what works centre for
local economic growth

Local green investments

Introduction

Many local authorities are committed to helping achieve net-zero carbon emissions. Green investments will be needed to achieve these ambitions. Such investments may create employment opportunities and help achieve other local goals such as improving health. For this reason, there is growing interest in using green investments to stimulate more inclusive and sustainable economic growth as part of the recovery from Covid-19.

This paper reviews the evidence on the local economic impacts of three types of green investments – active travel, energy efficiency and natural capital investment. We focus on these, because local investment is feasible and there is evidence available on their impacts. A recent paper, by the Centre for Economic Performance (CEP) and Grantham Research Institute (GRI) examines the broader case for investing in these and other net-zero aligned areas including renewable power generation, distribution and storage, electric vehicle production and charging infrastructure, carbon capture, use and storage, and blue and green hydrogen production. Reflecting our remit, we focus on the local economic benefits, primarily employment and health. Investments may also have other benefits, including on the natural environment and public realm, but these are not considered.

Our other evidence reviews use studies with a score of 3 or above on the Maryland Scientific Methods Scale (SMS), which classifies evaluations based on methodological robustness and implementation. Our toolkits use studies with a score of 2 or above. Few papers on green investment meet these criteria, so we also include studies calculating benefit-cost ratios and the net present value of green investments, as well as studies estimating their impact on the economy through supply chain linkages (input-output models) and other methods. The Annexes provide more details.

Lessons

Policy lessons

- Green investments can have local employment benefits.
- Many of the jobs created are direct as many green investments (e.g. building cycle lanes, planting trees, etc) are relatively labour intensive compared to other infrastructure investments. Some studies find employment is created in supply chains. Local areas can increase the employment benefits of green investment by ensuring residents have the skills to take up the jobs created.
- The evidence available, whilst positive, is less robust than for other local economic growth policies. This is an issue with the evidence base rather than a reflection of the value of green investments.
- The evidence is more compelling on health outcomes. This provides another important channel through which investments may deliver local economic benefits.
- The local benefits of active travel, energy efficiency and natural capital investments vary, reflecting their different objectives and characteristics. This suggests that local areas should focus on carefully assessing which green investments are better for achieving their policy goals.
- The impact on local economies will also vary as a result of the pre-existing endowments of relevant assets. For example, the energy efficiency of housing stock varies across the country.[1] The scope to create jobs or improve health is greater in areas with a high proportion of housing that is energy inefficient.

Appraising local green investments

- Local appraisals of green investment aim to assess the costs and benefits of the investment to the local area, for example, the contribution it will make to local employment, air quality or health of residents. Whilst reducing carbon is an important policy goal and active travel, energy efficiency and natural capital investments will contribute to this, it is important to recognise that national and international decisions affecting carbon emissions will swamp any local impact.
- It is important to carefully consider the quality of the evidence used to identify and quantify the benefits of a proposed green investment, particularly when comparing different types of green investments. Our assessment is that the evidence on health is the most compelling.
- Much of the evidence on job creation comes from bespoke input-output exercises. Whilst these provide useful insights, they can be costly, and results are likely to be imprecise. What Works Growth's local multipliers toolkit provides a simple alternative for estimating the potential indirect employment benefits of local green investments.
- Where the lack of evidence makes appraisal difficult, local areas should focus on making the strategic case for green investments. Recent research from the CEP and GRI provides evidence that may be helpful in making the strategic case.

Need for further evidence

- The evidence on the local economic impacts of green investment is more limited than for other local economic growth policies. Funders of green investments should undertake robust impact evaluations[2] of their interventions. This will help improve understanding of their impacts and ensure that public money is being most effectively spent in the pursuit of both economic and environmental goals.

1 See Unsworth et al. (2020).

2 What Works Growth has published a Guide to Scoring Evidence that rates evaluation methodologies from most robust to least robust.

What is green investment?

An International Monetary Fund (IMF) working paper on 'Who's Going Green and Why?', (Eyraud et al., 2011) defines green investment as "the investment necessary to reduce greenhouse gas and air pollutant emissions, without significantly reducing the production and consumption of non-energy goods". Green investment may include investment in energy sources that have no or low emissions, efforts to improve energy efficiency and to capture and sequester carbon. The focus of this paper is on public investment. This includes the funding of schemes and use of subsidies to modify private behaviour.

We consider three green investments – active travel, energy efficiency and natural capital investment. These are areas of investment where there is potential for local areas to intervene and where there is evidence available on local economic impacts.

Active travel

Active travel describes journeys made by physically active means, such as cycling or walking. Investments include the building of cycle lanes or making areas more pedestrian-friendly by introducing traffic calming measures. Active travel may contribute to local economic growth by reducing congestion and by making places more attractive locations to live and work. It is also likely to increase wellbeing by improving health and reducing pollution.

The most recent statistics show that 26 per cent of all trips in England in 2019 were made by foot and 3 per cent by bicycle. Although approximately two-thirds of trips are under five miles, the share of cyclists in the UK is low compared to other northwestern European countries, with 39 per cent of trips in the Netherlands made by bicycle. This presents an opportunity for a modal shift towards active travel in the UK.

The UK government published its vision for cycling for walking, Gear Change, in 2020. The vision includes actions to create better streets for cycling and people, put cycling and walking at the heart of transport, place-making and health policy, empower and encourage local authorities to do more for cycling, and enabling people to cycle and protect them when they do. A £2 billion investment fund for cycling and walking was announced in May 2020, with early priorities for funding including the creation of 'school streets', where streets around schools are closed to motorists at certain times, low-traffic neighbourhoods, where residential side streets are closed to through traffic, segregated cycle lanes and improvements for pedestrians.

Energy efficiency

Energy efficiency measures aim to reduce energy consumption. Investments include building retrofitting and installing systems that reduce energy use. From a local economic perspective, policymakers may seek to improve energy efficiency to reduce energy costs, making firms more competitive and increasing consumers' disposable income, as well as to improve health and reduce pollution.

The most recent National Energy Efficiency Data-Framework shows that median annual gas and electricity consumption for households in England and Wales has been falling since 2005, with average consumption generally lower in newer and smaller properties. The median reduction in gas consumption resulting from energy efficiency measures installed in 2017 ranged from 4.2 per cent for loft insulation to 18.9 per cent for solid wall insulation.

