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Perverse effects of carbon markets on HFC-23 and SF_6 abatement projects in Russia

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Carbon markets are considered a key policy tool to achieve cost-effective climate mitigation[1,2]. Project-based carbon market mechanisms allow private sector entities to earn tradable emissions reduction credits from mitigation projects. The environmental integrity of project-based mechanisms has been subject to controversial debate and extensive research[1,3–9], in particular for projects abating industrial waste gases with a high global warming potential (GWP). For such projects, revenues from credits can significantly exceed abatement costs, creating perverse incentives to increase production or generation of waste gases as a means to increase credit revenues from waste gas abatement[10–14]. Here we show that all projects abating HFC-23 and SF_6 under the Kyoto Protocol's Joint Implementation mechanism in Russia increased waste gas generation to unprecedented levels once they could generate credits from producing more waste gas. Our results suggest that perverse incentives can substantially undermine the environmental integrity of project-based mechanisms and that adequate regulatory oversight is crucial. Our findings are critical for mechanisms in both national jurisdictions and under international agreements.

The Kyoto Protocol's project-based mechanisms, the Clean Development Mechanism (CDM) for emission reductions projects in developing countries and Joint Implementation (JI) for projects in industrialized countries, provided industrialized countries flexibility in meeting their greenhouse gas (GHG) reduction commitments. Numerous sub-national and national jurisdictions are implementing similar mechanisms around the world, often in combination with emissions trading schemes[2].

Projects abating waste gases with a high global warming potential (GWP) can generate large volumes of emission reductions at low abatement costs[1,15]. Under the CDM, the two largest waste gas project types—incineration of hydrofluorocarbon-23 (HFC-23) from hydrochlorofluorocarbon-22 (HCFC-22) production and destruction of nitrous oxide (N_2O) from adipic acid production—account for only 0.3% of the registered projects but generated about half of the 1.5 billion emission reduction credits issued so far[16]. For such projects, revenues from credits can significantly exceed GHG abatement costs and, in some instances, the costs of producing the main product[10,11]. This can create perverse incentives for plant operators to increase production or waste generation beyond levels that would occur in the absence of crediting[12–14,17]. If more waste gas is generated owing to the incentives from crediting, emission reductions are overestimated; the emissions baseline is inflated compared to the emissions that would actually occur without crediting, and, in consequence, excess credits are issued.

Such perverse incentives can be avoided through appropriate safeguards in methodological standards for the calculation of emission reductions, mainly by capping the amount of production and waste generation to historically observed levels or conservative benchmarks for the purpose of calculating emission reductions. Under the CDM, safeguards to prevent perverse incentives were gradually introduced and strengthened over time, following observations that the initial safeguards may not have been adequate[13,14,18]. Whereas the CDM requires using internationally agreed standards and international approval for registering projects and issuing credits, JI allows using a project-specific approach for calculating emission reductions, and either the host countries or the international Joint Implementation Supervisory Committee (JISC) execute regulatory oversight. Under host country oversight, countries can largely establish their own rules for approving projects and issuing credits without international oversight. The host country can determine whether it deems emission reductions as additional. Under international oversight, the JISC oversees project approval and issuance of credits.

This Letter assesses perverse incentives in the context of JI. We evaluate JI projects that incinerate high GWP waste gases, as these project types were particularly vulnerable to perverse incentives under the CDM. Four such projects were registered under JI, all of them under host country oversight. They account for 54 out of the 863 million credits issued to the 604 JI projects registered as of 1 April 2015 (ref. 16). The four projects involve five plants: two hydrochlorofluorocarbon-22 (HCFC-22) and two sulphur hexafluoride (SF_6) production plants in Russia, and one trifluoroacetic acid (TFA) production plant in France. The production of HCFC-22 generates hydrofluorocarbon-23 (HFC-23) as an unwanted waste gas; in the production of SF_6 a waste stream of SF_6 is generated at rectification; and the production of TFA generates various unwanted fluorinated waste gases. The amount of waste gas generated depends on the production level of the main product—HCFC-22, SF_6 and TFA—and the waste generation rate, which is defined as the quantity (mass) of waste gas generated per quantity (mass) of product produced[14]. The waste generation rate depends on factors, such as plant design, product purity requirements, and degree of process optimization[19]. In the absence of regulations, incentives, or voluntary commitments by the industry, the waste gases are usually vented to the atmosphere. The five registered JI plants capture and incinerate these waste gases (see Supplementary Documentation).

The plant in France aimed to address perverse incentives by capping the emission reductions to the historical emissions of the installation. However, data on historical and monitored production and waste gas generation are not available to assess whether the cap adequately prevented perverse incentives.

