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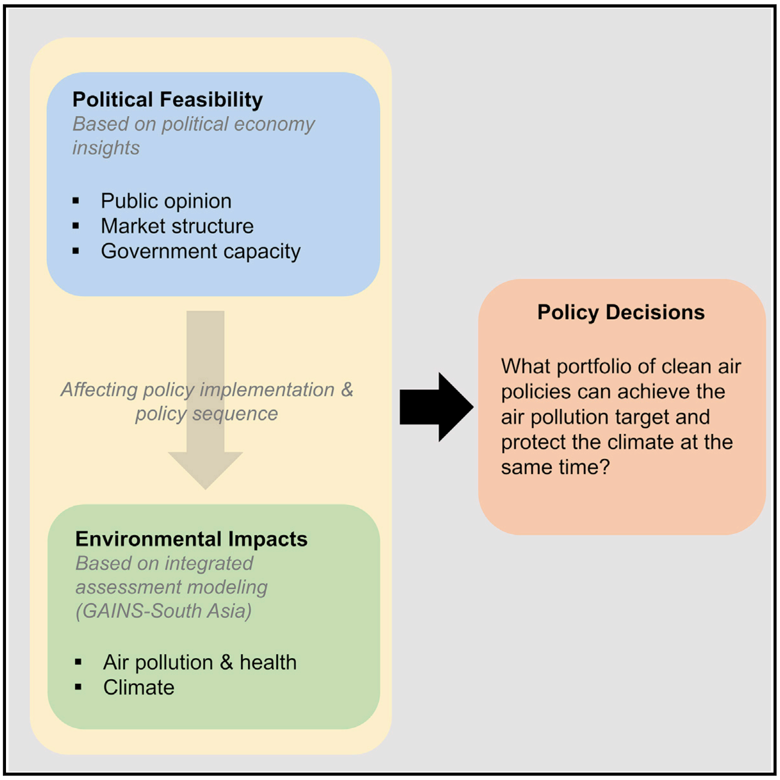
Incorporating political-feasibility concerns into the assessment of India's clean-air policies

Graphical abstract



Highlights

- Clean-air policies in India have varying degrees of political feasibility
- We assess how political feasibility affects air-quality and climate impacts
- We develop a policy tool to integrate political and environmental assessments

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In brief

Political feasibility is at the center of air-pollution policymaking in the developing world. We assess the political feasibility of a wide range of clean-air policies in India and find substantial variations. Such variations have important implications for real-world policy decisions, affecting which policies might be selected and their implementation outcomes. By developing a policy tool (PACE-India) that combines political and environmental assessments, we highlight the importance of political concerns in achieving air-pollution and climate objectives simultaneously.

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Article

Incorporating political-feasibility concerns into the assessment of India's clean-air policies

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SCIENCE FOR SOCIETY Political feasibility is at the center of air-pollution policymaking in the developing world, affecting both the choices of policies and their implementation outcomes. Using India as a test case, we demonstrate how political considerations (e.g., public opinion, market structure, and government capacity) can be incorporated into quantitative models for environmental impact assessment. By examining a wide range of clean-air policies across the electricity, industrial, transportation, residential, and agricultural sectors, we find that policies with a great potential to mitigate air pollution can have varying degrees of political feasibility. Because some lower-feasibility policies also co-reduce carbon emissions (e.g., phasing out existing coal units), considering the effects of political feasibility is particularly important in achieving air-pollution and climate objectives simultaneously.

SUMMARY

Political-feasibility concerns are at the center of real-world air-pollution policymaking. Yet, these concerns are often not represented in leading decision-support tools that have been used for assessing policies' environmental impacts. Focusing on a wide range of clean-air policies in India, we assess their political-feasibility scores on the basis of public opinion, market, and institutional considerations and then incorporate these scores into the evaluation of environmental impacts by using an integrated assessment model (GAINS-South Asia). We demonstrate that although some policies with substantial potential to mitigate air pollution are also highly politically feasible (e.g., replacing solid fuels with cleaner fuels in households), others can be less politically feasible (e.g., banning agricultural waste burning). Because some clean-air policies co-reduce CO_2 emissions and aerosols, considering varying degrees of political feasibility is particularly important in achieving air-pollution and climate objectives simultaneously because of its implications on the implementation scale and policy sequence.

INTRODUCTION

Air pollution is one of the leading public health threats to the developing world. Exposure to air pollution leads to 6.7 million premature deaths every year, of which half occur in China and India.[1] A variety of measures have been proposed and implemented to tackle air pollution, such as installing end-of-pipe controls on power and industrial plants, switching to less-polluting fuels, and improving efficiency to reduce energy use. From the United States and Europe to China, the implementation of these measures has contributed to noticeable improvements in air quality and the associated health burden.[2–4]

As countries take action to clean up the air, these measures can simultaneously affect the global climate system. Some strategies for tackling air pollution, such as switching from fossil to renewable energy, reduce greenhouse gas (GHG) emissions simultaneously.[5–10] However, a net warming effect is anticipated from removing all ambient aerosols,[11–14] which is a major type of air pollutant that affects surface warming by blocking (cooling aerosols such as sulfate) or absorbing (warming aerosols such as black carbon) incoming sunlight. Therefore, there is a growing emphasis among policymakers and analysts on coordinating the efforts to tackle air pollution and climate change.

Nevertheless, real-world policy decisions are almost never made entirely on the basis of environmental considerations. In fact, political feasibility remains at the center of policymaking and affects both the implementation success and the policy sequence.[15] First, policies with stronger political support are generally more successful in implementation. Even when policy measures have substantial technical potential to mitigate air pollution, governments are unlikely to fully implement the policies if they lack institutional capacity or face strong opposition from the public and interest groups.[16] For instance, although India introduced a ban on stubble burning in 2015,[17] the law enforcement has been lax given that no political party is willing to support the crop-burning ban that is likely to antagonize the farming lobby.[18] Second, policies that are more politically feasible are often chosen to be implemented first. For instance, China prioritized end-of-pipe control strategies to clean up the air initially and later turned to strategies for reducing coal consumption. This is largely because installing end-of-pipe controls reduces air pollution while allowing for a continued dependence on coal. The former strategy caused less disruption to domestic coal interest groups than the latter strategy, which requires a transition away from coal.[19]

Yet the decision-support tools that have been used for assessing air-pollution policies often lack the ability to model political considerations. Although these tools are good at characterizing physical factors (such as technology costs and emissions) and natural processes (such as atmospheric transport and chemistry processes), they are poor at representing political factors that shape actual policy choices and implementation outcomes in the real world. Indeed, some models have started to add political aspects,[20,21] but the examples are few. Bringing together a team of modelers and political scientists, we contribute to filling this gap by adding assessment of political feasibility to the quantitative modeling frameworks for environmental impact assessment. Our goal is to increase the utility of these models to inform real-world decisions.

Here, we use India as a test case. India suffers from the worst air quality in the world, such that 1.7 million people die prematurely from exposure to ambient and indoor air pollution in 2019.[1] To tackle the toxic air, the Indian government launched the National Clean Air Program in 2019, aiming for 20%–30% reduction of $PM_{2.5}$ (particulate matter $\leq$ 2.5 μm) and PM_{10} concentration by 2024 relative to 2017 levels.[22] At the same time, India is a major player in the global climate challenge. It is already the world's third largest GHG emitter, and its emissions are expected to increase rapidly in the coming decades with a growing economy and energy demand.[23] Finally, India's political system is an important "tough case" for political feasibility given that the Indian federal structure is highly decentralized and reforms have proved difficult.[24] Lessons about success and failure of policy implementation in India can be applied to other democratic countries with decentralized governance structures, from Brazil and Mexico to Indonesia.