In 2014, the UK Government published a National Energy Efficiency Action Plan, setting out the potential for energy efficiency investments. However, enthusiasm has waned as programmes have struggled with low take-up. In September 2020, the Government announced a £2 billion Green Homes Grant scheme that will provide homeowners with grants towards the costs of energy efficiency measures such as insulation of walls, floors and roofs, installation of double or triple glazing, and low-carbon heating like heat pumps or solar thermal. A new £1 billion Public Sector Decarbonisation Fund was also announced to improve the energy efficiency of public buildings, including schools and hospitals.

Natural capital investment

Natural capital investments improve an area's natural assets, such as mountains, saltmarshes, forests or fish stocks. The links between natural capital investment and local economic growth include the prevention of adverse environmental incidents (for example, drought or flooding) and the creation of new economic activity, for example, in tourism.

The Office for National Statistics estimates that the (partial) asset value of UK natural capital in 2016 was £958 billion (in 2018 prices). Cultural services flowing from natural assets accounted for £479 billion, with recreation (£401 billion) the largest single category in these experimental accounts. Other sources of value include agricultural biomass (£118 billion), carbon sequestration (£104 billion), fossil fuels (£95 billion), water abstraction (£76 billion) and air pollutant removal (£43 billion).

In 2011, for the first time, the UK Government set out a formal ambition to halt environmental degradation and natural capital decline. In 2018, a 25-year environment plan was published that aimed to place the environment at the heart of future economic considerations and reverse the current trend of environmental decline. However, the Natural Capital Committee, established as an advisory body by the UK Government, has argued that more needs to be done, both in terms of politics and actions, to achieve this goal.

Understanding the impact of green investments

What Works Growth uses the Maryland Scientific Methods Scale (SMS), to assess whether an evaluation provides convincing evidence on likely policy impacts. Only two studies – both on energy efficiency - reached our normal minimum threshold. As a result, this rapid evidence review adopted a different approach.

We searched for studies estimating costs, benefits and impacts of green investments that were publicly available online, written in English and from the UK, Europe, New Zealand, Canada and the US. Studies were classified based on our assessment of the study's methodology, assumptions and limitations. In total, 12 studies on active travel, 15 on energy efficiency and 11 on natural capital investment were identified and assessed as suitable for inclusion. Given that the rapid nature of this review, some relevant studies may have been overlooked.

Annex I provides more information on our approach to identifying and classifying the studies and Annex II gives a brief summary of each study. Studies on active travel are prefixed by AT (e.g. AT-3), on energy efficiency by EE and on natural capital investment by NC. The findings are organised by type of impact – employment, health and other – followed by a summary of the evidence from cost-benefit analyses. Some studies provide insights on more than one topic and are referenced in more than one section.

As the evidence in these three policy areas is limited and mostly below What Works Growth's normal robustness threshold, care should be taken in comparing the conclusions from this rapid evidence review with those in our normal evidence reviews.

Evidence on impacts

Employment impacts

Twelve studies consider employment impacts – three for active travel, five for energy efficiency and four for natural capital). None of these studies met the SMS 3 standard. Most use input-output methodologies.

Estimates of full-time equivalent (FTE) jobs created by green investments range from around seven jobs per US$1 million to almost 50 jobs per €1 million[3].

- Three **active travel** studies provide estimates, all with similar findings.
    - AT-1 estimates that cycling infrastructure investment in the US created 11.4 jobs per US$1 million spend plus three jobs per US$1 million through supply chain linkages.
    - AT-11 estimates that active travel infrastructure investments in New Jersey supported 10.3 jobs per US$1 million spend.
    - AT-12 estimates that 17 active travel projects funded by the Linking Communities programme in England supported 6.9 jobs per £1 million spend and 0.9 jobs per km of route construction.
- Two **energy efficency** studies provide estimates, with these being very different in scale.
    - EE-3 estimates that energy efficiency investment in the US creates 7.72 per US$1 million spend.
    - EE-12 meanwhile estimates that a nationwide building renovation programme in Hungary would generate between 37 and 49 per €1 million spend.

3 These are full-time equivalent (FTE) jobs that allow comparison of jobs involving different number of hours per week. The unit is obtained by comparing the number of hours worked to the average number of hours of a full-time worker.

- Three **natural capital** studies provide estimates.
    - NC-12 finds that projects implemented across the US after the American Recovery and Reinvestment Act of 2009 (for example, improving fish passages, collection of marine debris and reconnection of water to coastal systems) created 17 jobs per US$1 million spent.
    - NC-6 estimates that water use efficiency projects in Los Angeles created 7.2 direct person years of employment per US$1 million, with a multiplier of 1.9 for indirect and induced employment. However, as Los Angeles faces water shortages and the projects included measures to recycle and desalinate water, the findings may not be applicable in the UK.
    - NC-5 assesses the impact of planting trees in Ontario, Canada, and finds that each Can$1 million of expenditure on the 50 Million Tree Program created 14.4 jobs.

Only one study (EE-9) finds a negative relationship, with energy efficiency investments across the EU between 1995 and 2009 reducing the employment growth rate, especially in energy intensive industries. However, the study did find a positive relationship between energy efficiency investment in the public sector and employment growth.

Some studies find that the majority of the jobs created were direct (e.g. AT-1, EE-12), whilst others find a large proportion of jobs created through supply chain linkages (e.g. EE-3, NC-6). Energy efficiency also has potential to create employment by reducing energy costs, with one study (EE-4) assuming 90 per cent of jobs created by energy efficiency investment were in other non-energy sectors as households spent their energy cost savings.

Where jobs created by green investments are compared to investments that were close substitutes, green investments generated more jobs. For example, AT-1 finds that investment in cycling infrastructure created 11.4 jobs per US$1 million spend compared to 7.8 for roads projects. EE-3 estimates that US$1 million spend created 7.72 jobs in energy efficiency industries compared to 7.49 jobs in renewable energy industries and just 2.65 jobs in fossil fuel industries. Similarly, EE-4 finds low carbon technologies created more jobs per unit energy than fossil fuels, with energy efficiency creating 0.38 average job-years per gigawatt hour, second only to solar photovoltaics in a comparison of 15 different technologies. Combined, these findings suggest shifting investment from traditional, higher carbon approaches to green investments should increase employment. One potential explanation for this is that the activities involved in green investment (e.g. installing cycle lanes, retrofitting housing, planting trees, etc) are relatively labour-intensive compared to other investments.

