]... amounts to burning money.’ (Niinistö 2017a)
	‘In a separate event Finland co-hosted here this morning, experts from government, science and business highlighted two promising ways to tackle black carbon emissions in the Arctic. One is modernising outdated heating and power plants. Another is investing in clean and sustainable shipping. These approaches will not only bring climate and health benefits. They also make sense economically.’ (Niinistö 2019a)
	‘Reducing emissions of black carbon from transportation and heat and power production will result in almost immediate climate and health benefits. Tighter regulation of emissions will bring also business opportunities for providers of soot-free technologies.’ (Niinistö 2019b)
<i>Institutional dimension incl. policies, regulation and informal institutions</i>	‘Focusing on this goal [combating climate change via BC mitigation], Finland is advocating a first-ever Arctic Summit, bringing together the heads of state and government from the eight members of the Council: the United States, Russia, Canada and the five Nordic states.’ (Niinistö, 2018b)
	‘In addition to multilateral co-operation Finland seeks to enhance its Arctic policies through bilateral partnerships. Our first bilateral Arctic partnership was concluded with Russia – with you. In addition to sectoral co-operation, we organize together annual Arctic seminars. They bring our experts, regional bodies and businesspeople to the same table. I use this occasion to call upon Russian and Finnish businesses and scientists to actively develop common projects in the Arctic. I believe Arctic co-operation has a potential to become one of the key sectors in our bilateral relations.’ (Niinistö, 2013)
	[N.B.: bilateral approaches towards the USA (e.g. Niinistö, 2017b; 2017c.); and repeatedly towards Russia (e.g. Niinistö, 2013); multilateral engagement in the United Nations context (e.g. Niinistö, 2017a; 2017d, )]

the way for introducing low-cost BC mitigation devices. In this area, regulatory stringency varies between countries, frequently fails to address BC directly, and is too much dependent on the awareness of workers themselves (Table 7.1).

Further institutional constraints are identified in the transport sector wherein emission regulation varies between countries and market areas. BC-specific performance standards are rare. In the EU, regulation is stringent on the laboratory-based type approval of vehicles and non-road mobile machinery but fails to address BC emissions directly. The type approval process is found inappropriate in not guaranteeing low on-road emissions (Hooftmann et al., 2018). Furthermore, the periodic technical inspection practices of vehicles followed in the EU do not adequately detect malfunctioning, for example tampered or removed

**Table 7.1**  
The structural context in the Finnish RDI cluster's frame.

Structural dimension	Example(s)
<i>Resources, technologies and infrastructure dimension</i>	
Measurement in general	[...] current air quality data... is incomplete because it does not measure this property at all. In certain situations, for technological reasons, it simply is not possible to measure black carbon (Interview, measurement technology manufacturer, 4.9.2019). [...] for example, about ten years ago new important parameters were identified to monitor small particles from combustion sources better than particulate mass, that is, PM2.5 [on which current EU legislation is based – the authors]. We started measuring particulate number to better assess the effectiveness of air pollution control measures. Long-range transportation and regional background pollution affect PM2.5, as can street dust and exhaust fumes or smoke from wood combustion [...] (Interview, public air quality monitoring unit, 20.9.2019) [...] with no long-term measurements, it is difficult to conduct health-focused research... we are waiting for the WHO or some other body to boldly define [the guideline value]. That is challenging. Particle number data partly comprises substances from natural sources given BC's multiple sources. Also, particle mass can contain sea salt; it doesn't harm health but increases particle mass. So, we need the [guideline values] (Interview with municipal air quality monitoring experts, 20.9.2019)
Measurement of health effects	'The research over the health impact of particulates keeps treating small particles as dangerous... also for unborn babies and asthmatics, [...] but hasn't been able to clearly demarcate which level is poisonous or lethal to human beings' (Interview, measurement technology manufacturer, 9.9.2019)
<i>Financial dimension incl. markets, costs and business models</i>	'[...] it would be cool to see someone to commercialize the [Black Carbon Footprint] concept. We need companies portraying themselves as low-black carbon' (interview with a measurement technology manufacturer, 25.9.2019). 'Vehicle emissions depend on the level of technology used, but also on the quality of fuel, and European fuel is expensive, a high-technology product. For Chinese refineries to produce ultra-low sulphur fuel, as required for emissions aftertreatment systems, will take time. It took a long time in Europe to get rid of sulphur from fuel' (Interview, measurement technology manufacturer, 9.9.2019)
<i>Institutional dimension incl. policies, regulation and informal institutions</i>	
Policies & standardization across countries	'It would be easiest for everybody if the global map were harmonized... now in this N+1 system, we produce different machines for different markets. It's very difficult to control logistics and cost-effectiveness' (Interview with an industry representative, 8.10.2019) 'In Japan, vehicles removed from use... are sold to Africa, and then... the filters can even be removed because they are

