Addressing the Carbon-Crime Blind Spot

A Carbon Footprint Approach

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Summary

Governments estimate the social and economic impacts of crime, but its environmental impact is largely unacknowledged. Our study addresses this by estimating the carbon footprint of crime in England and Wales and identifies the largest sources of emissions. By applying environmentally extended input-output analysis–derived carbon emission factors to the monetized costs of crime, we estimate that crime committed in 2011 in England and Wales gave rise to over 4 million tonnes of carbon dioxide equivalents. Burglary resulted in the largest proportion of the total footprint (30%), because of the carbon associated with replacing stolen/damaged goods. Emissions arising from criminal justice system services also accounted for a large proportion (21% of all offenses; 49% of police recorded offenses). Focus on these offenses and the carbon efficiency of these services may help reduce the overall emissions that result from crime. However, cutting crime does not automatically result in a net reduction in carbon, given that we need to take account of potential rebound effects. As an example, we consider the impact of reducing domestic burglary by 5%. Calculating this is inherently uncertain given that it depends on assumptions concerning how money would be spent in the absence of crime. We find the most likely rebound effect (our medium estimate) is an increase in emissions of 2%. Despite this uncertainty concerning carbon savings, our study goes some way toward informing policy makers of the scale of the environmental consequences of crime and thus enables it to be taken into account in policy appraisals.

Introduction

Crime[1] is not simply an infraction of criminal law, but is also a social issue that affects everybody and imposes high costs to society. These costs can be divided between the tangible (those more amenable to measurement, such as the cost of policing), and the intangible, which are more difficult to quantify, such as the emotional cost to victims (Dolan et al. 2005). Within the UK, the Home Office[2] uses cost estimates to value the social and economic impact of crime to individuals and households. These "cost of crime" estimates are monetized in order to produce a single metric for use within policy appraisal. The environmental impact of crime, however, has barely been acknowledged in current literature and represents a new intangible cost that is yet to be considered within policy making.

An important aspect of industrial ecology (IE), as a discipline, is that it considers environmental impacts of products and services. Carbon footprinting, in particular, is often used as a way of presenting environmental impacts given that it offers a broadly understood measurement that can be grasped and placed into context easily (Weidema et al. 2008). The IE literature thus includes studies of the carbon footprint of

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products (Tukker and Jansen 2006; Wells et al. 2012; Ziegler et al. 2012), households (Lenzen et al. 2006; Peters and Hertwich 2006; Druckman and Jackson 2009; Tukker et al. 2010; Wilson et al. 2013), companies (Wiedmann et al. 2009), cities (Collins et al. 2006; Moharab and Kennedy 2012; Wiedmann et al. 2015), and even nations (Munksgaard et al. 2005; Li and Hewitt 2008; Hertwich and Peters 2009; Davis and Caldeira 2010). Taking the need to achieve emissions reductions across every aspect of the economy, this study broadens the approach to consider the carbon footprint of crime.

The importance of evaluating the environmental impacts of crime to help inform policy making has been highlighted as part of a recent review into "Sustainability in the Home Office" by the UK Parliament House of Commons Environmental Audit Committee (EAC) (EAC 2014). However, to our knowledge, there is only one existing study on the subject, by Pease (2009), which included a tentative estimate. In this study, Pease asserted that "crime is not carbon neutral" (p. 16) and that "it is difficult to envisage a high crime society being a low carbon society," (p.3) thereby identifying the carbon-crime blind spot and suggesting that a synergy between crime and climate change exists.

Human-induced climate change is thus such a fundamental issue that it should permeate all policy areas, including crime (Pease and Farrell 2011). It is widely agreed that recent anthropogenic emissions of greenhouse gases (GHGs) have reached unprecedented levels and have widespread impacts on human and natural systems (IPCC 2013; Solomon et al. 2009). The carbon emissions that result from crime represent an unknown entity, which may add an extra burden on the environment and contribute toward global warming and climatic change. This study seizes the opportunity to address this omission by quantifying the carbon footprint of criminal offenses.

Our study builds on and extends the analysis by Pease (2009) and is partly sponsored by the Home Office, along with the Secured by Design (trading name of Police Crime Prevention Initiatives Limited). In particular, we present a more-robust estimate than Pease's (2009) figure on the total carbon footprint of crime and also provide more-detailed per incident analysis. We include estimates of the emissions that result from different criminal offenses when they occur and also actions taken in anticipation of crime. We consider emissions associated with the criminal justice system (CJS), such as police investigations and the running of prisons and court buildings, alongside the replacement of stolen or damaged goods, the provision of insurance, use of the health service attributed to injuries and other crime-related activities.

We discuss the possibility of reducing this footprint, but note that cutting crime does not automatically result in a net reduction in carbon. Rebound effects that potentially offset the carbon savings are an important consideration (Berkhout et al. 2000; Hertwich 2005; Chitnis et al. 2014), and reflection of the wider consequences of crime is therefore needed. An example of this approach was demonstrated by Pehnt and colleagues (2008), who explored the potential carbon dioxide (CO_2) reductions from utilization of offshore wind power using an extended system boundary to illustrate the economy-wide consequences. They found that the construction and operation of wind farms were lower in carbon than the fossil fuel alternative, but that these benefits were offset by around 10% by the emissions associated with the back-up system required to stabilize the fluctuating amount of electricity created by wind power. To take this approach in our case, we need to reflect how public and private money currently spent in association with criminal offenses would be spent in the absence of crime. Though such an estimate is inherently uncertain, we include rough estimates of the likely rebound effect along with estimates of the upper and lower bounds and discuss the assumptions used.

Of course, the estimates of the carbon footprint of crime provided by this study are not intended to inform or influence behavior of police or of criminals themselves. The intention is to enable policy makers, as part of the policy appraisal process, to assess the environmental impact of crime alongside the social and economic impacts already considered. It is believed that the Home Office is the first UK Government department, or indeed the first organization, to be considering the externalities of crime through this environmental lens. Though the methodology is applied to England and Wales, it can be applied to other countries.

The article proceeds as follows. We first provide a brief background of previous research and then detail the carbon footprinting methodology chosen in the current study. This is followed by the presentation of the results. Finally, we discuss the main findings and provide some consideration of the policy implications of our research, before concluding.