There is no high-quality evidence that compares active travel, energy efficiency and natural capital investment in generating employment. Similarly, there is no evidence of the relative effectiveness of different types of active travel, energy efficiency or natural capital investments in generating jobs. EE-3 does, however, consider four different energy efficient industries – building weatherisation (i.e. protecting residential and commercial buildings from sunlight, wind and rain), industrial energy efficiency, mass transit and freight rail, and electrical grid upgrades – and finds that they had similar rates of job creation.

The evidence on employment effects has several limitations. Most studies only examine short- to medium-term employment effects, for example, those created in the construction, manufacturing and installation stage. There are two potential implications. First, the jobs created are unlikely to be permanent. Second, longer-term employment effects (for example, jobs created in maintaining active travel, energy efficiency and natural capital infrastructure) are not included. In addition, where sensitivity analysis is undertaken (e.g. EE-12), jobs estimates were sensitive to the assumptions made.

Health impacts

Within the studies we examined for their local economic growth benefits, eight consider the health impacts of green investments (five for active travel and three for energy efficiency). Two studies (EE-1 and EE-2) – both randomised control trials – are rated as SMS 3 or above. All studies that examine the health impacts find some positive effects.

Active travel improves health by making people more physically active, with this also potentially affecting mental health. AT-5 quantifies the personal costs and benefits of modal shift toward active travel using EU city-level data. It concludes that those undertaking a 5km bicycle journey twice a day, five days a week, would accrue individual health benefits worth around €1,300 per annum due to their increased physical activity. It also estimates the value of public health gain through reduced air pollution (in a large city with a population of at least 500,000 people) is around €30 per annum per additional cyclist. AT-4 estimates that if all settlements of 20,000 residents or more in England and Wales achieved London's level of cycling and walking, the NHS could save roughly £17 billion (in 2010 prices) in total over a 20-year period.

AT-3 uses road casualty data to compare areas in New York City that used neighbourhood slow zones (NSZs) to introduce traffic calming measures to those that did not. The study finds that NSZs reduce road casualties, with casualties falling by 8.74 per cent in areas with a NSZ compared to an increase of 0.31 per cent in control areas. This is equivalent to a gain of 0.002 in quality-adjusted life years and a net saving of US$15 over the lifetime of the average NSZ resident.

One study (AT-6) examines the wellbeing effects of commuting behaviour and found that psychological wellbeing was significantly higher when using active travel or public transport compared to driving, and that switching from car driving to active travel improved wellbeing. AT-7 examines the impact of commuter cycling on absenteeism. We include this as a health impact as absenteeism should decline as health improves. The average duration of absenteeism over the one-year period of study was one day shorter in cycle commuters than those who did not cycle to work and people who cycled more often and over longer distances were absent for fewer days on average.

Energy efficiency investments address poor insulation and older heating technologies, which are known to have negative impacts on health. EE-1 finds that installing more effective heaters led to a decrease in absence from school amongst asthmatic children. EE-2 finds that more effective heating reduced nitrogen dioxide levels by half, with children reporting better health, lower levels of asthma symptoms and sleep disturbances and having fewer days off school. EE-8 assesses the potential public health impacts of housing being retrofitted to more energy efficient standards and finds these had mixed results. Only one scenario – fabric and ventilation retrofits – has a positive effect with an increase of 2.2 quality-adjusted life years per 10,000 population aged over 50. Two other scenarios – installing ventilation for problem homes and repairing existing ventilation – reduce quality-adjusted life years.

None of the **natural capital** studies focused on health but the wider literature suggests there may be health benefits from some natural capital investments, for example, through better air quality. These effects are usually grouped with other positive benefits of natural capital under the term 'ecosystem services'. For instance, in Ontario, Canada (NC-5) it is estimated that each Can$1.80 tree has a Can$19.85 ecosystem service value. While the health benefits of natural capital investments have generally not been the focus in the cost-benefit analyses we reviewed, a number of studies in medical journals[4] demonstrate linkages of proximity to one particular natural capital investment – parks/green spaces – and physical activity. Physical activity in turn is associated with known health benefits, such as reduced risk for all-cause mortality and many chronic diseases.

4 For example, Wolch, Byrne and Newell (2014).

As most studies examining health focus on a limited set of health impacts – e.g. on morbidity and not mortality or on a limited range of diseases – these positive effects are likely to be underestimates.

Other impacts

Several studies consider other impacts. Again, none of these meet the SMS 3 standard. Most of these findings are drawn from studies that considered multiple impacts and are therefore also discussed in other sections.

Two studies look at the impact of natural capital investments on output, finding positive effects. NC-5 assesses the impact of planting trees in Ontario, Canada, and finds that Can$1.7 million of GDP is generated for each Can$1 million of expenditure. This is in addition to the employment effects discussed earlier. NC-8 estimates the impact of land change in Dorset between 2015 to 2050, with Gross Value Added (GVA) estimated to increase by 0.3 per cent. If ecosystem service flows are included, GVA is estimated to increase by 5 per cent. In addition, NC-6 reviews the impact of 50 water use efficiency projects on the Los Angeles economy and concludes that an investment of US$1.2 billion stimulated a further $1.2 billion in indirect and induced spending in the local economy. However, as outlined earlier, this study may not be transferable to the UK due to the nature of the projects.

AT-9 finds that there were benefits related to reduced congestion as a result of a reduction in car travel (number of trips and distance travelled) and increase in bus travel, walking and cycling in three towns designated as Sustainable Travel Towns (Darlington, Peterborough and Worcester) as part of the Smarter Choices Programme. This focused on encouraging active travel, for example, through personal travel planning, travel awareness campaigns, promoting walking and cycling, and public transport marketing. Comparator towns saw smaller reductions in driving and experienced declines in bus travel, walking and cycling.

Evidence from cost-benefit analysis

In addition to the evidence on impacts, 22 studies (nine for active travel, six for energy efficiency and seven for natural capital) undertake cost-benefit analysis (CBA) of green investments. The quality of this evidence is variable. Some of the studies that examine impacts also undertake CBAs.