**Table 7.1 (continued)**

Structural dimension	Example(s)
Work safety polices and standards	blocked and old, with no money to renew them, [...], so our problem is exported there to deplete the local air and our climate' (interview, measurement technology manufacturer, 25.9.2019) 'Occasionally oil droplets or something from the engine end up in the aircraft's cabin through the air conditioning. Some court cases are in progress from the work safety perspective. This is one aspect the aviation industry is quietly researching...' (interview, measurement technology manufacturer, 9.9.2019)
Informal institutions: individual behaviour in vehicle ownership, recreational heating and use of stoves and fireplaces	'[...] many small companies are helping the owners to remove these emission-control devices or reprogramming them. This big problem... [also extends] beyond the passenger cars sector' (interview, industry representative, 8.10.2019) '[...] to convert our beloved sauna concept to a less emitting one... is challenging. People easily object. Communication-wise it is difficult to decide if we blame people or point at positive examples [...]' (interview, municipal air quality monitoring experts, 20.9.2019).

diesel particulate filters. Tampering into emission control systems can save fuel costs and improve engine performance, and as such serve the economic interests of vehicle owners by offering lower fuel costs with less filtering. Some powerful informal institutions exist here in the form of deeply entrenched socio-cultural expectations of effective vehicle performance as part of fossil fuel cultures (Sovacool and Griffiths, 2020). In the case of low-income countries with high pollution, more stringent regulation may be thwarted by the vehicle owners being unable to afford cleaner technologies or resisting such investment (Table 7.1).

Finally, formal institutions could more effectively tackle individual behaviour in the case of emission performance standards for domestic combustion devices such as stoves and fireplaces. The individual behaviour of homeowners is the source of 40 % of PM<sub>2.5</sub> and BC emissions in the Nordic region (NCM, 2019). In these latitudes, wood burning stoves are typical auxiliary heating devices, favoured as such by regulation, and associated with lower fuel costs (Penttinen et al., 2021), especially with the high energy prices in Europe during winter 2022–2023. Wood-burning fireplaces and sauna stoves also exemplify some firmly entrenched informal expectations (Table 7.1).

Overall, the RDI cluster's frame has a nuanced reading of the structure that is in line with its broad knowledge on the subject (see Fig. 7.1; also, Section 8).

## 8. The CCAC/UNEP's sustainable development frame

In the CCAC/UNEP material, references appear roughly equally to BC (1350/5789), SLCPs (1276/5789), and aerosols, particles and particulate matter (908/5789). However, air pollution in general is the outstanding category (2255/5789; see Table 6.1). This wide agenda converges with the CCAC's mandate that views work on SLCPs as a contribution to the climate change agenda and a potent source of co-benefits (Unger, 2020).