Three plants in Russia initially applied caps on the production and waste generation rate to avoid perverse incentives, drawing upon CDM standards. In the second quarter of 2011, the plant operators decided to retroactively change the way emission reductions

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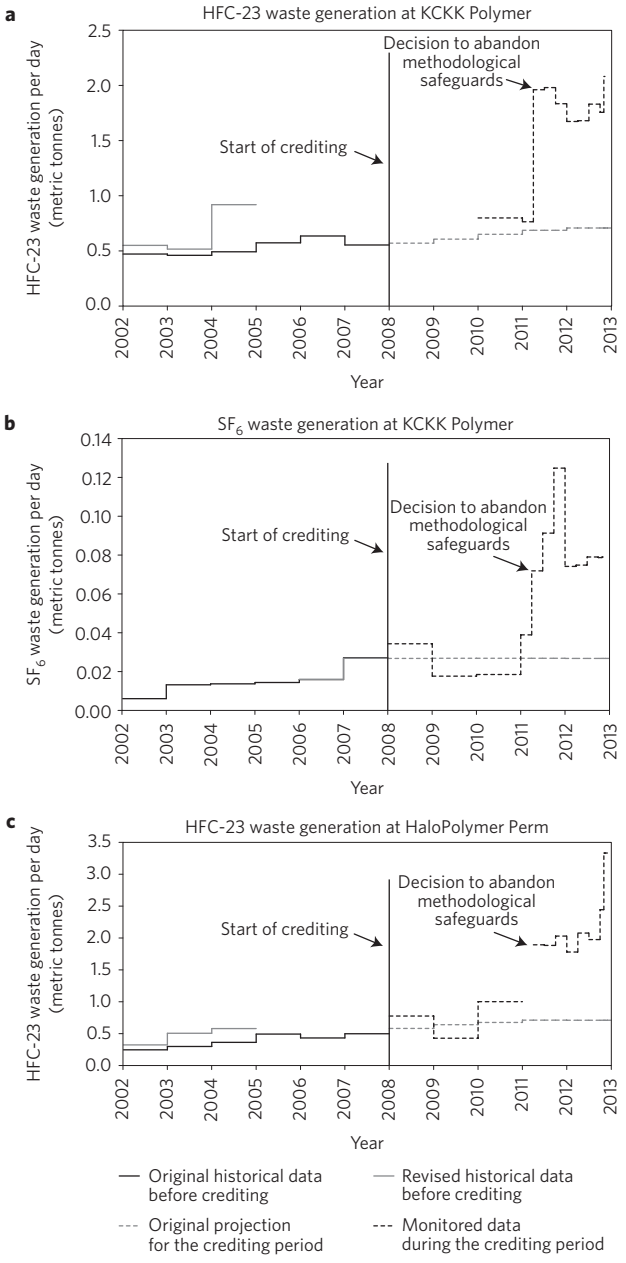

Figure 1 | HFC-23 and SF_6 waste generation at three plants in Russia. **a**, HFC-23 waste generation at the KCKK Polymer plant. **b**, SF_6 waste generation at the KCKK Polymer plant. **c**, HFC-23 waste generation at the HaloPolymer Perm plant. Waste generation increased in all three plants beyond previously reported levels when plant operators decided in 2011 to abandon methodological safeguards to prevent perverse incentives.

are calculated as of 1 January 2010, removing the caps and crediting all waste gas destroyed. Moreover, data and information provided in the original project documentation was considered incorrect, or not applicable, and replaced (see Supplementary Information). Figure 1 shows that waste gas generation increased in all three facilities to unprecedented levels compared to both historical and originally projected levels, after abandoning methodological safeguards in 2011.

The project at the fourth plant in Russia was developed and approved in 2011/2012 and claimed credits retroactively as of 1 January 2008. The project did not apply any methodological safeguards to avoid perverse incentives; all waste gas destroyed was credited. For the period 2008 to 2010, for which data on both

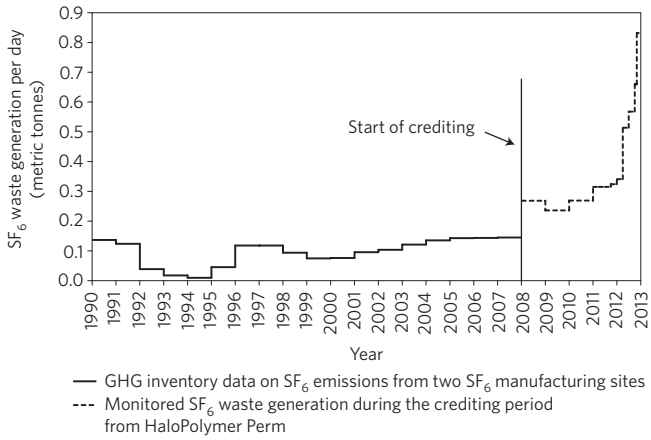

Figure 2 | SF_6 waste generation at the HaloPolymer Perm plant. The GHG inventory data includes emissions from both SF_6 production plants in Russia (KCKK Polymer and HaloPolymer Perm). After the start of crediting, the waste generation from HaloPolymer Perm increased beyond historical emission levels reported in the Russian GHG inventory from both plants.