Methodologically, we develop a policy tool (Political Assessment of Clean air and Environmental Policies for India [PACE-India]) to integrate political and environmental assessments on the basis of the following steps:

(1) Use a state-level integrated assessment model (GAINS-South Asia, available at http://gains.iiasa.ac.at) to project the air-pollution and climate impacts of implementing 35 clean-air policies across the power, industry, transportation, residential, and agricultural sectors in 2030 by assuming successful implementation to their maximum technical feasibility (see more in Note S1); we then select the top 12 policies with the greatest potential to mitigate air pollution for further analysis.
(2) Assess the political-feasibility score for each of the 12 policies on the basis of six key metrics related to public opinion, market structure, and government capacity that have been identified to be critical in the political-economy literature.
(3) Re-assess the air-quality and climate impacts of each policy by adjusting the plausible implementation scale on the basis of their political feasibility.
(4) Compare different sequences to implement these policy measures to prioritize air-pollution or political-feasibility considerations.
(5) Identify a desirable set of policies to achieve different combinations of air-pollution and climate targets.

This policy tool is available as Data S1 and from online database; steps 1 and 2 are user-specified inputs, and steps 3–5 are model-calculated outputs.

RESULTS

Twelve policies with the greatest potential to mitigate air pollution

Among the 35 policies included in our initial assessment, the 12 policies with the largest potential to mitigate nationwide air pollution, on the basis of maximum technical feasibility, are summarized in Table 1. Implementing these 12 policies can realize 90% of the total mitigation potential of all 35 policies (see Note S1 and Table S2 for the full list of 35 measures and their impacts). Although a careful evaluation of all current policies goes beyond the scope of our analysis, our selection of policies covers a wide range of key policies across all major emitting sectors, hence providing useful information to inform future priority setting and policy design.

A few of these policies are already high on the Indian government's agenda, as supported by a series of recent welfare policies and air-pollution control policies, including (1) Pradhan Mantri Ujjwala Yojana (PMUY), which provides 80.34 million liquefied petroleum gas (LPG) connections to poor households[25,26] (RES-1); (2) the Swachh Bharat Mission, which built 110 million toilets between 2014 and 2019 to end open defecation[26,27] (RES-2); (3) eliminating all crop-residue burning[26] (AGR-2); and (4) scaling up renewable energy capacity to 175 GW by 2022[26] (POW-1).

Political-feasibility scores

On the basis of the political-economy literature, we consider six metrics in three dimensions (Table 2; for more details, see the experimental procedures):

(1) Public opinion: successful policy implementation requires support from the public; here, we consider one metric to evaluate whether the costs of policy implementation are directly borne by the public.

Table 1. Twelve clean-air policies with the largest mitigation potential among the 35 policies included in the initial assessment

Sector	Abbreviation	Description
Power	POW-1	use incentives to foster extended use of wind, solar, biomass or bagasse, and hydro power for electricity generation and phase out the least efficient coal power plants
	POW-2	introduce state-of-the-art end-of-pipe measures to reduce NO_x emissions from power plants
Industry	IND-1	introduce state-of-the-art end-of-pipe measures to reduce SO_2 and particulate-matter emissions from large-scale industries
	IND-2	encourage centralized waste collection with source separation and treatment, including gas utilization
	IND-3	introduce state-of-the-art end-of-pipe measures to reduce NO_x emissions from large-scale industries
	IND-4	reduce process emissions by upgrading brick kilns to modern technologies
Transportation	TRA-1	seal unpaved road surfaces to reduce fugitive dust from unpaved roads
	TRA-2	enforce mandatory checks and repairs of vehicles
Residential	RES-1	use clean fuels (such as LPG and advanced stoves) for cooking and heating
	RES-2	strictly enforce bans on the open burning of household waste
Agriculture	AGR-1	use urease inhibitors and/or substitute with, for example, ammonium nitrate for more efficient application of fertilizer
	AGR-2	strictly enforce bans on the open burning of agricultural residues

For more information, see Table S1.

(2) Market structure: policy implementation is often easier if it is compatible with the current market structure; here, we include three metrics that measure the expected benefits and costs for the market, the degree of market concentration, and the presence of organized interests.
(3) Government capacity: stronger capacity often yields better implementation outcomes; here, we consider two metrics that measure government concentration and institutional capacity, respectively.

We highlight three issues related to our selection of metrics. First, in this work we focus on political feasibility instead of political will. Political will reflects the government's level of interest in the outcomes that a successful policy reform would generate. Political feasibility, in contrast, is a measure of whether a motivated government can carry out these policy reforms. As such, political will should be separated from political feasibility,[38] and we focus specifically on political feasibility in our assessment. Second, we include institutional capacity as a stand-alone metric to capture the challenge of implementing policies even when they have broad political support. Although institutional capacity is not sufficient for policy implementation in the absence of political support, it is necessary for success, especially where policy implementation is complicated. The 12 policies on our list fit the bill because they require financing, regulatory changes, coordination, and enforcement over time. Therefore, considering institutional capacity is important for understanding the likelihood that a government succeeds in carrying out an emission-reducing policy change. We also note that institutional capacity is to some extent endogenous given that governments can invest in capabilities in policy areas that they consider important.[39] Capacity building is a complex and lengthy process, however, and pre-existing institutional capacity is an important consideration in policy implementation. Finally, we do not include the potential scope of rent seeking on our list of political-feasibility attributes because the literature on rent seeking does not generate clear predictions about the effect of rent-seeking potential on political feasibility.[40] On the one hand, rent seeking can be detrimental when it takes the form of corruption and undermines the quality of public works. For example, a road-paving or waste-management project could be compromised by bribery that allows low-quality contractors to win bids. On the other hand, rent seeking could "grease the wheels" and motivate bureaucrats to approve projects. For example, road paving could be politically feasible specifically because both major infrastructure construction firms and powerful local politicians expect rents from it. Although such projects might not be optimal or cost effective, corruption could lead to emission-reduction activities that would otherwise not get through the political system. Given this lack of definite predictions, we view rent seeking as an important area of future research.

We find the degrees of political feasibility to vary significantly across different clean-air policies with scores ranging from 2 to 12 (Figure 1; see experimental procedures for the general meaning of the scores and Note S2 for detailed justification for each score for each policy). This is because these measures impose costs on different industrial sectors, affect exposure to air pollution in different communities, and are implemented through different government agencies with varying degrees of institutional capacity.

The two policies with the highest political-feasibility scores are RES-1 (i.e., use clean fuels such as LPG and advanced stoves for cooking and heating) and AGR-1 (i.e., improve fertilizer application practices) because they score highly in all aspects of public opinion, market structure, and government capacity. The high scoring for these two policies is consistent with their relatively successful implementation in the real world. For RES-1, India has a massive national program, PMUY, to expand the use of LPG to all households. By subsidizing installation charges and cylinder deposit, this program does not impose any costs on

Table 2. Six metrics on political feasibility

Political-economy considerations	Metrics	Interpretation	Relevant political-economy literature
Public opinion	popular opposition	when the costs of implementing a policy are directly borne by the public, the policy is more likely to face strong popular resistance	Benes et al.,[28] Cheon et al.,[29] Overland[30]
Market structure	market benefit or cost	when the affected industry expects benefits or costs from the policy implementation, the policy is more or less, respectively, likely to be supported by the industry	Benes et al.,[28] Busby and Shidore,[31] Busby et al.[32]
	market concentration	when the affected industry is characterized by a small number of producers and product lines, emission mitigation will be more feasible from a collective-action perspective	Busby and Shidore,[31] Busby et al.,[32] Olson,[33] Mitchell[34]
	organized interests	the presence of an organized interest group representing the affected industry will make implementing a policy easier or more difficult when the industry expects benefits or costs, respectively	Benes et al.,[28] Bernhagen,[35] Grossman and Helpman[36]
Government capacity	government concentration	when the authority over rulemaking and policy-implementation activities are fully centralized, the degree of government concentration is high, which is often beneficial for effective policymaking and implementation; when they are under the control of state governments with or without coordination with the central government, government concentration is medium or low, respectively	Busby and Shidore,[31] Busby et al.,[32] Tsebelis[37]
	institutional capacity	stronger institutional capacity improves the feasibility of implementing a policy	Benes et al.[28]

households, while producers are directly controlled by the central government.[41] Studies found that this program indeed encouraged the adoption of modern cooking gas, although its effect on regular use of LPG remains questionable.[42] For AGR-1, improving the efficiency of fertilizer application involves technical solutions that carry little cost, provided that government support is available. The fertilizer market is highly concentrated, and government capacity to control it is plentiful. In fact, urea is a controlled fertilizer that is highly subsidized at present—the difference between the cost of production and a fixed selling price is now paid as a subsidy to manufacturers. To close the price gap between agricultural and industrial uses and also reduce the use of urea, the Indian government announced a resolution for 100% mandatory neem coating of urea in 2015.[43] The use of neem-coated urea can decrease the urea requirement while increasing the efficiency of nitrogen fertilizer, which brings the environmental benefits of reducing air pollutants and GHG emissions. It also checked the pilferage of heavily subsidized urea by the chemical industry and other applications.