We find health interests to comprise the major driving force of the CCAC/UNEP's policy entrepreneurship (394/1050 instances; Table 3.2), followed by climate interests (256/1050), and several expected co-benefits, including food security (115/1050), sustainable development (61/1050), the nature/environment relationship (58/1050), cost and resource efficiency (45/1050) and socioeconomic development (38/

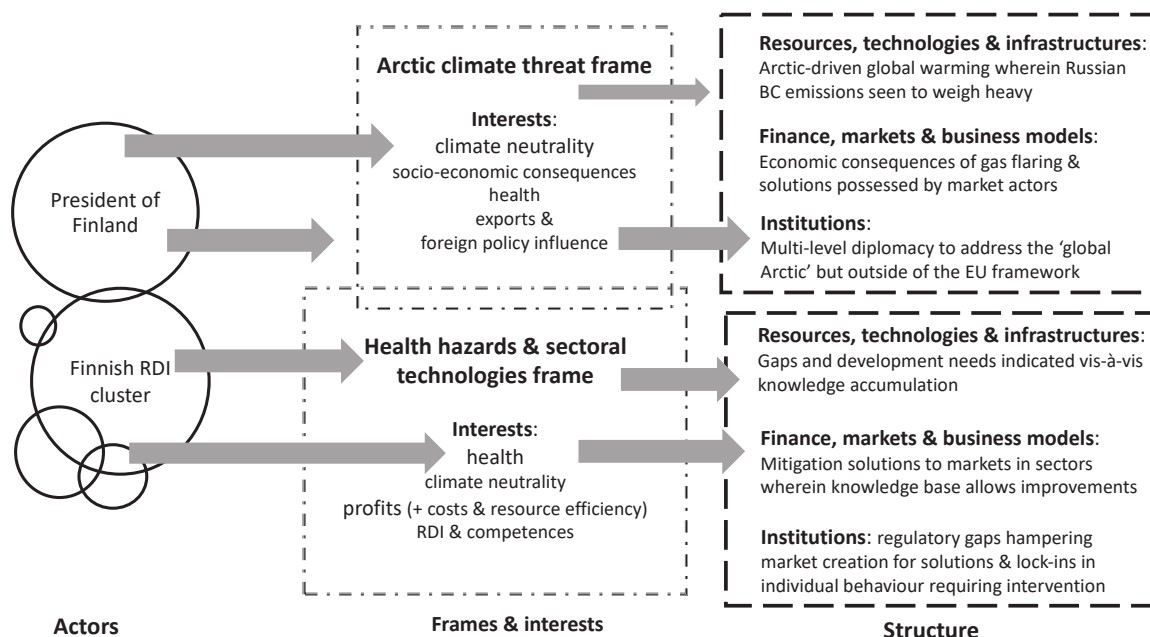


Fig. 7.1. Policy entrepreneurship of Finnish actors.

1050) (Table 6.1). Taken together, these multiple interests reflect a broad sustainable development frame reminiscent of the UN Sustainable Development goals. This is fitting given the CCAC's links to the UN family through the UNEP.

The emerging sustainable development frame shares with the Finnish RDI actors a broad, science-based view on the BC problem. However, the CCAC and UNEP treat BC as part of the wider group of SLCPs which is not present in the Finnish actors' lexicon, and ventures deeper into socio-economic co-benefits, and on to development policy and North-South issues. The frame's baseline can be illustrated in more detail by examining how it approaches the structural context.

In terms of the resources, technologies and infrastructure dimension, the CCAC and UNEP concur with Finnish RDI actors on the need for better scientific knowledge regarding BC and its measurement. A different emphasis is found in how the CCAC and UNEP elaborate on these gaps in the context of developing countries, many of which experience rapid population growth and urbanization. Several high exposure municipalities, and rural and industrial sites, remain poorly equipped to measure and monitor emissions. Although over a hundred countries have ambient air quality standards, many of them routinely exceed the WHO's respective norms, failing to monitor and measure emissions, or cover enough pollutants such as carbon monoxide (CO), ozone (O<sub>3</sub>), sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), particulate matter (PM) and lead (UNEP, 2016, p. 11). The CCAC and UNEP propose satellite data and modelling as potential solutions. Yet such policy proposals quickly move us towards the financial dimension and questions like who finances research, monitoring and inventory development and indeed, where (CCAC, 2017b; 2019; UNEP, 2019a; UNEP and CCAC, 2017).