Background

In order to assess the economic and social impact of criminal offenses in the UK, the costs of crime were calculated by Brand and Price (2000). We believe that this was the first comprehensive attempt worldwide to place a monetized value on the cost of crime to victims, businesses, the taxpayer, and society generally (Dubourg et al. 2005). These estimates play an important part in helping the UK Government achieve the greatest impact on crime for the money spent (Brand and Price 2000). They are published in Her Majesty's Treasury Green Book Supplementary Guidance relating to crime, which values crime for policy and project appraisal purposes. Policy appraisals relating to crime do not currently include assessment of environmental impacts; therefore, the quantification of this aspect of crime will enable a more sustainable approach regarding the valuation of crime.

Pease calculated the first estimate of the "carbon cost of crime" in 2009, and this is the only known study of this type. Pease tentatively put forward a carbon footprint of over 6 million tonnes of carbon dioxide equivalents (tCO_2-eq) attributable to crime within England and Wales (Pease 2009). Pease considered the carbon cost of both recorded crime and estimates of unrecorded crime and based these on the monetized economic and social cost of crime described above. Pease acknowledged that a precise quantification was beyond the scope

of his initial report, and his estimate was merely to demonstrate that crime is not carbon neutral. Pease's study asserted that this carbon footprint is measurable and likely to have a large impact. Hence, the current study's attempt to quantify this footprint in more detail and help ensure that this important impact is taken into account and reduced, where possible.

Many of the limitations in Pease's original estimates have been addressed within this study. These include more-recent crime figures, updated monetized costs and, importantly, use of more-detailed and accurate carbon emissions factors in order to provide a more-robust footprinting methodology.

Methods

Life Cycle Thinking

This study takes a life cycle perspective, which we explain first with respect to a product. A product's carbon footprint measures the GHG[3] emissions over its life cycle stages with the aim of assessing its whole life impact (Carbon Trust 2012). To illustrate this, we consider an alarm system installed as a preventative measure against crime. Emissions arise because of energy use during operation, known as "direct emissions." Emissions also arise along the supply chain because of the extraction of the resources required for its manufacture, energy used during its manufacture, transportation and retail stages, as well as disposal at end of life. These emissions are termed "indirect" or "'embedded emissions." Embedded emissions may occur anywhere in the world and should, in theory, be included wherever they occur (Wiedmann et al. 2007; Peters and Hertwich 2008; Druckman and Jackson 2009; Lenzen et al. 2012; Kanemoto et al. 2012). The methodology used to assess the carbon footprint of an individual product or service is life cycle assessment (LCA). LCA is a bottom-up, process-based approach for which extensive methodological guidance is available, such as the Publicly Available Specification (PAS) 2050 or international standards (BSI 2011; ISO 2006). A major strength of LCA is its high specificity (Wiedmann and Barrett 2011).

The concept of a carbon footprint can also be applied at a higher-level scale to systems and organizations such as households, communities, companies, and nations (Wiedmann 2009a), and, in this case, we focus on crime. In such cases, use of LCA is not pragmatic because of the wide scope required in assessing many products and services. For example, assessment of the carbon footprint of crime must include goods that get stolen and damaged as well as services such as insurance, health, legal, police, and prisons. For such systems, environmentally extended input-output analysis (EE-IOA) is the preferred methodology (Wiedmann and Barrett 2011) and is therefore the methodology used in this study. EE-IOA is a top-down methodology, which, although it lacks the specificity of LCA, overcomes the limitations of boundary cut-off problems found in LCA (Matthews et al. 2008; Wiedmann 2009a; Wiedmann and Barrett 2011). For further information on the differences between LCA and EE-IOA, see Hendrickson and colleagues (1998) and Lenzen (2000).

This choice follows a precedent already set that informed policy making, with the UK's National Health Service (NHS) Sustainable Development Unit (SDU) recently using this method to assess the carbon footprint of its operations. Analysis of their supply chain found that 65% of its footprint was attributable to purchased goods and services, over 22% (4 million tCO_2-eq) of which was attributed to procurement of pharmaceutical products (NHS SDU 2010). The realization that a large proportion of their footprint could be managed from procurement practices, rather than estate management (building energy only attributed 18% of emissions), was unlikely to have been considered before the study was conducted.

Environmentally Extended Input-Output Analysis

EE-IOA uses economy-wide modeling to estimate supply-chain emissions (Wiedmann 2009b). It is based on economic input-output tables that detail all the flows of economic activity between producers and consumers within a given region (usually a country) (ONS 2012). These tables are used to calculate gross domestic product (GDP), but an extension of this analysis can also be used to estimate the undesirable by-products (environmental impacts) of the economic system (Leontief 1970).

The basic equation for EE-IOA modeling is presented in equation (1):

$$c = u\prime(1 - A)^{-1}\mathrm{y} \tag{1}$$

where c = GHG emissions (i.e., carbon footprint), u′ = a vector of GHG intensity coefficients, $(1\text{-}A)^{-1}$ = Leontief Inverse matrix, and y = a vector of final demand (£ spent in each sector by final consumers) (Leontief 1970; Miller and Blair 2009).

In order to operationalize this equation, two sets of data are required: EE-IOA derived multipliers (u′ $(I\text{-}A)^{-1}$), which detail the GHG emissions arising because of each monetary unit of expenditure of final demand (Defra 2012), and final demand (y) itself, which is represented by the (monetized) expenditure associated with crime in different sectors of the economy. These two sets of data are described in the following sections.

Environmentally Extended Input-Output Analysis Multipliers

EE-IOA-derived multipliers provide a measure of indirect impacts per (monetary) unit of output by industry (UN 2013). In other words, they represent the amount of GHGs embodied per British pound (£) of goods and services produced (Lenzen et al. 2004). They thus effectively act as conversion factors, which can be viewed as translating the expenditure associated with crime into an equivalent carbon footprint. Several data sets exist[4] that include EE-IOA multipliers ready for use and thus eliminate the need for full EE-IOA modeling.

The accuracy of an EE-IOA data set has been shown to increase with the number of regions and also the number of economic sectors included within the model. The more industry sectors in a model, the more robust the analysis will

be, because more interdependencies between sectors that have distinct production technologies are being considered (Lenzen 2011; Wiedmann et al. 2007).