In general, the evidence tends to show that the benefits of green investments outweigh the costs. Looking first at studies that calculate benefit-cost ratios (BCRs):

- **Active travel** investments appear to have the highest BCRs, with these generally between 3 and 6, although some are higher. For example, AT-2 finds that the benefits of investments in cycle track networks in Norway were four to five times the costs. The largest benefits identified in relation to active travel are health benefits. These are often an order of magnitude higher than other types of benefits. This is despite health benefits nearly always only being quantified in terms of mortality, not morbidity, meaning they are likely to be underestimates.
- Only two studies look at BCRs for **natural capital** investments (NC-1 and NC-2), with both showing benefits outweighing costs. However, the BCRs are relatively small in both cases. For example, NC-2 estimates the BCR of the Peatland Action Programme was 1.39, based on a survey of the monetary value people place on peatland restoration.
- The evidence is more mixed for **energy efficiency** investments. The most robust study (EE-7) finds the upfront investment costs of a programme to improve energy efficiency

of homes in Michigan were twice the energy savings. The study examines whether increasing energy use as a result of energy savings could account for this finding, but finds no evidence of higher indoor temperatures in treated homes. The study also finds that the costs outweigh the benefits when broader societal benefits resulting from emissions reductions are included. EE-10 examines the BCR of a carbon dioxide refurbishment programme of old buildings in Germany for both society and private investors. The BCR for society as a whole is positive in both scenarios examined, but highest (2.56) in the high emission damage, high carbon dioxide price scenario. The BCR for private investors depends on the rental increases they are able to impose, with medium rental increase taking investors to the break-even point where benefits outweigh costs. One final study (EE-6) finds benefits exceed costs in three scenarios for solid wall insulation.

Some studies calculate Net Present Value (NPV) of investments, including some that also provided a BCR. Reflecting the varied nature of the projects considered – ranging from small local projects to multi-national programmes – the results are diverse. Some examples include:

- EE-11 monetises the annual benefit to society of energy efficiency renovations in the EU in two scenarios, ‘low energy efficiency’ and ‘high energy efficiency’. Both scenarios increase GDP and public revenues. The low scenario generates €104 billion of benefits and the high scenario generates €175 billion of benefits.
- NC-3 estimates the value of carbon storage from British woodland, suggesting that the minimum NPV of all British woodlands was £82 million in 2001.
- NC-4 measures the economic benefits and costs from investments of managed realignment of saltmarshes in the UK’s North Devon Biosphere Reserve. Overall, there is a negative NPV. However, this is mainly driven by a small number of sites with high property damages. If these are excluded, the NPV was positive, with prioritised sites having a NPV between £152,000 and £185,000.

One study (EE-6) compares the net benefits of different subsidy scenarios for solid wall insulation – a private householder scheme with a 2:1 funding ratio between the government and private householders, a social housing scheme with a 1:1 funding ratio invested by government and social housing providers, and a loan scheme with a 1:4 funding ratio provided by the government and private householders – and finds that the loan scheme provides the highest level of net benefit to government, primarily through additional income tax and lower unemployment.

Given our remit, we focus on identifying studies that looked at benefits that are relevant to local economic growth, primarily employment and health. Across the evidence as a whole, a wide variety of costs and benefits are considered but most individual studies focus on small set of benefits. For example, a BCR of walking and cycling track networks in Norway (AT-2) focuses on pedestrian and cyclist safety, health effects of walking and cycling and negative externalities such as air pollution and noise.

Only natural capital studies appear to include a reduction in carbon explicitly as a benefit, reflecting the role of natural captial investments in sequestering carbon. Natural capital studies also appear to take the broadest approach, for example, with NC-10 including both the loss avoidance benefits from the prevention of flooding, climate change, soil loss and coastal storm damage and the non-monetary ecosystem values from protecting nature. However, some studies lack detail about how costs and benefits are calculated or sensitivity analyses.

Annex I: Scoring method

This rapid evidence review involved three stages. First, we searched for studies that estimate the costs, benefits and effects of investments on active travel, energy efficiency and natural capital that were publicly available online, written in English and related to the UK, a European country, New Zealand, Canada or the US.

Second, we classified studies into four groups (low, medium-low, medium-high and high) according to whether the methodology was well-described including details of assumptions made, limitations and a sensitivity analysis. In the spirit of the SMS scoring system, the assessment of the methodology concentrated on the internal validity of the estimates. Most studies reviewed use an input-output matrix approach or estimate the benefit-cost ratio (BCR) of the programme. Each study was assessed within their respective methodological group. For instance, a medium-low input-output paper, would be directly compared with a medium-high input-output paper. This ensures that a minimum standard is reached within each group of studies.

Finally, estimates were compared both within and across categories to identify outliers. A study predicting a higher multiplier than other studies, would be scored lower, but not removed from the review, unless the multiplier was unreasonably high.

Four categories were used to classify studies:

- ***High***: Studies that would receive a SMS score of 3 and above because a robust counterfactual is considered.
- ***Medium-high***: Studies that are well executed and transparent. Such papers typically exhibit a thoroughly explained methodology as well as assumptions and caveat results through a sensitivity analysis or outline of limitations. Nonetheless, these studies do not consider a robust counterfactual and their SMS score is below 3.
- ***Medium-low***: Studies that provide a well-described methodology but have issues. Examples could include missing sensitivity analysis, no mention of limitations or unclear assumptions.
- ***Low***: Studies that rely on non-transparent or poorly-explained methodologies and provide unlikely estimates of impact. These are not included in this review.

Annex II: Summary of the evidence

Active travel: studies with medium-high or high scores

Study AT-1 uses an input-output model, with data from 2008, to estimate employment impacts of building and refurbishing pedestrian and bicycle infrastructure in the US. Data were gathered from departments of transportation and public works departments on 58 projects in 11 cities in the US, with most cost estimates having multiple sources allowing an average to be used. It finds that bicycle infrastructure is the most labour intensive, creating 11.4 in-state jobs per US$1 million spent. When supply chain employment is added, an additional three jobs per US$1 million spent arise. This contrasts with road-only infrastructure, which creates the least number of jobs at 7.8 per US$1 million.

Study AT-2 provides a cost–benefit analysis (CBA) of walking and cycling track networks in Norway in the early 2000s, taking into account pedestrian and cyclist safety, health effects and negative externalities (e.g. air pollution and noise) as well as broader costs such as parking. The benefits of investments in cycle networks are estimated to be at least four to five times the costs. The study notes that they used high cost estimates and low benefit estimates to reach a conservative CBA. It concludes that cycle network investments are more beneficial to society than other transport investments.