In comparison, the three policies with the lowest political-feasibility scores are POW-2 (i.e., introducing NO_x [nitrogen oxide] control on power plants) and RES-2 and AGR-2 (bans on open burning of residential waste and agricultural residues, respectively). Indeed, we observe implementation challenges for these three policies in India. Regarding POW-2, the political difficulty of controlling air pollution from power plants, especially NO_x emissions, is readily seen in recent developments. Despite the stringent emission standards released in 2015[44] (i.e., 300 mg/Nm^3 for NO_x emissions), power companies continue to claim that this standard is infeasible without the use of sophisticated and expensive technologies such as selective catalytic reduction and selective non-catalytic reduction.[45] As a consequence, the Supreme Court of India recently relaxed the limits for coal-fired power stations commissioned between December 2003 and 2016 from 300 to 450 mg/Nm^3.[46] Because of the cost of retrofitting pollution-control technology and the lack of rigorous enforcement, coal-fired power plants continue to violate the emission rules. Regarding RES-2, given that Indian cities currently burn 2%–24% of their

Policy	Metrics						Aggregate Score (rescaled to 0-12)
	Public Opinion	Market Structure			Government capacity		
	Popular opposition	Market benefit/cost	Market concentration	Organized interest	Government concentration	Institutional capacity	
POW-1	No direct cost (+1)	Market cost (-1)	Not concentrated (-1)	Organized losers (-1)	Middle (0)	Middle (0)	4
POW-2	Direct cost (-1)	Market cost (-1)	Not concentrated (-1)	Organized losers (-1)	Concentrated (+1)	Low capacity (-1)	2
IND-1	No direct cost (+1)	Market cost (-1)	Not concentrated (-1)	No organized losers (+1)	Concentrated (+1)	Low capacity (-1)	6
IND-2	No direct cost (+1)	Market benefit (+1)	Not concentrated (-1)	No organized winners (-1)	Middle (0)	Low capacity (-1)	5
IND-3	No direct cost (+1)	Market cost (-1)	Not concentrated (-1)	No organized losers (+1)	Concentrated (+1)	Low capacity (-1)	6
IND-4	No direct cost (+1)	Market cost (-1)	Not concentrated (-1)	No organized losers (+1)	Middle (0)	Low capacity (-1)	5
TRA-1	No direct cost (+1)	Market benefit (+1)	Not concentrated (-1)	No organized winners (-1)	Middle (0)	High capacity (+1)	7
TRA-2	Direct cost (-1)	Market benefit (+1)	Not concentrated (-1)	Organized winners (+1)	Middle (0)	Low capacity (-1)	5
RES-1	No direct cost (+1)	Market benefit (+1)	Concentrated (+1)	Organized winners (+1)	Concentrated (+1)	High capacity (+1)	12
RES-2	Direct cost (-1)	Market benefit (+1)	Not concentrated (-1)	No organized winners (-1)	Not Concentrated (-1)	Low capacity (-1)	2
AGR-1	No direct cost (+1)	Market benefit (+1)	Concentrated (+1)	Organized winners (+1)	Concentrated (+1)	High capacity (+1)	12
AGR-2	No direct cost (+1)	Market cost (-1)	Not concentrated (-1)	Organized losers (-1)	Not Concentrated (-1)	Low capacity (-1)	2

Figure 1. Political feasibility score for the 12 clean-air policies

Darker blue or black indicates a higher political-feasibility score. We give a score of 1, −1, or 0 if a given dimension is favorable, unfavorable, or neither, respectively, for policy implementation in terms of political feasibility. See the general meaning of the scores in Table 4. A detailed justification for each numerical score for each policy is presented in Note S2. Alternative political-feasibility scores as a robustness check are reported in Notes S4–S6 and Figures S1–S3. The descriptions of the 12 measures are included in Tables 1 and S1.

generated waste per day,[47] municipal waste burning is a major contributor to regional air pollution, especially in urban areas.[48,49] Poor waste-collection efficiency results in the burning of municipal solid waste. The management of household waste is one of the main functions of urban local bodies (ULBs). Although ULBs are required for planning, implementing, and monitoring all systems for managing municipal solid waste, they are constantly striving to meet this challenge with limited financial resources, technical capacities, and land availability. Moreover, a lack of centralized authority results in a patchwork of fragmented policies that often face public opposition because of the costs to the population. Regarding AGR-2, stopping the fires would be costly given that farmers are a politically powerful group. Farmers are spread across the countryside with little concentration and agricultural residue fires cross state boundaries. The government has little capacity to enforce policies in this sector. In fact, there has already been a ban on burning agricultural residue, but state authorities have not been able to entirely stop it. Every year, the air quality in North India deteriorates rapidly when farmers begin to burn the stubble to clear their fields for the next harvest.[50] For instance, according to satellite data, there were 61,332 instances of stubble burning in Punjab, Haryana, and Uttar Pradesh between October and November 2019.[51]

In this study, we test the robustness of our political-feasibility scores by using an alternative weighting method that gives an equal weight to the three dimensions (public opinion, market structure, and government capacity) instead of the six metrics. We find that the measures with the highest and lowest feasibility scores remain robust (see Notes S4–S6 and Figures S1–S3).

Furthermore, recognizing that different decision makers and policy analysts could have different views and assessments, the PACE-India policy tool developed along with this paper allows users to provide their own political-feasibility scores, as well as other choices on political insights and policy targets that would be relevant for later sections (for more details, see the discussion, experimental procedures, and Data S1).

Air-pollution and climate impacts of individual policies

By comparing the policy implementation scenarios with a no-policy scenario that considers only current legislation, we project the nationwide impacts of implementing each individual policy on air pollution (measured by national average exposure level to particulate matter in $\mu g/m^3$) and climate (measured in CO_{2eq} [carbon dioxide equivalent] based on GWP_{100} [100-year global warming potential]) in 2030. Given the environmental impacts of a policy change with the implementation scale,[52] we consider two implementation levels in this paper (note that more options are available in the PACE-India policy tool):

(1) Full implementation to its maximum technical feasibility (e.g., for RES-1, this means that *all* households will use clean fuels such as LPG and advanced stoves for cooking and heating; assumptions for all 12 policies are summarized in Table S1);
(2) Partial implementation assuming a lower implementation rate for policies with a lower political-feasibility score. For simplicity, here we present the result for a linear case where the implementation scale increases from