The strong socio-economic interest pervading this frame criticizes the contemporary global political economy in terms of our financial and institutional dimensions. As production moves from developed to developing countries, it increases energy consumption in the latter together with emissions and impairs local food security in already needy countries via shorter crop cycles. Overall, we suggest that the CCAC and UNEP prefer developmentally aware technological modernization (Table 8.1). Here they share with the Finnish RDI cluster a belief in growth, and the problem-solving capacity of sectoral technologies and business, but push stronger for development policy. Chief targets are outdated industrial processes, and technological lock-ins linked to

omnipresent and durable high-emitting technologies in the developing world.

Some solutions are straightforward: less emitting diesel engines and traditional cook stoves can be mainstreamed through economies of scale and scope. However, taking into use advanced, less emitting low-sulphur fuels is less straightforward, involving fuel refineries, energy infrastructures, supply chains, purchasing power, market development and availability of capital (Table 8.1). On such occasions we encounter the financing limitations of existing global mechanisms (e.g., the Green Climate Fund) (CCAC, 2015; UNEP and CCAC, 2016, p. 183).

Moving further towards the institutional dimension, these organizations lament how the mere supplementary status of BC and other SLCPs in relation to that of CO<sub>2</sub> in the Paris Agreement impairs inventory development, regulation and financing of BC mitigation. Enforcement gaps aggravate the situation, as do competing interests, for example on energy security (see Table 6.2). Here it is worth noting how energy security in the developing world remains firmly tied to fossil fuels.

Finally, like the Finnish RDI actors, the CCAC also extends its gaze towards informal institutions in identifying numerous independent and small emission sources sensitive to user conduct. Informal norms such as traditions, practices and habits either directly cause many emissions or sustain high-emitting technologies (open-fire cooking stoves, burning of agricultural waste). Deep-seated behavioural lock-ins may persist even with better infrastructure and alternative technologies being available (see Kotilainen et al., 2019, p. 579), due to the high cognitive cost of switching to cleaner technologies. Such social embeddedness exposes fragile groups (women, children, the elderly) particularly to indoor air pollution. The formal-institutional problem for its part concerns how regulation oftentimes is weak on small-scale polluting practices (Table 8.1).

Overall, the policy entrepreneurship of the CCAC and UNEP has an equally nuanced reading of the structure as that of the Finnish RDI cluster while it has a very wide socio-economic agenda wherein food security interests stand out as a distinct CCAC/UNEP concern (see Fig. 8.1).

## 9. Results and discussion

In this article, we have examined the politics of knowledge in the

**Table 8.1**

The structural context in the CCAC's frame.

Structural dimension	Example(s)
Resources, technologies and infrastructure dimension	'The ratio of BC to its co-pollutants varies depending upon the emission source and fuel-type, and impacts whether the source has a net-positive or -negative warming effect. For example, emissions from diesel engines have a high proportion of BC to cooling co-pollutants, whereas emissions from wildfires and the open-burning of biomass contain a more balanced ratio' (CCAC, 2014, p. 13) 'Several reasons make the compilation of a global black carbon inventory difficult including variable emissions from similar sources, different measurement techniques, different particulate matter size cut points used in measurements, as well as differing definition of black carbon itself used in inventory development' (CCAC, 2017a, p. 2)
Financial dimension incl. markets, costs and business models Global political economy of emissions	'Globally, decreasing emission trends from local air pollutants in certain sectors and regions have been offset by larger increases in others, including some rapidly developing countries and areas of rapid urbanization' (UNEP, 2019b, p. 108)
Fuel switch	'Fuel desulfurization in refining countries is key to unlocking the deployment of soot-free diesel engines, but it is also challenging. Major barriers to producing low-sulphur fuels include access to capital, access to technical capacity, governance, existing policy, and economic factors (including fuel subsidies)' (CCAC, 2016, p. 45)
Institutional dimension incl. policies, regulation and informal institutions	'Many households employing traditional methods of cooking are unable or unwilling to pay a commercially viable price for cleaner cooking devices and fuels—particularly those that are effective at reducing black carbon emissions. The reasons include the high cost, competing household priorities, low exposure to and appreciation of cleaner technology, limited awareness of the health benefits, cookstove designs that do not match user needs, and entrenched cooking habits.' (CCAC, 2015, p. 24)