The data set chosen for this study was produced by Defra (2014). It has only two regions (UK and rest of the world), which results in a loss of detail provided by data sets with more regions, given that imported emissions coefficients used are only an average of all countries of the world instead of considering the coefficients by country of origin. However, it was considered the most suitable because it provides an appropriate level of detail for matching emissions factors to the crime expenditure data set (final demand) (106 sectors categorized by Standard Industrial Classification [SIC]). Importantly, it also enables estimates using final demand in purchaser prices (i.e., inclusive of taxes, subsidies, and distributors' margins) and thus negated the necessity of converting final demand to basic prices, which can be highly problematic (Akers and Clifton-Fernside 2008; Druckman et al. 2008; OECD 2006). This data set also provided the most up-to-date multipliers and two previous studies carried out for government policy users, assessing the carbon footprint of the NHS and the footprint of all UK Central Government departments, also utilized this data set for similar analysis (NHS SDU 2010; Wiedmann and Barrett 2011).

The use of this data set highlights improvements on the previous tentative estimate of the carbon cost of crime. Pease's (2009) study used a single emission factor sourced from the International Energy Agency (IEA), which estimated that around 1 kilogram of CO_2-eq ($kgCO_2$-eq) was emitted per £ spent within the UK economy (IEA 2007). This represents a very high carbon intensity per £ spent on goods and services. In contrast, the most utilized emission factor within our study, public administration and defense, estimates that only 0.27 $kgCO_2$-eq is emitted per £ spent. The industrial sectors with emissions factors closer to 1 $kgCO_2$-eq per £ include the chemicals industry (Standard Industrial Code SIC 20c) and production of wood and wood products (SIC 16) (Defra 2014).

Final Demand

The "Economic and Social Costs of Crime" (monetized costs associated with specific criminal offenses[5]) (Brand and Price 2000; Dubourg et al. 2005; Home Office 2011b) are used for final demand (y in equation (1)). These "cost of crime" estimates are divided into three categories: those in *anticipation of crime* (defensive expenditure and insurance); as a *consequence of crime* (damaged/stolen property, emotional and physical impacts, health services and victim services); and, last, those in *response to crime* associated with the CJS (police, legal defense, probation, prison and jury services) (Brand and Price 2000). Importantly, these estimates include costs to society, the taxpayer, and the victims of crime; no benefits received by the offenders (such as good stolen) are accounted for and have a zero rate applied because these are not deemed beneficial to society or households. For a full list of offenses included, see Appendix 3 in the supporting information available on the Journal's website.[6]

The methodology used for estimating these monetized costs largely draw on various data from the security industry, the Department of Health's quality-adjusted life years (QALYs), and the Crime Survey for England and Wales (CSEW) (Brand and Price 2000; Dubourg et al. 2005; Home Office 2011b).

In order to estimate carbon emissions, a mapping process to convert the monetized costs of crime categories (insurance, police activity, victim services, etc.) into SIC sectors, as found in the EE-IOA data set, was performed. For example, the insurance administration expenditure sector is mapped to the insurance, reinsurance, and pension funding sector (SIC code 65) and police activity is mapped to the public administration and defense sector (SIC code 84). For full details, see Appendix 4 in the supporting information on the Web.

Estimating the Carbon Footprint per Offense

The carbon footprint per offense is estimated by multiplying the appropriate SIC sector EE-IOA multiplier [$u'(1 - A)^{-1}$] by each element of expenditure final demand [y] in that sector. For example, the monetized cost of the health service aspect of a single homicide is £934 (Appendix 2 in the supporting information on the Web). Multiplying this by the appropriate multiplier (SIC code 86: human health services) of 0.25 $kgCO_2$-eq/£ (Appendix 4 in the supporting information on the Web) yields a footprint of the carbon emissions that result from this spending in the health services, attributed to this single criminal offense, of just over 234 kg CO_2-eq. Detailed carbon footprints per offense thus estimated enable identification of the most carbon costly crime overall and which aspects of these crimes result in the highest emissions.

Estimating the Total Carbon Footprint of Crime in England and Wales

Once a footprint per offense has been estimated, a total carbon footprint of crime can be established by scaling up these footprints by the number of offenses that occur within a given year. Crime statistics are found within the Crime in England and Wales statistical bulletins, published by the UK's Office for National Statistics (ONS). These include both police recorded crime and the results from the CSEW, a household-based victimization survey (ONS 2013a). For commercial offenses not included within these bulletins, including "commercial—theft of a vehicle" and "commercial—theft from a vehicle," estimates from the Commercial Victimisation Survey (Home Office 2013) are used.

The true number of total offenses that occurs is not known with certainty, because both police recorded crime and CSEW estimates exclude some forms of crime (ONS 2013a). Most of the available statistics refer only to those that result in a court conviction or other formal penalty (Maguire 2007). In this study, police recorded crime figures[7] are first used to estimate the total carbon footprint of recorded crime, and then an estimate of unrecorded crime is made.

Table 1 Crime adjustment factors to estimate unrecorded crime from recorded crime figures

Offense	*Crime adjustment factor*
Homicide	1
Serious wounding	1.5
Other wounding	1.5
Sexual offenses	13.6
Common Assault	7.9
Robbery	4.8
Burglary in a dwelling	2.8
Theft—not vehicle	4.6[a]
Theft of vehicle	1.3
Theft from vehicle	3.5
Attempted vehicle theft	2.3
Criminal damage	5.9
Burglary—not in a dwelling	1.9
Commercial—robbery	4.8
Commercial—theft of vehicle	1.3
Commercial—theft from vehicle	3.5
Shoplifting	16.1
Commercial—criminal damage	5.9

Source: Home Office (2011b).
[a]"Theft from the person" factor selected.

To include unrecorded crime in the carbon footprint, adjustment factors[8] from the Home Office Integrated Offender Management (IOM) toolkit are used. This enables grossing up of recorded crime figures to a total crime volume estimate (Home Office and Ministry of Justice 2011; Home Office 2011b). The adjustment factors detailed in table 1 effectively represent the ratio between the estimated total number of offenses (from the CSEW) to the number of comparable recorded offenses (police figures) (Home Office 2011b). For example, an adjustment factor of 1 (homicide) implies that all incidents that occur are recorded, whereas an adjustment factor of over 16 (shoplifting) implies that over 16 times more incidents of shoplifting occur than are actually recorded by the police. The unrecorded crime carbon footprint excludes the expenditure associated with the CJS, given that, these unrecorded incidents do not result in emissions arising from the police service, courts, probation, or prison sentences.

Assumptions and Limitations

As can be seen from table 2, the assumptions and limitations of this study are many. We discuss the relevance and impact of each assumption/limitation in the comments section of the table.