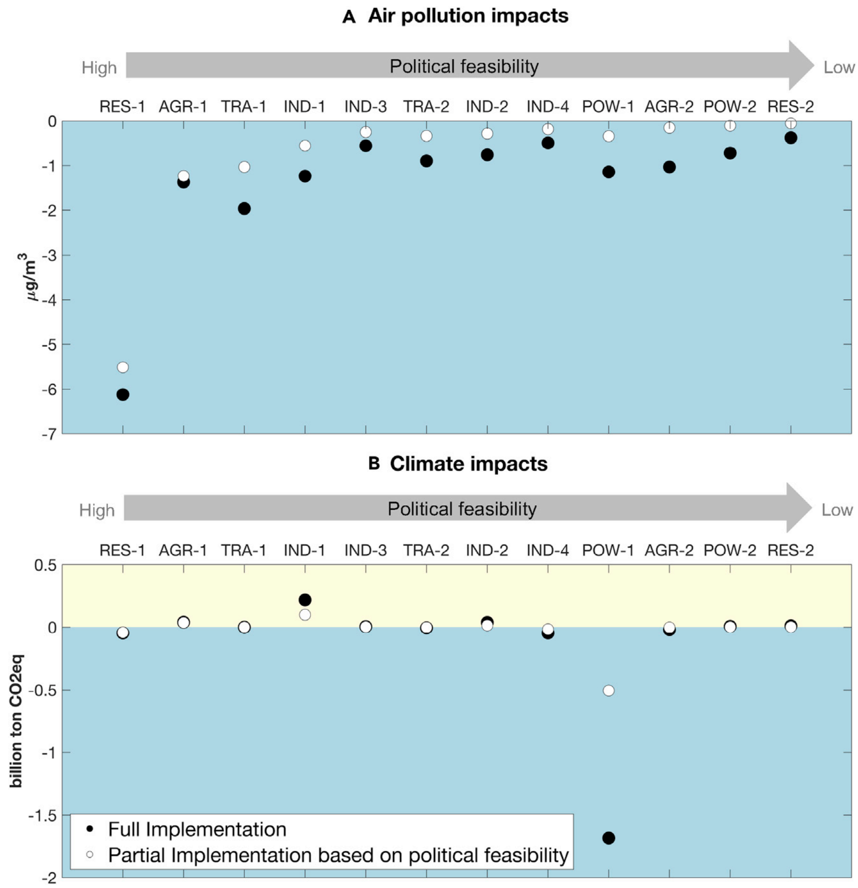

Figure 2. National total air-pollution and climate impacts in 2030 from implementing each of the 12 clean-air policies, as ranked from high (left) to low (right) political-feasibility score

Changes in impacts relative to a no-policy scenario that considers only current legislation. The filled circles indicate the impacts with full implementation to their maximum technical feasibility, and the open circles indicate partial implementation assuming that the implementation rate increases linearly with political-feasibility score (i.e., the implementation rate increases from 0% to 90% as the political-feasibility score increases from 0 to 12). The light-blue areas indicate potential benefits for air quality (a reduction in national average exposure level to particulate matter) or for climate (i.e., a reduction in warming effects). The light-yellow area indicates potential co-harms for the climate (i.e., an increase in warming effects).

0% to 90% as the political-feasibility score increases from 0 to 12. To test alternative shapes, PACE-India also includes four non-linear functional forms to characterize the relationship between political feasibility and the implementation scale (e.g., see Notes S7–S9 and Figures S4–S6 for the results assuming a convex and concave relationship). Although immediately achieving a high implementation rate is challenging given the low starting point at present, it is often an attainable goal in a 10- to 20-year time horizon if it is supported by appropriate policies and interventions. If we take RES-1 as an example, only 48% of India's population had access to clean cooking fuels or technologies in 2018, but with strong policy support, the penetration level by 2030 is expected to reach 90% or higher.[53]

With full implementation (filled circles in Figure 2), some policies that are highly politically feasible also have a great potential to reduce nationwide exposure to air pollution. For instance, RES-1 (i.e., cleaner fuel for cooking and heating) ranks the highest for both the political-feasibility score and the mitigation potential for air-pollution impacts. Yet, other policies with large potential to mitigate air pollution are less politically feasible. For instance, AGR-2 (i.e., bans on the open burning of agricultural residues) is among the policies with the lowest political-feasibility scores despite the substantial air-quality benefits from implementing this policy. In comparison, with partial implementation (open circles), the air-quality benefits almost always decrease with the political-feasibility scores because lower political feasibility reduces the implementation scale and hence the associated improvement in air quality. As such, when the implementation rate is affected by political feasibility, the ranking of the 12 policies based on their political feasibility is similar to their ranking based on air-quality benefits.

The climate impacts from most clean-air policies are small, except for two policies: (1) IND-1 (i.e., SO_2 and PM control in large-scale industry), for which a climate co-harm is expected because of the warming effects from removing inorganic cooling aerosols; and (2) POW-1 (i.e., switching to renewables and phasing out inefficient coal units), for which a climate co-benefit is expected given that increasing zero-emitting renewable power co-reduces GHG emissions. With full implementation, IND-1 increases 2030 GHG emissions by 0.25 billion tons of CO_{2eq}, whereas POW-1 decreases GHG emissions by 1.75 billion tons of CO_{2eq}. The climate impacts of all the measures for partial implementation are lower than for full implementaion as a result of the reduced implementation scale. The difference between full and partial implementation is larger for POW-1 than for IND-1 because POW-1 has a lower political-feasibility score, which results in a greater reduction in the implementation rate and associated climate impacts under partial implementation.

Policy sequences and the cumulative environmental impacts

To assess the cumulative impacts of implementing all 12 policies, we consider three plausible sequences grounded in real-world contexts (Figure 3; note that more options are available in the PACE-India policy tool).

- Sequence 1: from high to low air-quality benefits, assuming full implementation

Table 3. Desirable sets of policies for achieving varying combinations of air-pollution and climate objectives

		Air-pollution objective: Moderate target (i.e., reducing national average exposure by 5.6 μg/m^3)	Air-pollution objective: Ambitious target (i.e., reducing national average exposure by 11.1 μg/m^3)
Climate objective	no consideration	• sequence 1: first policy • sequence 2: first policy • sequence 3: first two policies	• sequence 1: first five policies • sequence 2: first five policies • sequence 3: unattainable
	moderate consideration (i.e., cumulative climate impact is non-warming)		• sequence 1: first five policies • sequence 2: first nine policies • sequence 3: unattainable
	strict consideration (i.e., excluding policies with climate co-harms)	• sequence 1: first policy • sequence 2: first policy • sequence 3: first and fifth policies	unattainable by sequence 1, 2, or 3

Sequence 1: from high to low air-quality benefits, assuming full implementation. Sequence 2: from high to low political feasibility, assuming full implementation. Sequence 3: from high to low air-quality benefits, assuming partial implementation. See Note S3 and Table S3 for the detailed lists of policies following each sequence.

- Sequence 2: from high to low political feasibility, assuming full implementation
- Sequence 3: from high to low air-quality benefits, assuming partial implementation based on political feasibility

Sequence 1 can be viewed as the optimal path to tackling air pollution with no consideration of political feasibility, implementation challenge, or climate impacts. Sequence 2 is the most politically feasible path but does not prioritize air-quality or climate considerations; it also assumes that political feasibility affects only the sequence to implement these policies and not the implementation scale of each policy. Sequence 3 integrates the considerations of both air-pollution benefits and political feasibility; it prioritizes the policies that bring greater air-quality benefits under partial implementation, which are often the policies that are more politically feasible. Here, we further assume that the cumulative impacts are a linear addition of the impacts of each individual policy, although in reality the atmospheric chemistry processes and the transport of pollution can introduce non-linearities (see, e.g., prior studies from China[8,54] and India[55]).

For these 12 policies to be implemented one after another, the cumulative reduction in air-quality impacts is slightly smaller under sequence 2 (based on political feasibility) than under sequence 1 (based on air-quality impacts) until all 12 policies are implemented. This is because some policies that are more politically feasible bring less air-quality benefit (for instance, industrial measures, IND-2 to IND-4). With partial implementation (sequence 3), given that low political feasibility also reduces the implementation scale, the ranking based on air-pollution impacts is similar to the ranking based on political feasibility. As such, the shape of the line for sequence 3 is similar to that of sequence 2, although the magnitude of the air-quality benefits is smaller as a result of partial implementation.