SF_6 production and SF_6 waste generation are available, the average waste generation rate was 16.9%, which considerably exceeds the default value of 0.2% suggested by the Intergovernmental Panel on Climate Change (IPCC; ref. 20) or the average historical waste generation rate of 2.0% observed at the KCKK Polymer plant. A comparison with GHG inventory data reported by Russia to the United Nations Framework Convention on Climate Change (UNFCCC; ref. 21) shows that waste generation significantly increased with the implementation of the JI project (Fig. 2). Before project implementation, the GHG inventory emissions from SF_6 manufacturing—which cover both SF_6 plants and which may not only include waste gas emissions from SF_6 production but also emissions from handling of SF_6 at the production site, and thus represent the upper end of the possible range—varied between 4 and 53 tonnes of SF_6 over the period 1990 to 2007, whereas after project implementation the plant reported an average annual waste gas generation of 117 tonnes of SF_6.

The abrupt increase occurred in all four plants exactly at the point in time when plant operators could generate (more) credits by producing more waste gas, and higher levels of waste generation were sustained thereafter. The increase in waste generation is mostly attributable to an increase in the waste generation rate, and not in production levels (see Supplementary Information). There was also no reporting of any changes in plant capacity, design, or product specifications which might have affected the waste generation rate. Without credit revenues, plant operators would have economic incentives to reduce rather than increase waste generation[13,14].

Absent methodological safeguards to prevent perverse incentives, increasing waste gas generation beyond levels that would occur in the absence of crediting leads to excess issuance of credits. The extent of such over-crediting is uncertain; it depends on how much waste gas the plants would otherwise have generated. We assess the magnitude of over-crediting using three scenarios to estimate the plausible range of waste gas generation that would have occurred in the absence of crediting (see Methods). We conclude that, in the periods where methodological safeguards were not applied, about 28 to 33 million credits were issued in excess, corresponding to 66 to 79% of the credits issued for these periods.

Several lessons can be learned from this analysis. First, although previous research indicated that perverse incentives affected plant operations, the extent and implications were more confined[13,17,18]. Our results suggest that perverse incentives arising from project-based mechanisms can have rather substantial adverse impacts on environmental integrity, with about two-thirds of the credits

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being issued in excess in periods when no safeguards were applied. Second, regulatory oversight by the host country alone may not be sufficient to ensure environmental integrity. Under the Kyoto Protocol, Russia had no incentives to ensure environmental integrity of JI projects; it had an emissions target well above its actual emissions and could issue credits from its emissions budget without repercussions for meeting its target. For the three plants in Fig. 1 the methodological safeguards were removed at a point in time when perverse incentives from HFC-23 CDM projects received wide media and policymaker attention, leading ultimately to a ban of HFC-23 credits under the EU's emissions trading scheme and a revision of the applicable methodological standard under the CDM (refs 14,22). Third, the Accredited Independent Entity (AIE) performing the relevant auditing functions—Bureau Veritas Certification—did not address the perverse incentives. Although AIEs were accredited by the JISC, the projects were implemented under oversight by the host country, in which case the JISC did not assess the performance of auditors or apply any sanctions in cases of non-performance. Finally, we note a lack of transparency, with project information being only partially publicly available.

These lessons are critical for both ongoing international discussions on the review of JI and market-based mechanisms under the new climate agreement, as well as the growing use of domestic carbon markets around the world. Our findings confirm earlier research that project-based mechanisms are exposed to significant risks of over-crediting, for example, due to the information asymmetry between project operators and auditors or regulators[4,5,7,8]. If crediting mechanisms are further pursued, it is essential that adequate international oversight be executed for any mechanisms involving international transfer of credits, that methodological standards be internationally accepted and include appropriate safeguards to prevent perverse incentives, that mechanisms monitor the performance of auditors and apply effective sanctions in the case of non-performance, and that information on credited activities is transparent and publicly accessible.

Methods

Methods and any associated references are available in the online version of the paper.

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Author contributions

L.S. evaluated the data and analysed the results. L.S. and A.K. wrote the paper.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to L.S.

Competing financial interests

L.S. is member of the CDM Executive Board under the Kyoto Protocol.