The estimates produced utilizing this detailed methodology are considered to be a good first step to enable the carbon footprint of crime to be quantified. In the next section, we present the results, followed by discussion of the potential applications of the estimates to inform policy making.

Results

In this study, we present estimates of the carbon footprint of individual crimes, followed by the footprint of all crime (recorded and unrecorded) in England and Wales. From these estimates, we identify sources of high emissions, including the most carbon costly offense.

Carbon Footprint of Crime per Incident

Figure 1 shows the total carbon footprint per incident. A detailed breakdown is given in Appendix 5 in the supporting information on the Web.

The crime/offense that results in the highest estimated carbon footprint is homicide at around 71 tCO_2-eq per incident and is considerably larger than any other. This is mostly attributable to the carbon emissions resulting from a long prison sentence and higher policing costs compared to other offenses. Serious wounding is the next prominent carbon footprint per incident at around 5 tCO_2-eq emitted per offense. Robbery and burglary both result in emissions of around 1 tCO_2-eq per incident, and several offenses, such as common assault, shoplifting, and criminal damage, have a much smaller footprint, under 0.1 tCO_2-eq per incident.

For personal crimes, including homicide, wounding, and sexual offenses, the carbon emissions associated with the expenditure in anticipation of crime are estimated as the smallest proportion of the total carbon footprint, and the CJS emissions appear as the largest source. Property and vehicle offenses, including burglary, vehicle theft, and shoplifting, have a larger anticipation of crime carbon footprint attributed to the emissions resulting from defensive expenditure and insurance. These offenses have much smaller CJS footprints, but a higher amount of emissions from the consequences of crime. This is likely to be because of the high value of items stolen or damaged, such as the emissions embedded in vehicles and their spare parts and the need for their maintenance or replacement after these incidents. Robbery, which includes an element of violence, has a large proportion of emissions associated with the consequences of crime because of emissions related to the health service.

Carbon Footprint of All Crime

To build upon the per incident footprints, we further investigate the carbon footprint of all crime by taking the number of offenses into account. Scaling up the estimate by the number of offenses that occurs is essential to emphasize the extent to which individual offenses contribute to this total carbon footprint.

The carbon footprint of all (recorded and unrecorded) crime is estimated to be just over 4 million tCO_2-eq for the year 2011 in England and Wales (see Appendix 6 in the supporting information on the Web for a detailed breakdown of recorded and unrecorded emissions by offense type). This carbon footprint results from around 3.5 million offenses recorded by the police in 2011, responsible for just less than 2 million tCO_2-eq emissions. The estimated additional 15 million offenses that went

Table 2 Major assumptions and limitations of study methodology

Process	*Assumption/limitation*	*Comments discussing the relevance and impact*
Use of EE-IOA multipliers	This study is subject to the standard limitations of EE-IOA. For example: • The outputs and carbon emissions of each industrial sector (whether in the UK or rest of the world) are assumed to be directly proportional to its inputs. • Every industrial sector is assumed to be homogenous with regard to its input requirements, the commodity it produces, and the emissions from the firms within the sector. • Accumulating or depleting stocks are not accounted for. • Data are generally collected from surveys and are therefore subject to the normal drawbacks of survey data (response rate, sampling errors, missing/incomplete data, and so on). • Data only include the formal economy and therefore goods sold on the black market, for example, are not taken into account. For more detailed explanations of the limitations of EE-IOA, see Lenzen (2000), Hertwich (2005), Miller and Blair (2009), Wiedmann (2009b), and CenSA (2010).	Limitations outweighed by the benefits of this methodology to estimate economy-wide footprinting on a national scale
Choice of EE-IOA data set	Other data sets may estimate higher/lower footprint estimates per offense depending on the EE-IOA source.	Justification of data set choice detailed in *Environmentally Extended Input-Output Analysis Multipliers* section.
Distinction between carbon emissions that arise in the UK and those that arise in the rest of the world	The emissions factors used take into account emissions relating to products supplied for consumption in the UK and those imported products that are used by UK industries for consumption in the UK. It is not, however, possible to apportion emissions between those based in the UK and those from the rest of the world, because results generated only provide an estimate of the total upstream emissions (Defra 2014).	Because of the data set chosen, this study is unable to distinguish between emissions that arise overseas and those that arise in the UK. Thus, the amount of the footprint that is leaking to other countries is not estimated in this study. We recommend that this is addressed in future studies.
Use of monetized costs of crime estimates as final demand. Estimates based on multiple sources including the British Crime Survey (BCS) and Department of Environment, Transport and the Regions (DETR) QALYs.	Only those offenses included within these estimates can subsequently provide a carbon footprint estimate. Offenses such as fraud, online (cyber) crime, and international crimes are omitted.	The Green Book guidance estimates (HM Treasury 2011) are used on a regular basis for project and policy appraisal within the Home Office and represent the best available data relating to the monetized cost of criminal offenses. Further analysis into the carbon impact of other offenses not included here will be addressed in future studies.

(*Continued*)

Table 2 Continued

Process	*Assumption/limitation*	*Comments discussing the relevance and impact*
Expenditure categories excluded from study	We omit four expenditure categories from our carbon footprint calculations because of ambiguities over the extent that they produce carbon emissions; physical and emotional impact on direct victims; lost output; Criminal Justice System (CJS) overheads; and criminal injuries compensation.	Lost output (victims taking time off work because of crime) could be said to reduce emissions during working hours (commuting, for example), but energy-consuming behavior of those not working may offset this. Likewise, the valuation technique used to estimate the physical and emotional costs of crime using QALYs is ambiguous as to whether this impact produces or reduces emissions (Pease 2009). Similarly, CJS overheads and criminal injuries compensation (salaries or payouts as result of injury) are ambiguous as to whether these expenditures result in carbon emissions, and so they are omitted from the estimates.
Mapping of expenditure categories to SIC codes	Some subjectivity required[a] Each expenditure category is only mapped to one SIC code. Process and justification of choices are detailed in Appendix 4 in the supporting information on the Web.	Exploratory sensitivity analysis was performed to investigate the effects of this subjective process.[b] When selecting industrial sectors, partial allocation of multiple sectors is also possible, but beyond the scope of these estimates. Possibility to improve accuracy in future estimates by supplementing with primary data, where available (e.g., energy/fuel use in prisons or police buildings).
Year of data	Emissions relate to the year 2011 as a result of these being the most recent supply-chain emission factors (multipliers) available. The recorded crime statistics used relate to the financial year 2011–2012 (April 2011–March 2012) to reflect the year of the Defra multipliers.	Future revisions can easily be carried out for updated monetized costs of crime figures, recorded crime statistics, unrecorded estimates, and supply-chain emission factors.
Data relating to region of England and Wales	Although the EE-IOA multipliers represent the whole of the UK, all other data sets, including recorded crime data and cost of crime estimates, relate to England and Wales only.	A data set of EE-IOA multipliers relating only to England and Wales is not currently available, and it is assumed that UK estimates are a sufficiently representative average of England and Wales.
Unrecorded crime estimates using adjustment factors within the Integrated Offender Management (IOM) toolkit	The assumption of when the emissions factors are applied to these unrecorded offenses is that the average cost of these unrecorded offenses is the same as those that are recorded, minus the costs associated with the criminal justice system.	The true number of crimes that go unrecorded or unreported by the police is an unknown entity, and these simply represent the best estimates available. Any updates to these adjustment factors can be integrated into future estimations of the carbon footprint of crime. We acknowledge a lower overall reliability of the estimate of total number of crimes in return for greater completeness of the cost of crime estimates (Dubourg et al. 2005).