The variations across the three sequences are much more significant for their cumulative climate impacts. Although the net impacts of implementing all 12 policies are a net cooling effect (i.e., climate benefits), only two policies have substantial impacts on climate: one with co-benefits (POW-1) and one with co-harms (IND-1). The cumulative climate impacts largely depend on when these two policies are implemented. In particular, because POW-1 (i.e., switching to renewables and phasing out inefficient coal units) is the key strategy for co-reducing CO_2 emissions, the cumulative climate impacts remain a warming effect until POW-1 is implemented. As such, given that the political-feasibility ranking of POW-1 is relatively low, the cumulative climate impacts become a net cooling effect at a later stage for sequence 2 or 3 (based on their political feasibility or air-quality impacts with partial implementation) than for sequence 1 (based on their air-quality impacts assuming full implementation).

Interactions between policy sequences and policy targets

Despite close connections, mitigating air pollution and mitigating climate change are still largely viewed as two distinctive policy targets in India and elsewhere. Here, we identify the choices and sequences of clean-air policies that can best deliver different combinations of policy targets for air pollution and climate mitigation. For air pollution, we consider a moderate target and an ambitious target, measured as one-third and two-thirds, respectively, of the maximum reduction potential from fully implementing all 12 policies (i.e., a reduction in national average $PM_{2.5}$ exposure of 5.6 and 11.1 μg/m^3, respectively). For the climate objective, we consider three levels of stringency: (1) no consideration, where climate concerns are completely ignored; (2) moderate consideration, where the cumulative climate impacts need to be non-warming; and (3) strict consideration, where policies with climate co-harms (i.e., those policies in the light-yellow area in Figure 2B) are excluded from implementation. Then, for each of the three sequences discussed in the previous section ("policy sequences and the cumulative environmental impacts"), we identify the sets of policies that need to be implemented to achieve these different combinations of air-pollution and climate targets (Table 3).

To achieve a moderate air-pollution target, fully implementing RES-1 (i.e., cleaner fuel for cooking and heating), which has the highest political-feasibility score and the greatest air-quality benefits, can already be successful. Given that switching to clean fuels for heating and cooking also reduces CO_2 emissions, fully implementing RES-1 contributes to the

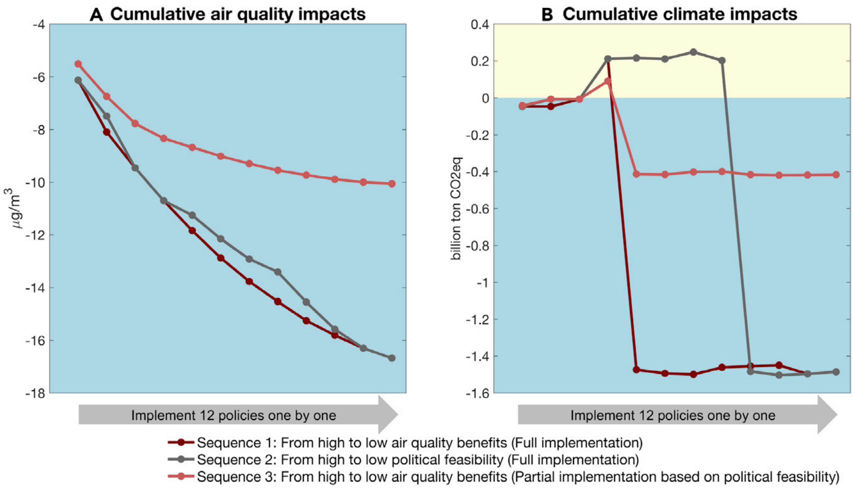

Figure 3. Cumulative impacts of different sequences to implement the 12 clean-air policies

Cumulative national air-pollution (A) and climate (B) impacts in 2030 from implementing the 12 clean-air policies according to three sequences: (1) from high to low air-quality benefits, assuming full implementation (dark red); (2) from high to low political feasibility, assuming full implementation (gray); and (3) from high to low air-quality benefits, assuming partial implementation based on political feasibility (orange-red). The light-blue areas indicate potential benefits for air quality (a reduction in national average exposure level to particulate matter) or for climate (i.e., a reduction in warming effects). The light-yellow area indicates potential co-harms for the climate (i.e., an increase in warming effects). The detailed sequences for the 12 policies are presented in Note S3 and Table S3.

climate objective even under a strict consideration. In comparison, with partial implementation, the moderate air-pollution target can be achieved by implementing both RES-1 and AGR-1 (i.e., improving efficiency of fertilizer application), which is consistent with no or moderate climate consideration (i.e., cumulative climate impacts are non-warming). However, AGR-1 leads to a slight increase in N_2O emissions as a warming gas. Thus, under a strict climate consideration, one needs to skip this policy and implement the next available policy, POW-1 (i.e., increase renewable electricity and phase out inefficient coal units).

In contrast, to achieve an ambitious air-pollution target, many more policies need to be fully implemented (i.e., under sequences 1 and 2). In fact, with partial implementation (i.e., political-feasibility concerns reduce the implementation scale under sequence 3), the ambitious air-pollution target cannot be met even when all 12 policies are implemented.

Furthermore, when an ambitious air-pollution target is combined with a moderate or strict climate target, the options become extremely constrained or even non-existent. For instance, to achieve an ambitious air-pollution target with no climate consideration, five policies need to be fully implemented under sequence 1 (based on air-quality benefits) or sequence 2 (based on political feasibility). With moderate climate consideration, the choices of the five policies remain the same for sequence 1 (based on air-quality benefits); however, one needs to implement the top nine policies under sequence 2 (based on political feasibility) to ensure non-warming effects cumulatively, and implementing these nine policies will overachieve the moderate air-pollution target. Finally, with strict climate consideration, none of the three sequences can achieve the ambitious air-pollution goal given that IND-1, the policy with climate co-harms but substantial air-quality benefits, has to be excluded.

In summary, our analysis indicates that considering the impacts of political feasibility on policy sequence and implementation rate matters the most in achieving an ambitious air-pollution target coupled with a strict climate consideration. This finding underscores that political-feasibility considerations will become particularly important when air-pollution and climate concerns are to be addressed simultaneously.

DISCUSSION

Using India as a test case, we demonstrate that different clean-air policies have varying degrees of political feasibility, which in turn affects their implementation scale and the desirable set of policies for achieving policy targets. Some policies with substantial air-quality benefits are also highly politically feasible, such as switching to cleaner fuels for cooking and heating in households. Other policies seem to be less politically feasible, such as banning the open burning of residential and agricultural waste. Therefore, our results identify the clean-air policies that might need additional efforts to overcome political barriers in order to ensure their implementation success and to achieve the associated improvement in air quality.

In addition, our analysis underscores that political-feasibility concerns are especially critical when the government aims to achieve an ambitious air-pollution control target in combination with some level of climate consideration. Substantial improvement in air quality requires mitigation efforts across all economic sectors, including the implementation of policies that could be less politically feasible. Some air-pollution control measures could bring climate co-benefits (e.g., switching to renewable electricity), whereas others lead to climate co-harms (e.g., reducing industrial SO_2 emissions and associated cooling aerosols). Simultaneously addressing climate concerns will require implementing climate-friendly clean-air policies that are less politically feasible and avoiding climate-unfriendly policies that could be more politically feasible. In the case of India, retiring coal-fired power plants (POW-1) is one such example that is necessary for ensuring a positive climate impact while cleaning up the air, despite its low political feasibility and critical implementation challenges. Without this policy, an effective sequence of policies to reduce air pollution could come at the expense of unsatisfying climate outcomes.