Study AT-3 uses road casualty data from 2009 to 2016 and compares neighbourhoods in New York City that had neighbourhood slow zones (NSZs) to those that have not (control neighbourhood) in a cost-benefit analysis. The aim of NSZ is to introduce traffic calming measures, ultimately benefiting active travel users. Ascribed benefits are reductions in road casualties using quality-adjusted life years. The study concludes that NSZs appeared to be cost-effective means of reducing road casualties: they fell by 8.74 per cent whereas in control neighbourhoods they increased by 0.31 per cent. This result implies a gain of 0.002 in quality-adjusted life year and a net saving of US$15 over the lifetime of the average NSZ resident relative to no intervention.

Study AT-4 attempts to monetise the impacts of increased walking and cycling in urban England and Wales on costs to the National Health Service (NHS) for seven diseases that are associated with physical inactivity.[5] The starting year for the cost-benefit analysis (CBA) is 2010. The study does not take into account health benefits occurring as a result of a fall in obesity due to active travel uplift, or the effects on environmental factors. They conclude that, should all urban areas (settlements of 20,000 residents or more) in England and Wales reach London's level of cycling and walking, the NHS would save roughly £17 billion (in 2010 prices) cumulative within 20 years. This is inclusive of adjustment for increased risk of road traffic injuries.

Study AT-5 looks at EU city-level data from 1999 to 2005 and estimates what the health benefits of switching car journeys to active travel are to the individual through a CBA. They evaluate four effects: the change in exposure to ambient air pollution for the individuals who change their transportation mode, their health benefit, the health benefit for the general population due to reduced pollution, and the risk of accidents. They conclude that undertaking a 5km journey by bicycle twice a day, five days a week, would have health benefits to the individual worth around €1,300 per year, and in a large city (>500,000) the value of the associated reduction of air pollution of each person switching to active travel is around €30 per year.

Study AT-6 explores the wellbeing effects of commuting behaviour using a fixed effects panel model on the British Household Panel Survey between 1991 and 2008. They account for potential time-

5 Diseases considered are type II diabetes, dementia, cerebrovascular disease, breast cancer, colorectal cancer, depression and ischaemic heart disease.

varying confounding variables, including job satisfaction, residence, workplace and health. They find that compared to driving, psychological wellbeing (measured via psychological symptoms in the General Health Questionnaire and a 36-point scale) was significantly higher when using active travel (0.185) or public transport (0.195) and switching from car driving to active travel improved wellbeing. Further, wellbeing improved as travel time increased for walkers, but decreased for drivers.

Active travel: studies with medium-low scores

Study AT-7 investigates the association between commuter cycling and rates of employee absenteeism and assess whether there is a dose-response relationship between absenteeism and the frequency, speed and distance of commuter cycling. It draws on cross-sectional data about cycling for 1,236 Dutch employees, obtained via a self-reported questionnaire. Company absenteeism records were also collected over a one-year period (May 2007 to April 2008). Propensity scores are used to try to make groups comparable and adjust for confounders, with Poisson models used to assess the differences in absenteeism among non-cyclist and cyclist commuters. The study finds that the mean total duration of absenteeism over the period of study was one day shorter in cycle commuters than those who did not cycle to work, and a dose-response relationship where people who cycle more often and over longer distances are absent for fewer days on average.

Study AT-8 provides an economic evaluation of the first phase of the English Cycling Demonstration Town investment programme (which allocated £18 million across six towns between 2006 and 2009), using the WebTAG framework in place at the time and the World Health Organisation's HEAT for cycling tool to monetise impacts observed in monitoring data. Monitoring data are based on surveys and counts of cyclists, which are used to estimate a broader modal shift. The study does not account for displacement. Sensitivity testing accounts for other initiatives at the sites, with minimal impact on the BCR. The study finds the programme had a BCR of between 2.6 and 3.5 and suggests this is likely a conservative estimate because of the limited monetisation of health benefits (only mortality, not morbidity) and restricting monetisation of benefits to individuals aged 16 and over.

Study AT-9 seeks to quantify the uplift in active travel due to Smarter Choice Programmes in three Sustainable Travel Towns – Darlington, Peterborough and Worcester. The primary data sources are detailed travel surveys in 2004 and 2008 (with 4,000 surveyed in each town, each year), with additional interim surveys in households, schools, and workplaces, automatic and manual counts of transport modes (bus passengers, cyclists, pedestrians, vehicles), and household travel survey data and traffic counts from comparable medium-sized towns. The data has limitations in relation to count location, timing and continuity. The study finds that car trips per person reduced, and other, more sustainable travel modes increased. A full BCR, including environmental, consumer benefit and health effects was outside the scope of this study. A BCR monetising only congestion effects finds ratios in the order of 4.5.

Study AT-10 assesses the evidence base on the value for money of cycling and walking investments, by reviewing the BCRs of 16 interventions. It finds that almost all studies identified show large economic benefits of walking and cycling interventions, with a mean BCR of 6.28 for all schemes in the report, and 5.62 for the UK schemes. The underlying BCRs adhere to the WebTAG methodology that was in place at the time of the research.

Study AT-11 estimates the state-wide economic impacts of active transportation in New Jersey, focusing on intervention spending that took place in 2011. The researchers solicited responses from local government bodies to identify active transport interventions. Nearly 200 active travel-related businesses were surveyed on their revenue, and 300 participants in bicycling, running and walking events were surveyed to understand their local spending as part of their attendance at such events. Reliance on the forthcoming nature of local government and survey participants may present some self-selection effect. This data was entered into the R/ECON™ input-output model, which is tailored specifically to New Jersey. As with many regional input-output models, this model assumes that the nation's average technology coefficient is a good proxy for regional coefficients. In total, active travel-related infrastructure, businesses and events were estimated to contribute US$497 million to the state's economy in 2011, supporting 4,018 jobs, with multipliers above 2 in most settings. This is nearly eight times the estimated US$63 million invested in active transportation-related infrastructure in 2011 by governmental agencies. There are no sensitivity tests of the results.

Study AT-12 evaluates the impacts of the Linking Communities programme (2012-13), using pre- and post-intervention data from eight case studies of policies focused on design and delivery of small-scale walking and cycling links within communities, and calculates BCRs of the programme for a range of outcomes (economic, health) using usage data. The findings are caveated by the failure to account for weather, seasonality or local effects. There is also no clear measure of displacement. WebTAG methodology was used to derive BCRs, which ranged from 3.7 to 32.8, with an aggregate score of 10.9. Some 6.9 FTE jobs were sustained per £1 million spent on the programme, with 0.9 FTE jobs sustained per km of route construction.