(*Continued*)

Table 2 Continued

Process	*Assumption/limitation*	*Comments discussing the relevance and impact*
Direct emissions omitted from estimates	The direct emissions from fire associated with a case of arson, for example, of which there were 27,218 incidents[c] recorded in the year 2011-2012 (Home Office 2012), are not currently within our estimates.	Although indirect (embedded) emissions associated with replacing any damaged property are included, the direct emissions from burning property and vegetation are not.
	Direct transportation emissions, from the burning of fuel in vehicle engines associated with crimes being carried out or dealt with, are not currently considered. Even though offenders tend not to travel particularly far, distances traveled to commit crimes can vary and have been seen to have increased steadily since World War II decades (Wiles and Costello 2000).	These direct emissions (arson and travel) are outside the scope of this study and are likely to be the subject of future work.
Other emissions that could be associated with crime are omitted from estimates.	Emissions that result from moving house may be as large as those from other sources. Security is considered one of the main reasons why people move home and is shown by the strong relationship between high crime rates and tendency for people to move (Dugan 1999). Pease (2009) considered these emissions and made a tentative estimate of around 5.6 tCO_2 emissions attributable per house move. He argued that if only 1 million of house moves in the UK were attributed to high crime rates, this would double the emissions from all other crime that occurs. Armitage and Monchuk (2009) go on to suggest that poorly designed areas that require premature refurbishment and regeneration, along with additional costs derived from moving home from crime-challenged areas, are reflected with an increased carbon footprint.	A detailed estimate of emissions from moving home or those from premature refurbishment and regeneration because of crime is not currently available and is beyond the scope of this study

[a]Expenditure associated with prisons, for example, could have been mapped to public administration and defense, as an alternative to the chosen accommodation services sector. Mapping this onto accommodation services involves many assumptions, one of which is that the energy behaviors of prison residents are akin to that of people on holiday. As shown by Barr and colleagues (2010), whereas individuals may be relatively comfortable carrying out environmentally friendly behaviors in and around their home, they can find carrying out such behaviors more problematic in a tourism context. Thus, this assumption may cause an overestimate of emissions.

[b]For example, we reallocated police expenditure from public administration and defense to security and investigation services. The results showed a variation of impacts for the different offenses. The carbon footprint was found to be 7% less for robbery offenses, but 5% more for serious wounding offenses. Overall, the total carbon footprint of crime would be 2% lower as a result.

[c]Arson endangering life and arson not endangering life.

EE-IOA = environmentally extended input-output analysis; QALYs = quality-adjusted life years; SIC = Standard Industrial Classification; tCO_2-eq = tonnes of carbon dioxide equivalents.

unrecorded account for a further 2 million tCO_2-eq, effectively doubling the footprint estimate. In order to investigate the nature of this footprint and how to reduce this in the future, we analyze the results first by offense type and second by source.

The carbon footprint of all crime, including both recorded and unrecorded crime, is split by offense type in figure 2. The offenses resulting in the highest overall carbon emissions are burglary (both in a dwelling and not in a dwelling), which, combined, account for nearly 30% of the total footprint (580,000 tCO_2-eq). "Other wounding" (which includes aggravated bodily harm) and theft also account for a large proportion of the overall footprint at around 11% each. These offenses with the largest contributions may help inform policy makers of where the greatest impact in terms of emissions can be found and where there might be the potential for largest reductions. Despite homicide having such a large footprint per incident (around 71 tCO_2-eq), this is offset by the relatively low number of offenses occurring each year, meaning it contributes only 1% to the total carbon footprint of crime.

Figure 2 also shows the effect of unrecorded offenses and how these increase the total footprint for each offense. This highlights that even offenses that are not formally recorded by

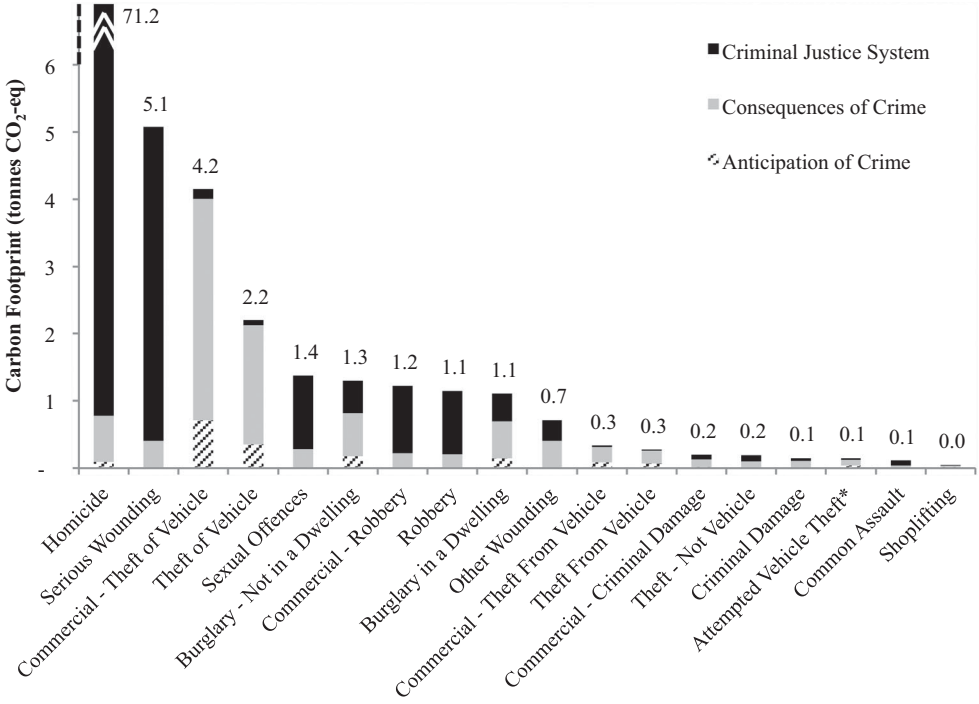

Figure 1 Carbon footprint estimates of individual criminal offenses. *Note:* *"Attempted Vehicle Theft" includes commercial and domestic offenses.