Our study takes a critical step toward integrating political considerations into the environmental impact assessment of policies. Although our political-feasibility scores are assessed on the basis of key insights from the political-economy literature, different policymakers and analysts could have different perspectives on a policy's political feasibility. These scores could

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Table 4. General meaning of –1, 0, and +1 scoring

Political-economy considerations	Metrics	Interpretation of the scores: −1 (unfavorable)	0 (neither favorable nor unfavorable)	+1 (favorable)
Public opinion	popular opposition	the public directly bears the costs of policy implementation	N/A	the public does not bear the costs of policy implementation
Market structure	market benefit or cost	an affected industry expects costs from policy implementation	an affected industry expects neither benefits nor costs from policy implementation	an affected industry expects benefits from policy implementation
	market concentration	the affected sector is not concentrated (i.e., characterized by a large number of producers and product lines that contribute to emissions)	N/A	the affected sector is concentrated (i.e., characterized by a small number of producers and product lines that contribute to emissions)
	organized interests	the industry expects costs and is represented by organized interest groups, or the industry expects benefits but is not represented by organized interest groups	the industry expects neither benefits nor costs	the industry expects benefits and is represented by organized interest groups, or the industry expects costs but is not represented by organized interest groups
Government capacity	government concentration	the government is not concentrated	the level of government concentration is moderate	the government is concentrated
	institutional capacity	the government has low institutional capacity (i.e., administrative apparatus for implementing a given policy)	the government has a medium level of institutional capacity (i.e., administrative apparatus for implementing a given policy)	the government has high institutional capacity (i.e., administrative apparatus for implementing a given policy)

N/A, not applicable.

also change over time as the economic, social, and political environments evolve. To embrace diverse opinions and provide a transparent platform for such debates, the PACE-India policy tool allows users to (1) provide their own political-feasibility score for each policy, (2) specify how political feasibility could affect the implementation scale, (3) choose the ranking method to decide the policy sequence, and (4) set the policy targets for mitigating air pollution and climate change. On the basis of the political insights and policy targets specified by users, the tool will demonstrate how these choices will affect the decisions on clean-air policies and the resulting implications on air quality and climate. PACE-India thus provides a concrete example of combining political and environmental assessments in a quantitative and transparent manner. By enabling users to offer their own insights, it also creates an opportunity to generate actionable knowledge to inform real-world policies that are both politically viable and environmentally friendly.

To encourage further integration of the political economy and environmental modeling communities, we highlight three directions of future research for India and globally. First, given that state governments are leading many of the policymaking and implementation efforts in India, incorporating local factors to assess political feasibility at the state level would be useful in providing relevant information for decision makers on the ground. We have treated India as a national unit and have only considered center-state interactions insofar as they affect the integration or fragmentation of markets and regulations. In reality, different Indian states face very different circumstances. Second, although we do not assess the economic cost of implementing each policy, high costs are often a critical obstacle, especially for large-scale implementation. We encourage future research to add cost consideration, especially how the costs could evolve in the future in response to technology innovation and economy of scale (e.g., learning by doing). These costs estimates can, in turn, improve our estimation of political feasibility given that low costs tend to encourage deployment. Finally, here we use simple assumptions to assess in a stylized way the impacts of political feasibility on the implementation scale and policy sequence. Other forms of policy intervention, such as subsidy programs, can overcome the political barriers and increase implementation. The policies analyzed here can also be considered in their constituent parts. For example, the political difficulties of moving away from coal stem far less from adding renewable power-generation capacity and more from displacing coal-fired power-generation capacity.

In addition, multiple policies are often implemented simultaneously to achieve air-pollution goals instead of strictly one after another, as we assume in this study. Future studies should consider these dynamics in a more sophisticated way to improve the representation of policymaking and implementation processes in the modeling setup.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Further information and requests for resources should be directed to and will be fulfilled by the lead contact, Dr. Wei Peng (weipeng@psu.edu).

Materials availability

This study did not generate new unique materials.

Data and code availability

All relevant data and codes are included in the Excel-based policy tool PACE-India. This tool is available as Data S1 and from the online database: Peng, Wei (2021), "PACE-India", Mendeley Data, V1, https://doi.org/10.17632/nngbkydf95.1. The GAINS-South Asia model can be accessed at https://gains.iiasa.ac.at/models/.

Assessment of air-pollution and climate impacts

We used a state-level integrated assessment model, GAINS-South Asia, to assess the impacts on air pollution and GHG emissions on the basis of 2030 projections of socioeconomic patterns, energy system changes, and air-pollution strategies. The GAINS model quantifies the emissions and impacts of nine air pollutants (SO_2, NO_x, $PM_{2.5}$, PM_{10}, black carbon, organic carbon, CO, NH_3, and volatile organic compounds) and six GHGs (CO_2, CH_4, N_2O, hydrofluorocarbons, perfluorocarbons, and SF_6). The model explores the impacts of more than 1,500 specific measures on multiple air pollutants and GHGs, identifies trade-offs and win-win measures, and assesses their impacts on ambient air quality, population exposure, and various climate metrics. The GAINS model has been utilized for government consultations and in a wide range of academic publications to assess the impacts of air pollution and climate change.[3,56–60] A detailed description of the GAINS-South Asia model is included in the supplemental experimental procedures.

Following the methodology and assumptions in UNEP (2019),[61] we assessed the impacts of implementing each individual policy to its maximum technical feasibility by comparing it with a current legislation scenario. The detailed assumptions for maximum technical feasibility are summarized in Table S1. The projections of future economic activity, energy use, and agricultural production are derived from the 2016 World Energy Outlook Special Report: Energy and Air Pollution.[62] For air-pollution impacts, GAINS-South Asia uses a state-level source-receptor matrix derived from the atmospheric chemistry and transport model, European Monitoring and Evaluation Programme, to evaluate the impacts of emissions on ambient pollution. We used the national average exposure level to ambient and indoor particulate matter to estimate the air-pollution impacts (measured in $\mu g/m^3$). For climate impacts, we used the long-term radiative forcing estimates for GHGs and aerosols to calculate the aggregate radiative forcing effects (measured in CO_{2eq}, assuming GWP_{100}). Although these impacts were assessed at the state level, we aggregated them to the national level for our main results.

To consider the impacts of partial implementation when political feasibility affects the implementation rate, we present a linear case whereby the implementation scale increases from 0% to 90% as the political-feasibility score increases from 0 to 12. Four alternative non-linear relationships are available from the PACE-India tool, two of which are presented in Notes S7–S9 and Figures S4–S6. We assume that the air-pollution and climate impacts scale up proportionally with the implementation scale (i.e., 90% implementation leads to 90% of the impacts). This assumption could result in uncertainties as a result of the non-linear formation of secondary aerosols from primary emissions as well as the non-linear transport of pollution.[8,54,55]

Assessment of political feasibility

We measured the political-feasibility score for each policy by adding the scores of six metrics: public opinion, market benefit, market concentration, organized interests, government concentration, and institutional capacity. These six metrics represent three types of political-economy considerations: public opinion, market structure, and government capacity. Table 4 explains the general meaning of −1, 0, and +1 scoring. Justification and reasoning in support of the scoring for each metric and policy are discussed thoroughly in Note S2. An alternative weighting method as a robustness check can be found in Notes S4–S6 and Figures S1–S3.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2021.07.004.