Energy efficiency: studies with medium-high or high scores

Study EE-1 is a randomised control trial of heating interventions in New Zealand in 2006 studying the effect on health outcomes. The intervention installed more effective heaters for 409 households with asthmatic children. To estimate the impact on health, demographic and health information was collected before and after the intervention. The study finds that asthmatic children living in households receiving the intervention were on average 21 per cent less likely to be absent from school than those in the control group. The effect was not significant for sibling children without asthma.

Study EE-2 reviews two randomised control trials in New Zealand from the early 2000s, one focusing on the impact of housing insulation and the other one on more effective heating. Both were carried out in partnership with local communities and find positive and significant results. Insulating 1,350 houses improved the occupant's self-reported health and wellbeing compared to the control group. In addition, insulated houses used 81 per cent of the energy of non-insulated ones, although indoor temperature increased (by 0.5°C) in comparison to non-targeted houses. More effective heating in 409 households showed that levels of nitrogen dioxide were halved compared to the control, and children reported better health, lower levels of asthma symptoms and sleep disturbances, as well as fewer days off school.

Study EE-3 compares the employment impacts of energy efficiency, renewable energy and fossil fuels in the US with data from 2013. It disaggregates these into a large number of relevant sub-industries with energy efficient industries including building weatherisation (i.e. protecting buildings from sunlight, wind and rain), mass transit and freight rail, as well as electrical grid upgrades. A key challenge when employing input-output models and comparing fossil fuels and energy efficiency is that the latter are not included in the models. This study overcomes this issue by creating a 'synthetic' group of industries for renewable energy and energy efficiency industries and modelling clean energy spend as a demand shock. Overall, they find on average 2.65 FTE jobs are created from US$1 million spending in fossil fuels, whereas 7.49 and 7.72 FTE are generated from renewables and energy efficiency respectively. From these, 4.59 of the jobs created by energy efficiency are direct jobs while 3.13 are indirect.

The four different energy efficiency industries considered had broadly similar rates of job creation. Moreover, the estimates include only short- to medium-term employment effects (i.e. construction, manufacturing and installation of new equipment and machinery, among others) and do not consider long-term operations and maintenance employment. The study uses these figures to estimate the impact of shifting US$1 billion of tax preferences for fossil fuels into energy efficiency programmes. They conclude this would have led in fiscal year 2015 to a decrease in fossil fuel employment of 2,650 jobs and an increase of 7,720 jobs in energy efficiency, with a net gain of 5,070. There are no sensitivity tests of the results.

Study EE-4 estimates the job creation impact of renewable energy and energy efficiency projects in the US. It follows a meta-study approach synthesising data from 15 job studies covering renewable energy, energy efficiency, carbon capture and storage and nuclear power. Two of the 15 studies looked at energy efficiency. To make estimates comparable, the study normalises job data to average employment per unit of energy produced over plant lifetime and accounts for job losses in other industries. Energy efficiency includes direct, indirect and induced jobs, while for other technologies only direct and indirect jobs were considered. The reason for this is the assumption that energy efficiency induces 90 per cent of jobs created. As the study notes, this approach may bias results in favour of energy efficiency.

The average job-years per gigawatt hour for energy efficiency was 0.38. The only technology considered with a higher average was solar photovoltaics at 0.87. The high proportion of induced jobs from energy savings means that most jobs created by energy efficiency spend are not strictly green jobs, but they would not have been created without the energy efficiency programmes. The study highlights that as well as having high potential to create induced jobs, energy efficiency is generally the least costly and often the most readily implementable approach. The estimates are also used to compare two electricity generation scenarios in comparison to the business-as-usual scenario. A medium scenario suggests energy efficiency can make large contributions to job creation and that a combination of energy efficiency, renewable energy, and other low-carbon approaches such as carbon capture and storage and nuclear could create 1 million additional FTE job-years between 2009 and 2030. Overall, the results indicate that low carbon technologies create more jobs per unit of energy than fossil fuels.

Study EE-5 evaluates the impact of the 2009 Recovery Act's State Efficient Appliance Rebate Program in the US. The paper estimates the potential for intertemporal substitution due to the programme. It relies on a difference-in-difference estimator to exploit variation across states in programme coverage, timing implementation and rebate amount. The study finds that 70 per cent of consumers would have bought energy efficient appliances in the absence of the programme. An additional 15 to 20 per cent of consumers simply waited for the rebate programme to start to make their purchase. The study concludes that the overall impact of the programme on long term energy demand will likely be small. Moreover, government expenditure per unit of energy saved is higher than for other programmes targeting energy efficiency.

Study EE-6 reviews the fiscal impact of different energy efficiency programmes in the UK. It defined three subsidy scenarios for the example of solid wall insulation. The first option is a private householder scheme with a 2:1 funding ratio between the government and private householders, the second is a social housing scheme with a 1:1 funding ratio invested by government and social housing providers and the third is a loan scheme similar to the German development bank (KfW) scheme with a 1:4 funding ratio provided by the government and private householders. Each option is then modelled with a low and high revenue scenario to review what is the best option for the Government. The study concludes that a loan scheme presents the highest level of net benefit to the Exchequer, primarily through additional income tax and the avoided cost of unemployment. As such, the scheme potentially offsets 100 per cent of the total costs with total benefits. In Germany, the programme benefits exceeded the cost of the subsidies by 45 to 92 per cent.

Study EE-7 evaluates the effectiveness of a large-scale residential energy efficiency programme in the US which started in 1976. The programme was targeted at the energy efficiency of dwellings of low-income families and has provided assistance to more than seven million households. The method is a combination of an experimental and quasi-experimental approach - a randomised encouragement experiment conducted with 34,161 households in Michigan, and a difference-in-difference estimator for all treated households. The results seem to be mainly derived from the experimental approach, although it should be noted that the take-up of was relatively low. The results suggest that upfront investment costs are about twice the energy savings. The study investigates whether this is a consequence of increasing energy use, although this could not be confirmed as the dwellings do not have significantly higher indoor temperatures. Overall, the average rate of return of this investment is -7.8 per cent.