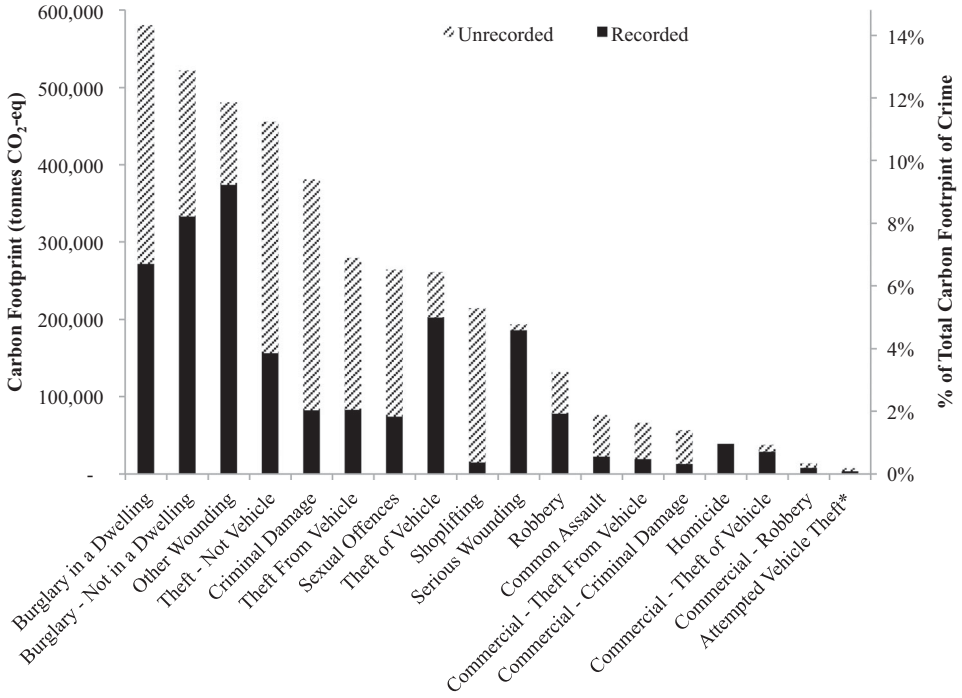

Figure 2 Carbon footprint (tonnes CO_2-eq and % of total) of recorded and unrecorded crime by offense type. *Note:* *"Attempted Vehicle Theft" includes commercial and domestic offences.

the police still result in environmental impacts, in the form of carbon emissions, and to overlook these unrecorded incidents would underestimate the scale of this impact. For example, theft, criminal damage, and sexual offenses contain large proportions of emissions resulting from unrecorded incidents. For sexual offenses, this is because of a known degree of under-reporting of these incidents (and therefore the number of estimated unrecorded offenses is higher) (ONS 2013b).

Given that there is a varied distribution of the number of offenses that go unrecorded, the overall carbon intensity[9]

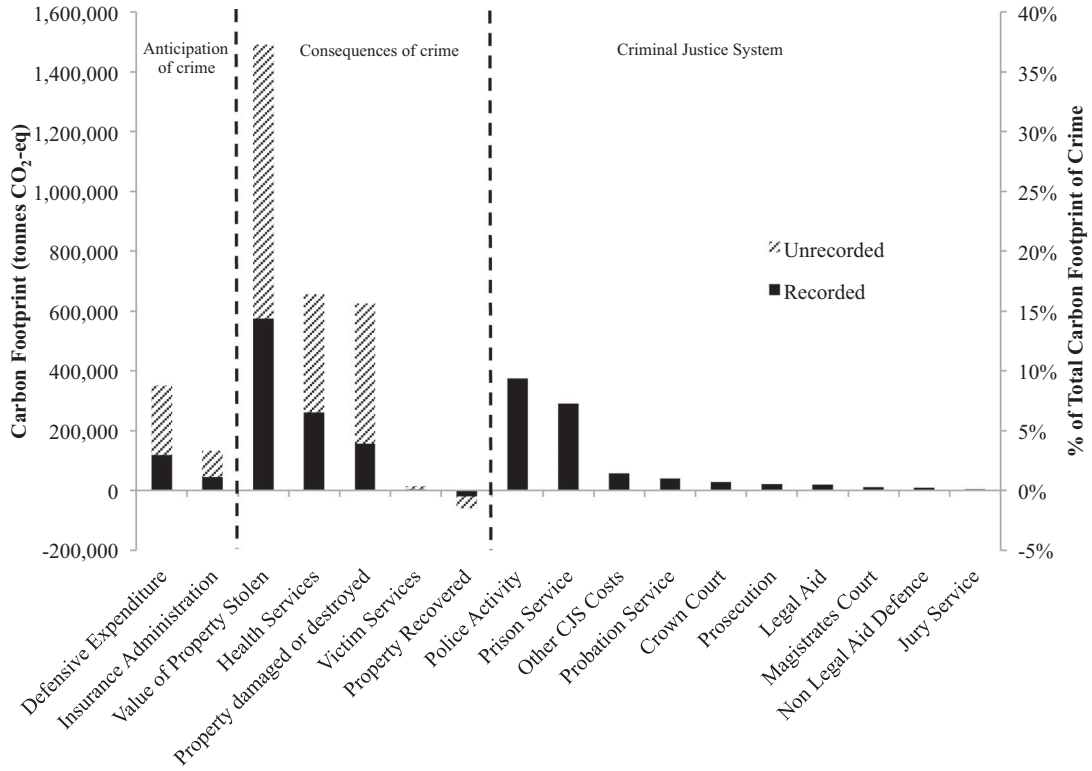

Figure 3 Carbon footprint (tonnes CO_2-eq and % of total) of recorded and unrecorded crime by source. CO_2-eq = carbon dioxide equivalent.