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Methods

Data on production and waste gas generation was gathered from project design documents (PDDs) and monitoring reports, published by the UNFCCC (http://ji.unfccc.int) and the Russian Registry of Carbon Units (http://www.carbonunitsregistry.ru), and audited by AIEs. The monitoring and verification reports publicly available are incomplete for four out of the five plants: for HFC-23 and SF_6 abatement at KCKK Polymer, the first and second monitoring report covering the years 2008 and 2009 are lacking. For HFC-23 abatement at HaloPolymer Perm, the first, second and fourth monitoring report, covering the years 2008 and 2009 and the period 1 January to 31 March 2011, are lacking, as well as the fourth verification report for the period 1 January to 31 March 2011. Moreover, as of 1 January 2012, HaloPolymer Perm reports only HFC-23 incineration but no longer HFC-23 generation. We conservatively assume that all HFC-23 generated was incinerated. If HFC-23 was partially vented or sold, the actual HFC-23 generation in 2012 would be even higher than presented in Fig. 1. Finally, monitoring reports are not publicly available for the plant in France.

Project-based mechanisms generally calculate emission reductions by comparing an emissions baseline with monitored project emissions and adjusting for any indirect upstream or downstream leakage emissions occurring as a result of the project:

$$\mathrm{ER} = \mathrm{BE} - \mathrm{PE} - \mathrm{LE}$$

where ER are the emission reductions, BE are the baseline emissions, PE are the project emissions and LE are the leakage emissions (all expressed as metric tonnes of CO_2 equivalent). Whereas project emissions can in most cases be directly measured, baseline emissions are estimated based on a counterfactual, hypothetical scenario. Baselines often aim to reflect the emissions level that would most likely occur if the project was not implemented, but could also be set at a lower, more conservative level—for example, to address uncertainties or to prevent perverse incentives. Over-crediting, or excess issuance of credits, occurs if the estimated baseline is higher than the emissions level that would occur if the project was not implemented (or if project or leakage emissions are underestimated).

Absent methodological safeguards, the four projects determine baseline emissions as the observed waste gas generation, that is, assuming that the same amount of waste gas would be generated and emitted in the absence of crediting. We estimate the extent of excess issuance of credits asthe difference between the claimed baseline emissions ($BE_{claimed}$) and different assumptions on plausible baseline emission levels ($BE_{plausible}$):

$$E = \mathrm{BE}_{\mathrm{claimed}} - \mathrm{BE}_{\mathrm{plausible}}$$

where E are the credits issued in excess, $BE_{claimed}$ are the baseline emissions specified in the monitoring reports of the plants and $BE_{plausible}$ is our estimate of the plausible range of baseline emissions (both expressed in metric tonnes of CO_2 equivalent).

We use three scenarios to reflect the range of plausible baseline emissions ($BE_{plausible}$). For the three plants in Fig. 1, historical data on waste generation is available. We estimate the magnitude of over-crediting over the period 1 April 2011 to 31 December 2012, when methodological safeguards were not applied, assuming that the three facilities would have produced the same amount of waste gas per day as before the start of crediting, as during the crediting period before their decision to abandon the methodological safeguards, or as originally projected when the project was approved. The credits issued in excess would amount to 19.7, 17.3, or 17.6 million, respectively, corresponding to 69%, 61%, or 62% of the 28.3 million credits issued to the three facilities over that period.

For SF_6 abatement at HaloPolymer Perm in Fig. 2 the magnitude of over-crediting is more uncertain because historical data is not available. We determine plausible baseline emission levels based on the SF_6 production and a range of plausible assumptions on the waste generation rate:

$$\mathrm{BE}_{\mathrm{plausible}} = P_{\mathrm{SF6}} \times w_{\mathrm{SF6}} \times \mathrm{GWP}_{\mathrm{SF6}}$$

where P_{SF6} is the SF_6 production at the plant (in metric tonnes of SF_6), w_{SF6} is the waste generation rate expressed as metric tonnes of SF_6 waste gas generated per metric tonnes of SF_6 produced, and GWP_{SF6} is the global warming potential of SF_6 valid for the first commitment period under the Kyoto Protocol (metric tonnes of CO_2 equivalent per metric tonnes of SF_6). We estimate the magnitude of over-crediting for the period 2008 to 2012 when methodological safeguards were not applied. For the period 2008 to 2010 we use the SF_6 production data reported by the plant. For 2011 and 2012, SF_6 production data is not reported; we conservatively assume that the plant would operate at its maximum production capacity. We use three scenarios to estimate the plausible range of the waste generation rate, assuming that the plant would have operated at a waste generation rate of 0.2%, as suggested by the IPCC, 2.0%, as observed before crediting at the KCKK Polymer SF_6 production plant, or 3.8%, as approximated based on SF_6 emissions data reported in the Russian GHG inventory (see Supplementary Information). The credits issued in excess would amount to 13.5, 11.9, or 10.2 million, respectively, corresponding to 99%, 87%, or 75% of the credits issued over that period.

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