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AUTHOR CONTRIBUTIONS

W.P, S.E.K., J.U., and F.W. conceived and designed the analysis. W.P. and S.E.K. performed the analysis. F.W. and P.P. provided important data for this analysis. W.P. led the writing of the manuscript with input from all authors. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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REFERENCES

1. Murray, C.J.L., Aravkin, A.Y., Zheng, P., Abbafati, C., Abbas, K.M., Abbasi-Kangevari, M., Abd-Allah, F., Abdelalim, A., Abdollahi, M., Abdollahpour, I., et al. (2020). Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet *396*, 1223–1249. https://doi.org/10.1016/S0140-6736(20)30752-2.
2. US Environmental Protection Agency (2011). The benefits and costs of the clean air act from 1990 to 2020. https://www.epa.gov/sites/production/files/2015-07/documents/summaryreport.pdf.
3. Amann, M. (2018). Progress towards the achievement of the EU's air quality and emissions objectives. Laxenburg Austria IIASA. https://ec.europa.eu/environment/air/pdf/clean_air_outlook_overview_report.pdf.
4. Zhang, Q., Zheng, Y., Tong, D., Shao, M., Wang, S., Zhang, Y., Xu, X., Wang, J., He, H., Liu, W., et al. (2019). Drivers of improved $PM_{2.5}$ air quality in China from 2013 to 2017. Proc. Natl. Acad. Sci. USA *116*, 24463. https://doi.org/10.1073/pnas.1907956116.
5. Yang, J., Li, X., Peng, W., Wagner, F., and Mauzerall, D.L. (2018). Climate, air quality and human health benefits of various solar photovoltaic deployment scenarios in China in 2030. Environ. Res. Lett. *13*, 064002. https://doi.org/10.1088/1748-9326/aabe99.
6. Nam, K.-M., Waugh, C.J., Paltsev, S., Reilly, J.M., and Karplus, V.J. (2013). Carbon co-benefits of tighter SO_2 and NO_x regulations in China. Glob. Environ. Change *23*, 1648–1661. https://doi.org/10.1016/j.gloenvcha.2013.09.003.
7. Gu, A., Teng, F., and Feng, X. (2018). Effects of pollution control measures on carbon emission reduction in China: evidence from the 11th and 12th

Five-Year Plans. Clim. Policy *18*, 198–209. https://doi.org/10.1080/14693062.2016.1258629.

8. Peng, W., Yang, J., Lu, X., and Mauzerall, D.L. (2018). Potential co-benefits of electrification for air quality, health, and CO_2 mitigation in 2030 China. Appl. Energy *218*, 511–519. https://doi.org/10.1016/j.apenergy.2018.02.048.
9. Bhanarkar, A.D., Purohit, P., Rafaj, P., Amann, M., Bertok, I., Cofala, J., Rao, P.S., Vardhan, B.H., Kiesewetter, G., Sander, R., et al. (2018). Managing future air quality in megacities: Co-benefit assessment for Delhi. Atmos. Environ. *186*, 158–177. https://doi.org/10.1016/j.atmosenv.2018.05.026.
10. Reynolds, C.C.O., and Kandlikar, M. (2008). Climate impacts of air quality policy: switching to a natural gas-fueled public transportation system in New Delhi. Environ. Sci. Technol. *42*, 5860–5865. https://doi.org/10.1021/es702863p.
11. Myhre, G., Shindell, D., Bréon, F.M., Collins, W., Fuglestvedt, J., Huang, J., Koch, D., Kanarque, J.F., Lee, D., Mendoza, B., et al. (2013). Anthropogenic and natural radiative forcing. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, T.F. Stocker, N. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, eds. (Cambridge University Press), pp. 659–740.
12. Arneth, A., Unger, N., Kulmala, M., and Andreae, M.O. (2009). Clean the air, heat the planet? Science *326*, 672. https://doi.org/10.1126/science.1181568.
13. Myhre, G., Aas, W., Cherian, R., Collins, W., Faluvegi, G., Flanner, M., Forster, P., Hodnebrog, Ø., Klimont, Z., Lund, M.T., et al. (2017). Multi-model simulations of aerosol and ozone radiative forcing due to anthropogenic emission changes during the period 1990-2015. Atmos. Chem. Phys. *17*, 2709–2720. https://doi.org/10.5194/acp-17-2709-2017.
14. Dang, R., and Liao, H. (2019). Radiative forcing and health impact of aerosols and ozone in China as the consequence of clean air actions over 2012-2017. Geophys. Res. Lett. *46*, 12511–12519. https://doi.org/10.1029/2019GL084605.
15. Rabe, B.G. (2018). Can We Price Carbon? (MIT Press).
16. Aklin, M., and Urpelainen, J. (2018). Renewables: The Politics of a Global Energy Transition (MIT Press).
17. Yadav, R.S. (2019). Stubble burning: a problem for the environment, agriculture and humans. DowntoEarth https://www.downtoearth.org.in/blog/agriculture/stubble-burning-a-problem-for-the-environment-agriculture-and-humans-64912.
18. Prakash, A., and Dolsak, N. (2019). Delhi's air pollution: a failure of democratic governance. Glob. Asia *14*, 14–19. https://www.globalasia.org/v14no4/cover/delhis-air-pollution-a-failure-of-democratic-governance_aseem-prakashnives-dol%C5%A1ak.
19. He, G., Lin, J., Zhang, Y., Zhang, W., Larangeira, G., Zhang, C., Peng, W., Liu, M., and Yang, F. (2020). Enabling a rapid and just transition away from coal in China. One Earth *3*, 187–194. https://doi.org/10.1016/j.oneear.2020.07.012.
20. Geels, F.W., McMeekin, A., and Pfluger, B. (2020). Socio-technical scenarios as a methodological tool to explore social and political feasibility in low-carbon transitions: bridging computer models and the multi-level perspective in UK electricity generation (2010-2050). Technol. Forecast. Soc. Change *151*, 119258. https://doi.org/10.1016/j.techfore.2018.04.001.
21. Keppo, I., Butnar, I., Bauer, N., Caspani, M., Edelenbosch, O., Emmerling, J., Fragkos, P., Guivarch, C., Harmsen, M., Lefèvre, J., et al. (2021). Exploring the possibility space: taking stock of the diverse capabilities and gaps in integrated assessment models. Environ. Res. Lett. *16*, 053006. https://doi.org/10.1088/1748-9326/abe5d8.
22. Government of India Ministry of Environment, Forest and Climate Change (2019). Government launches national clean air programme (NCAP). https://pib.gov.in/pressreleaseiframepage.aspx?prid=1559384.
23. Dubash, N.K., Khosla, R., Rao, N.D., and Bhardwaj, A. (2018). India's energy and emissions future: an interpretive analysis of model scenarios. Environ. Res. Lett. *13*, 074018. https://doi.org/10.1088/1748-9326/aacc74.
24. Jenkins, R. (1999). Democratic Politics and Economic Reform in India (Cambridge University Press).
25. Bhaskar, U. (2019). NDA Ujjwala surpasses targets, provides 80.33 million LPG connections. mint, September 9, 2019. https://www.livemint.com/news/india/nda-ujjwala-surpasses-targets-provides-80-33-million-lpg-connections-1568006076964.html.
26. Bharatiya Janata Party (2019). Sankalp patra (manifesto). https://s3.documentcloud.org/documents/5798075/Bjp-Election-2019-Manifesto-English.pdf.
27. Langa, M. (2019). Prime Minister Modi declares country open defecation-free. The Hindu https://www.thehindu.com/news/national/india-open-defecation-free-says-narendra-modi/article29576776.ece.
28. Benes, K., Cheon, A., Urpelainen, J., and Yang, J. (2015). Low oil prices: an opportunity for fuel subsidy reform, Center on Global Energy Policy working paper https://energypolicy.columbia.edu/sites/default/files/Fuel%20Subsidy%20Reform_October%202015.pdf.
29. Cheon, A., Urpelainen, J., and Lackner, M. (2013). Why do governments subsidize gasoline consumption? An empirical analysis of global gasoline prices, 2002-2009. Energy Policy *56*, 382–390. https://doi.org/10.1016/j.enpol.2012.12.075.
30. Overland, I. (2010). Subsidies for fossil fuels and climate change: a comparative perspective. Int. J. Environ. Stud. *67*, 303–317. https://doi.org/10.1080/00207233.2010.492143.
31. Busby, J.W., and Shidore, S. (2017). When decarbonization meets development: the sectoral feasibility of greenhouse gas mitigation in India. Energy Res. Soc. Sci. *23*, 60–73. https://doi.org/10.1016/j.erss.2016.11.011.
32. Busby, J., Gao, X., and Shidore, S. (2018). Turning the carbon supertanker: sectoral feasibility of climate change mitigation in China. Energy Res. Soc. Sci. *37*, 198–210. https://doi.org/10.1016/j.erss.2017.09.003.
33. Olson, M. (1965). The Logic of Collective Action: Public Goods and the Theory of Groups (Harvard University Press).
34. Mitchell, R.B. (2008). International Environmental Politics (Sage).
35. Bernhagen, P. (2012). Air pollution and business political influence in fifteen OECD countries. Environ. Plan. C Gov. Policy *30*, 362–380. https://doi.org/10.1068/c11179b.
36. Grossman, G.M., and Helpman, E. (2001). Special Interest Politics (MIT Press).
37. Tsebelis, G. (2002). Veto Players: How Political Institutions Work (Russell Sage Foundation).
38. Meltsner, A.J. (1972). Political feasibility and policy analysis. Public Adm. Rev. *32*, 859–867. https://doi.org/10.2307/974646.
39. Aklin, M., Bayer, P., Harish, S.P., and Urpelainen, J. (2018). Escaping the Energy Poverty Trap: When and How Governments Power the Lives of the Poor (MIT Press).
40. Shleifer, A., and Vishny, R.W. (1993). Corruption. Q. J. Econ. *108*, 599–617. https://doi.org/10.2307/2118402.
41. Sharma, A., Parikh, J., and Singh, C. (2019). Transition to LPG for cooking: a case study from two states of India. Energy Sustain. Dev. *51*, 63–72. https://doi.org/10.1016/j.esd.2019.06.001.
42. Kar, A., Pachauri, S., Bailis, R., and Zerriffi, H. (2019). Using sales data to assess cooking gas adoption and the impact of India's Ujjwala programme in rural Karnataka. Nat. Energy *4*, 806–814. https://doi.org/10.1038/s41560-019-0429-8.
43. Cabinet Committee on Economic Affairs (2018). Cabinet approves continuation of ongoing urea subsidy scheme beyond 12th Five Year Plan. India New Delhi. https://pib.gov.in/PressReleasePage.aspx?PRID=1524417.