established in our study is 0.55 tCO_2-eq /offense for recorded incidents and 0.14 tCO_2-eq/offense for incidents that go unrecorded. However, this is not to suggest that all unrecorded offenses are not as carbon intensive as recorded offenses in reality. Neither does this suggest that incidents should not be recorded in order to reduce this overall footprint. The footprints of unrecorded offenses do not result in emissions arising from the CJS, and this is likely to have resulted in this lower overall intensity. It is also worth noting that offenses with higher individual footprints, such as homicide, are those that are more likely to be recorded, given that they are more serious. Less-serious offenses, such as shoplifting, with a high number that go unrecorded, have a smaller individual footprint and contribute toward the smaller carbon intensity of unrecorded offenses.

Carbon Footprint by Source of Emissions

Finally, in order to highlight which aspect (expenditure category) of these offenses contributes the most emissions, the footprint of all crime is broken down by the source of emissions in figure 3. We find that the collective sources of emission associated with the *consequences of crime* (property stolen or damaged and health services) are around 67% of all emissions. Those associated with the CJS (police, prisons, probation, and legal defense) are around 21%, and the smallest proportion is attributed to those actions in *anticipation of crime* (defensive expenditure and insurance administration) at 12%.

If unrecorded offenses are omitted from the footprint (i.e., only recorded offenses included), it is worth noting that the distribution of these emissions is transformed. Activities in anticipation of crime account for 9%, consequences of crime 49%, and those from the CJS 43%. This highlights the larger proportion that the CJS represents when recorded offenses are considered in isolation from the estimated unrecorded offenses.

For property-related offenses (burglary, theft, or shoplifting), any "property recovered," usually following police investigations, produces a negative carbon value, similar to the negative monetized cost. This represents a saving of emissions, given that items will not need to be repaired or replaced.

The "value of property stolen" represents the largest source of emissions at just under 1.5 million tCO_2-eq (37% of the total), when both recorded and unrecorded incidents are taken into account, followed by the emissions associated with health services (16% of total) and those from property being damaged or destroyed (15%). Police activity and the prison service emissions also stand out as large proportions, accounting for 9% and 7% of the total, respectively. For public services such as these, it is helpful to present the carbon footprint attributed to crime per day, given that these are 24-hour, 365 days a year services. The policing proportion of the footprint, for example, equates to just over 1,000 tCO_2-eq per day. Prisons produce slightly less, at just below 800 tCO_2-eq per day, and the largest is the health service, with nearly 1,800 tCO_2-eq per day related to crime. These areas are highlighted as sources of emissions that policy

makers may consider have the greatest opportunities for further investigation and possible reduction in the future. Ways to reduce the emissions intensities of these services are varied and require assessment on a case-by-case basis, taking into account running and capital costs in monetary and carbon terms. For example, to improve the energy efficiency of a prison, hospital, or police building, existing facilities could be retrofitted with low-carbon measures, or, alternatively, the buildings could be demolished and rebuilt to modern energy-efficiency standards.

Discussion

This research has provided a detailed estimate of the gross carbon footprint of all crime in England and Wales. The money currently spent on crime gives rise to over 4 million tCO_2-eq for the year 2011. This represents the "carbon cost of crime." This footprint is equivalent to the direct energy use of around 900,000 UK homes, at an average carbon footprint of 4.5 tCO_2-eq per household (DECC 2013). By estimating this footprint, our study has addressed the carbon-crime blind spot and highlighted areas where the majority of emissions attributed to crime arise.

The replacement of goods that are stolen or damaged accounts for 51% of the total carbon footprint[10] (figure 3). This reflects the assumptions we have made regarding property offenses, where we assumed that new items replace property that is stolen or damaged. Because of the high volume of property offenses and the high value of items (albeit only an average monetized value), this results in the highest proportion of emissions. It may equally be the case that these items are utilized by the criminal or sold on as secondhand goods. This would imply that the value is an overestimate given that the reuse of these items may save emissions elsewhere in the economy. Because the fate of these items is unknown, estimating the scale of this indirect impact is beyond the scope of this study. However, we believe it is reasonable to assume that replacement of these items is likely following their theft, and the carbon emissions associated with this extra manufacture are thus highlighted as an area of significance.

Because the replacement of goods accounts for a large proportion of emissions, it is not surprising that, when looked at by offense type, burglaries are the offense that results in the largest proportion of the total carbon footprint, at 30% (figure 2). Burglary and property-related offenses contrast with personal crimes, such as homicide, which, although being the offense with the highest individual footprint, at around 71 tCO_2-eq per offense committed, only accounts for 1% of the total footprint attributed to the small number of occurrences. Personal crimes require time- and resource-intensive investigations and tend to lead to longer prison sentences than property offenses, hence their higher individual footprints. Given that these offenses involve more emissions arising from the CJS, a focus on the carbon efficiency of these public services may provide a path for reducing these emissions in the future.

In order to inform policy making, it is helpful to align these estimates with that of the monetized "economic and social costs of crime." We have therefore apportioned the carbon emissions that result from crime into three categories: those in *anticipation of crime*; those as a *consequence of crime*; and those attributed to the *criminal justice system* (figure 3). When looked at this way, emissions that arise as a *consequence of crime* account for over two thirds of the total footprint (67%), those from the *criminal justice system* amount to around one fifth (21%), and noticeably smaller is the 12% of emissions from actions in *anticipation of crime* (49%, 43%, and 8%, respectively, when the estimated unrecorded offenses are excluded). This highlights that actions in anticipation of crime tend to result in less carbon emissions, given that they are less costly overall than dealing with the offenses once they have occurred. This is generally echoed by advice that emphasizes that crime prevention is enormously cheaper than its investigation and the imposition of sanctions (HMIC 2014). Our results show that this may also be true from a carbon perspective, and policy makers may wish to consider the suggested areas of focus in light of carbon emission reduction targets. The carbon impact of crime prevention should also be explored in more detail and is encouraged as part of further work into the carbon impact of crime.

The analysis reported here forms the first part of a wider research project on "The Carbon Cost of Crime." Future work will expand upon these findings by investigating whether this footprint can be reduced and what the carbon impacts of crime prevention measures are.