mitigation of BC and SLCP emissions. With this concept we proposed that since uncertainty typically defines these mitigation efforts, the use of knowledge tends to remain partial and selective. As this makes the use of knowledge inherently political, we approached the knowledge/policy nexus with the concept of policy entrepreneurship. Three cases were scrutinized: the high politics natured BC initiative of Finland; the expertise of the Finnish RDI cluster; and the intergovernmental expert organization CCAC/UNEP. The empirical findings are summarized here along with conceptual and policy lessons.

(i) *Empirical findings*: our first research question concerned the interests and cognitive frames shaping the policy entrepreneurship in these cases. First, we found the Finnish initiative to frame BC abatement as a low-hanging fruit in global climate policy. This frame broadly corresponds to how the IPCC's fifth assessment report approached BC (Blanco et al., 2014). Despite the 'global Arctic' focus in Finland's initiative, its spokesperson, President Niinistö repeatedly addressed Russia, highlighting Russian emissions. His references to the financial benefits of mitigation and respective solutions Finnish actors could offer in a subtle manner served Finnish RDI export and foreign policy

interests. This Russia pivot is explainable given Finland's long-standing environmental and foreign policy interests and its structural environment wherein Russia weighs heavy. However, scientific knowledge on emissions could equally well have justified Finland targeting China or India.

Second, the Finnish RDI cluster's frame was found to treat BC as part of the wider group of particle emissions causing air quality problems. This frame is driven foremost by health concerns, scoping for the business opportunities that managing air quality problems could open. Such a public health priority corresponds to the IPCC's sixth assessment report, which downgrades BC's climate enforcer qualities from earlier assessments (Szopa et al., 2021; Kühn et al., 2023). The RDI cluster's frame calls for further improving the knowledge base to enhance mitigation. This could help in creating market for the cluster's technologies and solutions, serving its RDI, competence and profit interests.

Third, the CCAC/UNEP's frame was shown to align with the UN sustainable development goals including a broad focus on SLCPs in contrast to Finland's BC-specificity. Priority on health hazards is accompanied by concerns for climate and multifarious socio-economic and developmental consequences of pollution including changing precipitation and weather patterns, crop yield and food security. This wide scope is detectable to the CCAC's structural environment where a multi-pollutant approach encapsulates the multiple interests of the organization's 86-strong membership, for example East Asian countries, and caters for non-members such as China. Offering something for everyone, this frame portrays BC as only one item on the SLCP agenda. This reminds of how south-east Asian regional cooperation is built on issue linkages keeping diverse actors involved. That may eventually offer decent positive-sum prospects of resolution (Aalto, 2014; Stevenson, 2018).

(ii) *Conceptual contributions*: our second research question concerned the learnings vis-à-vis environmental governance wherein the more conceptual issues concern the study of policy entrepreneurship. We have sought to push further the conceptualization of policy entrepreneurs not only as skilful actors but also as institutionally embedded agents of change. By drawing upon institutional literature, we highlighted interests as useful conceptual entry points into what policy entrepreneurs seek to achieve vis-à-vis their structural context. By assessing the actors' interests we can scope the likeliest directions of their activities. Furthermore, we can study the interests driving other actors with whom the policy entrepreneurs need to interact. Once we know how these interests match, we can anticipate how likely the policy entrepreneurship may succeed.