Study EE-8 assesses potential public health impacts if UK housing were retrofitted to more energy efficient standards. The study relies on an advanced validated building physics model using data from the 2010 English Housing Survey to estimate the effect on public health. For this, the study models three retrofit scenarios and estimates the changes in quality-adjusted life years over 50 years. Only the first scenario with fabric and ventilation retrofits has a positive effect on net mortality and morbidity with 2.241 quality-adjusted life years per 10 000 persons over 50 years. quality-adjusted life years decreased in the second scenario, where ventilation was only installed for problem homes, and in the third scenario, which only repaired existing ventilation, but installed no new ventilation. Uncertainty analysis is undertaken, which was necessary due to, for example, the limited available data on how retrofits improve air quality.

Study EE-9 reviews the employment impacts of EU energy efficiency measures. It uses an econometric model to estimate the impact of a specific measure at the country and sector level with a panel data set between 1995 and 2009 and includes sector and time fixed effects. The study finds that energy efficiency measures are significantly and negatively related to employment growth, particularly in energy-intensive industries. A potential explanation for this could be that the variable mainly captures the costs associated with energy efficiency investments and not the complementarity effects of technological change and production efficiency. Moreover, higher taxation of energy in industries is positively related to employment growth since they have lower input costs and more cost savings from the energy efficiency gains, compared to sectors with a lower energy tax burden. Further, investments in the public sector on energy efficiency also have a positive effect on the employment in other sectors, mainly due to a higher labour demand stimulated by public expenditure of these interventions. As a result, the study argues in favour of a policy mix of higher energy taxation and public sector investments to achieve better employment results.

Study EE-10 evaluates the benefits of the carbon dioxide (CO_2) refurbishment programme of old buildings in Germany implemented in between 2005 and 2007, both from the societal and the private investor perspective. To estimate the social benefits for society, the study accounts for the additional public revenue from taxes and social security contributions through the STEIN input-output model and the value of avoided CO_2 emissions The STEIN input-output model is an extended model which also includes relevant sources of public revenue. The estimations rely on different CO_2 values as well as a sensitivity analysis. The results indicate that for all scenarios, the social return is positive. Estimates range between 2.56 in the high emission damage (high CO_2 price) scenario in 2005 and 0.40 in the low emission damage (low CO_2 price) scenario in 2007. The social return decreases between 2005 and 2007, possibly due to diminishing returns. For the private investor, the CBA includes three scenarios with different rental increases. It is assumed here that the landlord can reclaim the invested cost through an increase in rent. A medium rental increase takes investors to the break-even point, which should make them indifferent between investing and not investing.

Energy efficiency: studies with medium-low scores

Study EE-11 seeks to monetise the annual benefit to society of energy efficiency renovations in a cost-benefit analysis for EU member states in 2020. The benefits considered are direct energy savings and reduced outlay on subsidies for renovations in addition to indirect health benefits. Direct costs are the reduced energy tax income. Additionally, the study estimates how the investments stimulate the economy in the case of a recession. The projected benefits are modelled according to two scenarios, 'low energy efficiency' and 'high energy efficiency', relying on assumptions about the level of uptake and sophistication of energy efficiency measures following Fraunhofer et al. (2009). Overall, both scenarios increase GDP and public revenues. The low energy efficiency scenario brings benefits of €104 billion and the high energy efficiency scenario achieves €175 billion of benefits. Although the study identifies a variety of barriers to a successful implementation, these are not incorporated into the two scenarios, which also lack a sensitivity analysis and a more thorough description of the limitations of the methodology.

Study EE-12 simulates the effect of a nationwide building renovation programme in Hungary, considering a long-time horizon and several scenarios. For this it relies on a 2010 inout-output matrix and up-scaled figures. The study concludes that reaching ambitious mid-term climate targets, such as the often-quoted 75 to 85 per cent reductions in greenhouse emissions that are needed by 2050, will become extremely difficult, and expensive, to achieve. However, up to 85 per cent of Hungarian heating energy use, and the corresponding CO_2 emissions, can be avoided by a consistent and wide-spread deep retrofit programme in the country. The study estimates that the programme can generate between 15,000 and 42,000 FTE jobs per year, with between 37 and 49 FTE per €1 million spent, with most of the additional jobs created through direct effects on the construction sector. However, the study simply scales up smaller projects and does not consider general equilibrium effects. The net job creation results are sensitive to assumptions including rate of renovation, renovation costs and labour costs.

Study EE-13 evaluates two energy efficiency improvement schemes in Ireland, using cost-benefit analysis. The first is EAI's Home Energy Saving (HES) scheme, where over 100,000 homes were upgraded with a combination of improved insulation, high efficiency boilers and heating controls. The second is the Small and Medium Enterprise (SME) Programme, where over 1,470 companies were supported to improve their energy efficiency through assessments, advice, mentoring and training. Both schemes were subsidised by the Exchequer with the evaluations considering the period from 2008 onwards. The CBA for the HES estimates a net present value (NPV) between €222 million to €285 million after 20 years, depending on the scenario. The CBA for the SME programme also includes a deadweight adjustment and a sensitivity analysis for the CO_2 price and estimates a NPV between €162 million after 10 years and €386 million after 20 years. These estimates appear to be very optimistic, compared to those from more robust studies.

Study EE-14 predicts the impact of energy saving investment in residential and public buildings in Croatia between 2015 and 2020. The methods are a CBA from the perspective of the owner of residential dwellings as well as an input-output methodology for the overall assessment of the economic impact. The study finds that the social benefits of energy saving retrofits are larger than costs due to the positive effect on employment, economic growth and the environment, but result in a negative NPV for the owner. The study concludes that governments should subsidise the retrofitting, which could be completely financed by the additional tax revenues of the investments. However, the study also assumes constant energy prices of 2014. The multiplier effects are all above 2.5, which is large compared to related literature of higher quality.

Study EE-15 summarises the economic impacts of environment related activities in the EU. The study summarises three input-output studies as well as using the 2006 Cambridge Econometrics input-output E3ME model. The report provides a comprehensive overview of different types of investments and their different impacts across different countries. These impacts are then applied to case studies, among them on energy efficiency, where they find positive GDP and employment impacts if the manufacturing sector were to implement energy efficiency measures on their premises. A 10 per cent purchase reduction of inputs from energy sectors in Europe, would create 137,171 jobs and increase output by €482 million. Overall, the study is comprehensive, but simultaneously the macro-level perspective disregards how GDP and employment impacts might differ when implemented at a smaller scale. Moreover, the estimated multipliers are high compared to studies of higher quality.