44. The Gazette of India (2015). Ministry of Environment, Forest and Climate Change (MoEFCC) Notification Extraordinary. Regd. No. D. L.-33004/99 (Government of India Press).

45. Pathania, R. (2018). Why is there no serious discussion on NO_x control in the power sector? DowntoEarth. https://www.downtoearth.org.in/blog/air/why-is-there-no-serious-discussion-on-nox-control-in-the-power-sector–61052.

46. Ramanathan, S. (2020). Experts flag dilution of NO_x emission limit for coal-fired power stations. DowntoEarth. https://www.downtoearth.org.in/news/pollution/experts-flag-dilution-of-nox-emission-limit-for-coal-fired-power-stations-72254.

47. Nagpure, A.S., Ramaswami, A., and Russell, A. (2015). Characterizing the spatial and temporal patterns of open burning of municipal solid waste (MSW) in Indian cities. Environ. Sci. Technol. *49*, 12904–12912. https://doi.org/10.1021/acs.est.5b03243.

48. Saikawa, E., Wu, Q., Zhong, M., Avramov, A., Ram, K., Stone, E.A., Stockwell, C.E., Jayarathne, T., Panday, A.K., and Yokelson, R.J. (2020). Garbage burning in South Asia: how important is it to regional air quality? Environ. Sci. Technol. *54*, 9928–9938. https://doi.org/10.1021/acs.est.0c02830.

49. Sharma, G., Sinha, B., Pallavi, Hakkim, H., Chandra, B.P., Kumar, A., and Sinha, V. (2019). Gridded emissions of CO, NO_x, SO_2, CO_2, NH_3, HCl, CH_4, $PM_{2.5}$, PM_{10}, BC, and NMVOC from open municipal waste burning in India. Environ. Sci. Technol. *53*, 4765–4774. https://doi.org/10.1021/acs.est.8b07076.

50. Singh, J., Singhal, N., Singhal, S., Sharma, M., Agarwal, S., and Arora, S. (2018). Environmental implications of rice and wheat stubble burning in North-Western states of India. In Advances in Health and Environment Safety, N.A. Siddiqui, S.M. Tauseef, and K. Bansal, eds. (Springer Singapore), pp. 47–55.

51. (2020). Economic Survey 2019-20: stubble burning incidents come down. The Hindu https://www.thehindu.com/news/national/stubble-burning-incidents-come-down/article30705487.ece.

52. Peng, W., Dai, H., Guo, H., Purohit, P., Urpelainen, J., Wagner, F., Wu, Y., and Zhang, H. (2020). The critical role of policy enforcement in achieving health, air quality, and climate benefits from India's clean electricity transition. Environ. Sci. Technol. *54*, 11720–11731. https://doi.org/10.1021/acs.est.0c01622.

53. International Energy Agency (2019). SDG7: data and projections. https://www.iea.org/reports/sdg7-data-and-projections.

54. Peng, W., Yang, J., Wagner, F., and Mauzerall, D.L. (2017). Substantial air quality and climate co-benefits achievable now with sectoral mitigation strategies in China. Sci. Total Environ. *598*, 1076–1084. https://doi.org/10.1016/j.scitotenv.2017.03.287.

55. Chen, K., Guo, H., Hu, J., Kota, S., Deng, W., Ying, Q., Myllyvirta, L., Dahiya, S., and Zhang, H. (2019). Projected air quality and health benefits from future policy interventions in India. Resour. Conserv. Recycl. *142*, 232–244. https://doi.org/10.1016/j.resconrec.2018.12.008.

56. Amann, M., Purohit, P., Bhanarkar, A.D., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Kiesewetter, G., Klimont, Z., Liu, J., et al. (2017). Managing future air quality in megacities: a case study for Delhi. Atmos. Environ. *161*, 99–111. https://doi.org/10.1016/j.atmosenv.2018.05.026.

57. Purohit, P., Amann, M., Mathur, R., Gupta, I., Marwah, S., Verma, V., Bertok, I., Borken-Kleefeld, J., Chambers, A., Cofala, J., et al. (2010). GAINS-Asia: Scenarios for Cost-Effective Control of Air Pollution and Greenhouse Gases in India (IIASA). http://pure.iiasa.ac.at/id/eprint/9379/1/XO-10-061.pdf.

58. Purohit, P., Amann, M., Kiesewetter, G., Rafaj, P., Chaturvedi, V., Dholakia, H.H., Koti, P.N., Klimont, Z., Borken-Kleefeld, J., Gomez-Sanabria, A., et al. (2019). Mitigation pathways towards national ambient air quality standards in India. Environ. Int. *133*, 105147.

59. Wagner, F., Amann, M., Borken-Kleefeld, J., Cofala, J., Höglund-Isaksson, L., Purohit, P., Rafaj, P., Schöpp, W., and Winiwarter, W. (2012). Sectoral marginal abatement cost curves: implications for mitigation pledges and air pollution co-benefits for Annex I countries. Sustain. Sci. *7*, 169–184. https://doi.org/10.1016/j.envint.2019.105147.

60. Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P., et al. (2011). Cost-effective control of air quality and greenhouse gases in Europe: modeling and policy applications. Environ. Model. Softw. *26*, 1489–1501. https://doi.org/10.1016/j.envsoft.2011.07.012.

61. United Nations Environment Programme. (2019). Air pollution in Asia and the Pacific: science-based solutions. https://wedocs.unep.org/handle/20.500.11822/26861.

62. International Energy Agency (2016). Energy and air pollution: World Energy Outlook special report. https://www.iea.org/reports/energy-and-air-pollution.