We further sharpened this conceptualization of policy entrepreneurs with the concept of frame. Since policy entrepreneurs operate under conditions of uncertainty and complexity, we need to ascertain how they make sense of the structural context. By scrutinizing frames, we can assess what information actors use for knowledge accumulation regarding that context. For analytical purposes, we differentiated between three dimensions of the structural context: the resources, technologies and infrastructure dimension; financial dimension; and the institutional dimension. For the institutional dimension, we also referred to informal institutions. By examining how the frames of policy entrepreneurs cover the structural dimensions, we can further assess the prospects of successful policy entrepreneurship.

(iii) *Policy lessons*: our second research question also extended to the policy lessons for global mitigation purposes. Here we refer to how the three frames summarized above can be combined. The compatibility of interests underpinning each frame is central for this end (see Section 4).

The first observation concerns Finland's BC-specific, 'narrow' initiative and its coordination with the RDI cluster's wider frame. Finland's initiative built on Arctic climate interests, pivoting on Russia. However, at the apex of Finnish diplomacy, scientific knowledge was shifting to stress the health hazards of BC and other SLCPs. Better consultation with the Finnish RDI cluster could have advised on this shift. Wider scholarly consultation would have indicated the mismatch

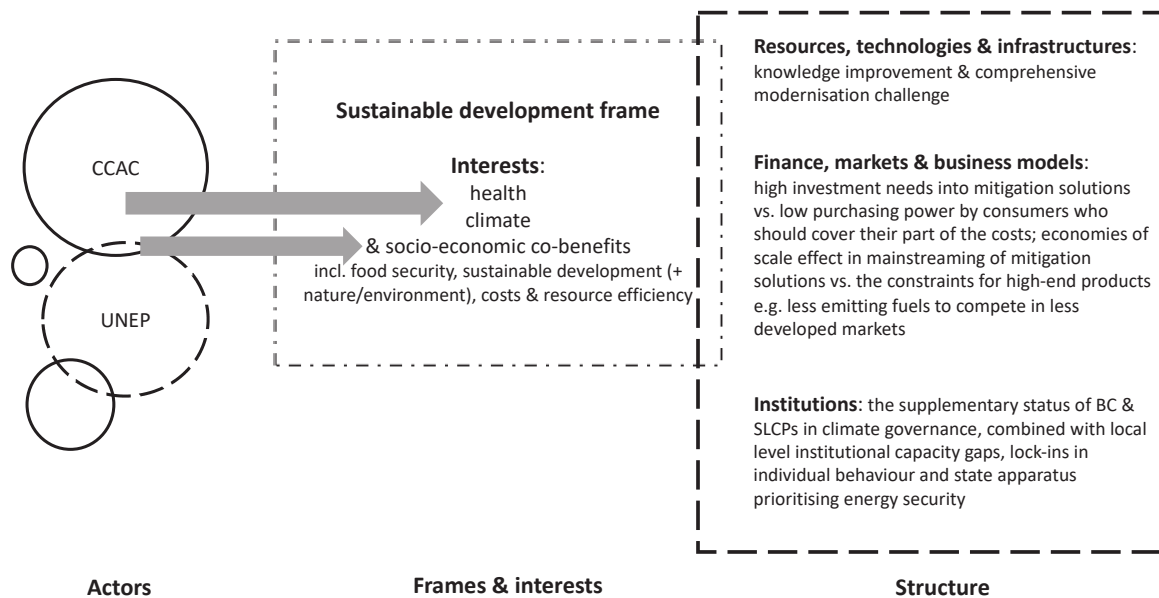


Fig. 8.1. policy entrepreneurship of the CCAC/UNEP.

of the climate focus with Russian priorities, due to Russia's climate change denialism, unambitious climate policy and its weak implementation (e.g. Ashe and Poberezhskaya, 2022; Korppoo, 2022). The Finnish RDI cluster moreover viewed the Arctic and Russia as unlikely destinations for their products and services, and instead looked for EU regulation to support market creation in mainland Europe, which in turn was a blind spot for the Finnish initiative. In sum, the disparities in the knowledge base utilized by the two actor groups, and in their readings of the structural context, was exacerbated by their insufficient mutual communication. Thus critical mass for synchronized Finnish actions was never achieved.