Natural capital: studies with medium-high or high scores

Study NC-1 reviews the benefits of peatland restoration using a CBA. The values considered for non-carbon benefits were obtained from Christie et al. (2011), and from the guidelines for policy appraisal and evaluation set by the UK government for carbon benefits. A wide range of costs were obtained from different studies. Overall, peatland restoration seems to be beneficial in the majority of scenarios, even when excluding non-carbon benefits. The benefit increases with a stronger emission differential (the difference between net emissions from a site if not restored and if restored), lower costs and a longer time period considered.

Study NC-2 assesses the value of non-market benefits associated with peatland restoration in Scotland through a representative choice experiment with 585 Scottish citizens in 2016. Respondents were asked to provide a monetary value to three different scenarios for peatland restoration while considering increased taxes needed for covering restoration costs. Then, the NPV was estimated using the benefits from these three scenarios and considering a range of costs drawn from NC-1. In general, the Scottish public seems to perceive significant benefits of peatland restoration. As a result, the study concludes that previous and future investment decisions into peatland restoration will likely be welfare enhancing. For instance, the Peatland Action Programme, through which 10,000 hectares of peatlands were restored between 2013 to 2016, the NPV is estimated to be £7.9 million with a corresponding BCR of 1.39.

Study NC-3 calculates the value of carbon storage from British woodland, using detailed forestry inventory records linked with other environmental data, including information on tree productivity, species, planting year and rotation data. The value of carbon storage is assessed by considering a range of social values per tonne and several discount rates. The estimates suggest that the minimum NPV of all British woodlands corresponds to £82 million in 2001, with a further £72 million that could be gained by additional afforestation. Moreover, these estimates increase with higher discount rates and social values.

Study NC-4 measures economic benefits and costs from investments of managed realignment of saltmarshes in the UK's North Devon Biosphere Reserve, taking 2016 as the baseline state. The benefits considered include carbon sequestration and recreational benefits. Costs included are the direct cost of saltmarsh realignment, opportunity cost from agricultural production and property damages due to flooding after managed realignment in three scenarios. Using these estimates, the study identifies priority sites for which the NPV is positive. On average, the value of property damages is large, leading to a negative NPV. However, this is mainly driven by a small number of sites with high property damages. If these were excluded, the NPV would be positive, ultimately providing large benefits for the whole of the UK. If prioritised sites were to be realigned, the NPV would be between £152,000 and £185,000, depending on the scenario.

Natural capital: studies with medium-low scores

Study NC-5 summarises the impact of an initiative to plant over 50 million trees in Ontario, Canada, through an input-output and ecosystem services methodology. The study estimates the direct economic cost of planting a tree through a survey of 10 planting delivery agents. Using this information an input-output model is constructed using Statistics Canada's 2014 input-output table. The study finds that the average annual direct economic impact of Can$7 million, which induces a GDP multiplier of 1.8 and 103.8 FTE jobs. Therefore, each Can$1.80 tree has a 305 per cent return on investment (Can$5.49). The ecosystem service relies on market value estimates from North America, Europe and New Zealand and includes services such as pollination and atmospheric regulation. The study finds that each tree has a Can$19.85 ecosystem service value. As the report lacks sensitivity analysis, an in-depth summary of methodology and limitations, the results should be interpreted with caution.

Study NC-6 reviews the impact of 50 recent water use efficiency projects on the Los Angeles economy using an input-output model. The economic impact is estimated using 2008/09 IMPLAN software and regional accounts data. The study concludes that an investment of US$1.2 billion and 8,654 direct person-years of employment generated a spend multiplier of 2 and employment multiplier of 1.9. The report estimates the multiplier effect for each type of investment separately. However, due to water shortages, projects in Los Angeles include measures such as desalination, which may not be applicable to the UK. In addition, it lacks an in-depth discussion of limitations.

Study NC-7 summarises the economic rationale for natural capital investment in England by determining the NPV of different natural capital investments in the UK. The estimates of NPV for the different types of investment are taken from case studies and linked to GIS data. For the suggested investments, the NPV ranges between £3.3 billion to £9.2 billion after 50 years. The NPV calculations are not well explained and no sensitivity analysis is mentioned.

Study NC-8 assesses future scenarios of land change in Dorset between 2015 and 2050. The report uses an input-output model and an agent-based model that incorporates land cover maps of Dorset and enables simulation of ecosystem service flows to businesses under different scenarios of environmental change. The results of the model indicate that the simulated land cover change had small economic impacts, with Gross Value Added (GVA) of Dorset increasing by 0.3 per cent and small employment increases of 0.25 per cent. In contrast, incorporating ecosystem service flows predicts larger changes of up to 5 per cent on GVA and 8 per cent on employment through both an input-output model and an agent-based model. The input-output model is not explained in detail. Similarly, the agent-based model does not mention the ecosystem services considered and whether a discount rate is considered.

Study NC-9 is an economic valuation of ecosystem services using a representative choice experiment in the UK in 2006. The choice experiment is meant to establish the marginal and total economic value of conservation activities. The results of the experiment are then used in a CBA to review the NPV of a current spend or an increased spend scenario. It is a robust experiment, except when the values of spending are broken down by region. Here, as the study acknowledges, the smaller sample size reduce representativeness. However, the methodology does not clearly state its assumptions and limitations.

Study NC-10 reviews what the benefits would be if post-2020 30 per cent of nature worldwide was protected, with a focus on forests and mangroves. The study employs a financial analysis, which includes revenues and costs, and an economic analysis, which includes non-monetary ecosystem service values. The financial results suggest higher overall output revenues of US$64 billion to US$454 billion as a result of the expansion of nature protection. Additionally, the economic estimation demonstrates large avoided-loss values of US$170 billion to US$534 billion due to the prevention of flooding, climate change, soil loss and coastal storm damage. The study is a macro-level analysis and does not review specific countries, through which estimates could strongly differ. The study acknowledges this by mentioning that costs might be even smaller in developing countries. There are no sensitivity tests and assumed discount rates are not reported.

Study NC-11 reviews 50 projects implemented across the United States after the American Recovery and Reinvestment Act of 2009. The study relies on the IMPLAN input-output matrix and estimates that the projects created on average 17 jobs per US$1 million spent. This is a result of the high demand for non-skilled labourers of certain projects. Examples of projects reviewed include improving fish passage, the collection of marine debris or the reconnection of water to coastal systems. The study highlights that most projects, like infrastructure investments, have specific timelines implying that the job creation is not permanent. There are no sensitivity tests.

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