It is tempting to conclude from our research that crime reduction will automatically result in a general reduction of carbon emissions. Further work in the current project is assessing the rebound effect attributed to specific crime prevention measures, but to answer the question, "Does crime cost carbon?", we must examine the wider consequences of crime and crime prevention. For example, although there are emissions associated with the running of prisons, offenders spending time in prison are likely to consume less than an average citizen in the UK given that they earn less; this may actually reduce their carbon footprint overall. We thus provide an estimate of the rebound effect associated with a small reduction in crime, in which the money associated with these offenses is spent in other ways. This is similar to the approach taken by Heyes and Liston-Heyes (1993), where the impact of reallocated military spending found that backfire (where interventions result in more emissions) might occur when spending was reallocated to households. Similarly, Lenzen and Dey (2002) assessed the rebound effect of government outlay, as one of several case studies relating to spending options in the Australian economy. They conclude that shifting government spending from administration and defense toward education, community services, parks, and museums, for example, is likely to result in fewer carbon emissions when compared to awarding tax rebates, which may increase consumption and emissions.

We find that the rebound effect of reducing domestic burglary by 5% may potentially either reduce emissions by 3% (a saving of 19,000 tCO_2-eq) or increase the carbon footprint by 23% (an increase of 134,000 tCO_2-eq). The most likely rebound

effect (our medium estimate) is an increase in emissions of 2% (10,000 tCO_2-eq). This is estimated by reallocating money saved from the reduction in crime proportionally according to the average UK household consumption pattern and UK central government spending. Our low estimate was generated by reallocating saved money to the lowest-emitting sectors of household and government expenditure, and our high estimate used the highest-emitting sectors. The low estimate's 3% drop of emissions would indeed imply that crime does currently "cost" society additional carbon, given that the alternative would produce a lower footprint. Conversely, our medium and high estimates imply that because crime exists this "saves" carbon given that the money may potentially be spent in more carbon-intensive ways. Appendix 7 in the supporting information on the Web provides further details of these estimates and its rationale. Being hypothetical, these are, of course, extremely rough estimates, and the wide range highlights the scale of the uncertainty involved in trying to answer this question. We reiterate the importance of our focus on presenting the footprint of emissions that arise as a result of offenses that have occurred—the attributional carbon footprint of crime—rather than those that could be saved if crime is prevented.

Conclusion

This study has highlighted the overlooked environmental impact of crime, addressing the carbon-crime blind spot, by demonstrating the scale of the carbon footprint that results from criminal offenses. The research reported here is being conducted with support of the Home Office, and we believe that the UK is the first country in the world to have undertaken such an initiative. These findings are intended to be integrated into the HM Treasury Green Book guidance relating to the valuation of crime for policy appraisals, in order to ensure that future valuations include not only the social and economic impacts, but also environmental. Of course, when setting policy, we acknowledge that the severity of criminal offenses will take priority over efforts to reduce carbon emissions. Also, it is unrealistic to expect police or criminals to consider their carbon footprints. However, policies that consider all impacts of crime (social, economic, and environmental) are now possible in the UK because this work has added the environmental dimension, which was previously missing.

We have identified burglary as an offense that results in a high proportion of the overall carbon footprint (30%) because of the emissions associated with the replacement of stolen or damaged goods. This indicates that crime prevention measures that target burglary, along with measures to increase the recovery rate of items that get stolen, may be particularly effective in terms of carbon savings. We have also highlighted that the carbon resulting from CJS services is an important aspect of personal offenses, such as homicide or assaults. If the carbon efficiency of these services can be improved, this may help reduce the carbon footprint of crime in the future.

Our inclusion of the carbon that results from unrecorded offenses is also important given that it highlights that even offenses that are not formally recorded by the police still have environmental impacts. To overlook these unrecorded incidents would underestimate the scale of the impact of crime. Nevertheless, given that the true volume of crime that occurs can never be fully estimated, particularly when considering newer, technology-driven offenses occurring online (cybercrime), overall our footprint is still likely to be an underestimate.

Although it is not possible to definitively state whether the carbon emissions that result from crime can be avoided completely by preventing crime, raising awareness of these emissions remains important for policy valuation of crime and should not be overlooked. These estimates can promote discussion around the environmental impacts of crime, and further work is encouraged to investigate whether these impacts can be reduced. The framework presented in this study enables the estimates to be updated over time in order to monitor the scale of this footprint. It is hoped that a more sustainable approach to the valuation of crime within policy in the UK will be encouraged in the future as a result. This may form an exemplar for other countries to follow.

Thus, we believe this study goes some way toward informing those interested in the impacts of crime of the scale of the environmental consequences. If the relationship between crime and climate change is overlooked, we risk undervaluing the impacts of crime and missing an opportunity as we strive toward a low-crime and low-carbon future.

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Notes

1. In the context of this research, "crime" refers to notifiable offenses, which include all offenses that could possibly be tried by a jury (Home Office 2011a). Murder, sexual assault, domestic violence, burglary, robbery, and shoplifting are examples of these offenses. The term crime, in this context, also refers to the impact of these offenses on the victims, on society, and the offender.
2. The Home Office is a Ministerial Department of the UK Government.

3. The six main GHGs consist of a number of pollutants including CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride as defined by the Kyoto Protocol (UN 1998).
4. Appendix 1 in the supporting information on the Web details various EE-IOA data sets considered.
5. A full breakdown of these monetized costs is included within Appendix 2 in the supporting information on the Web for reference.
6. To enable comparisons with government estimates of the economic, social, and environmental costs of crime, only the offenses included within the monetized costs of crime estimates are used to yield a carbon footprint.
7. These statistics relating to police recorded crime have very recently been dedesignated as national statistics because an assessment into the compliance of the Code of Practice for Official Statistics was conducted, meaning that although they are published by the ONS and remain the best estimates available, the recording process is under review.
8. Referred to as "multipliers" in the original source, but renamed for this study to avoid confusion between these and EE-IOA multipliers.
9. Total carbon footprint divided by the total number of incidents (all crime types) that make up this footprint.
10. Includes the footprint of stolen, damaged, or destroyed property, minus the footprint of property recovered.

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Supporting Information

Supporting information is linked to this article on the *JIE* website:

Supporting Information S1: This supporting information includes seven appendices with details on the monetized economic and social costs of crime, detailed summaries of the carbon footprint of crime, and estimates of the rebound effect.