The second observation is that better coordination between governmental and company actors would enable capitalizing on the inherent strengths that the narrow approach nevertheless comprises despite these remaining so far underexploited. A narrow single-pollutant approach is necessary for developing highly specialized knowledge that in turn can be leveraged by combining private and governmental RDI investment. The resulting technology improvements enable more precise emission measurement and monitoring, allowing the public sector to introduce stricter standards for emissions from engines and other combustion sources. Stricter standards in turn enable market creation for the commercialization and mainstreaming of products and services supporting BC mitigation such as sensors, measurement devices, filtering solutions, and cleaner burning engines, fuels, stoves, kilns and other industrial applications. In this way, a market would emerge for products and services with BC footprint (see also Timonen et al., 2019). BC measurement could also evolve into an indicator of air quality, as hinted in our expert interviews, although more scientific knowledge would be needed to corroborate this prospect.

The third observation relates to controlling the commercial risks in-built in a narrow single-pollutant approach despite its knowledge and competence-building strengths. For this end the narrow approach can be co-deployed or sequenced with the wider multipollutant approach as manifested in the CCAC/UNEP's frame. Since the emission sources and effects of BC vary globally, the problem's ownership will vary correspondingly. Some countries and municipalities will form the vanguard for BC mitigation; some as a shortcut supporting their global climate action; some as a national or local health policy measure; while some will be driven by a combination of interests. Some will rather prioritize SLCPs other than BC. In each case, specialized knowledge afforded by the narrow approach will be pivotal for developing solutions. Crucially,

the wide approach can help to control the risks in the mainstreaming of these solutions via political geography and issue linkage mechanisms.

As for political geography, the wide approach can bring more actors into the same table. The more countries participate in knowledge accumulation, dissemination and standardization, the more markets can form for BC solutions, methane solutions, and so on. This can mobilize larger numbers of local and regional actors for bottom-up mitigation actions irrespective of which pollutants or emissions sources they prefer to address, or the interests driving them forward. Our results concerning the emissions from individual behaviour and small combustion units also underline how bottom-up activities are also required. In this way, companies offering sectoral technological solutions on BC for example, lessen their risks, should regulatory or market risks in one country curb the business there. More markets opening could also bolster demand for new supplementary measurement and control technologies alongside currently standard high- and low-end devices.

The issue linkage in the multipollutant approach for its part enables more positive sum outcomes in international cooperation when co-benefits can be identified in terms of combined climate, health, food security or other socio-economic benefits. In this way all parties can gain something and hence likelier stay in the same boat. The proposed co-application of the narrow and wide approach for BC mitigation in this way comprises a strategy wherein activist countries in environmental diplomacy should seek close coordination with RDI actors and environmental technology companies, seeking to create a home market whilst also sequencing and combining their actions with those of multilateral organizations in order to identify the likeliest niches for their technologies and solutions.

#### Author

For this revision (R2), Pami Aalto was fully responsible for funding acquisition, project administration, supervision and visualization. He was part-responsible for investigation, writing of the original draft, as well as for review & editing of the ms.

Anna Claydon was fully responsible for data curation, software, methodology, took the main duties for investigation, and was part-responsible for conceptualization, and for writing of the original draft as well as for review & editing of the ms.

## CRedit authorship contribution statement

**Anna C. Claydon:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Data curation, Conceptualization. **Pami Aalto:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

## Declaration of Competing Interest

the authors have no competing interests to declare.

## Data Availability

The data that has been used is confidential.

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