BRIEF COMMUNICATIONS

Regional commitment to reducing emissions

Local policy in the United States goes some way towards countering anthropogenic climate change.

The non-participation of the United States in the recently ratified Kyoto Protocol[1] is a matter for global concern because it is estimated that the country produces 24% of all greenhouse-gas emissions worldwide[2]. Here we analyse the commitment of individual states and municipalities to addressing this problem and find that, despite the federal policy, between 24 and 35% of the US population are currently (or soon will be) engaged in policies directed towards significantly reducing anthropogenic climate change. The importance of this sub-national effort, which we estimate corresponds to 27–49% of the gross domestic product, will depend — like the targets adopted in Kyoto — on the real reductions achieved in greenhouse-gas emissions.

The current administration plans to adopt carbon-intensity targets that would allow the United States a 30% increase in emissions above those specified in Kyoto's designated base year of 1990 (ref. 3). We have analysed the extent of the commitment at the sub-national level towards targets more like those of Kyoto. Because of the varying nature and maturity of any such regional policies, we divided the states and municipalities adopting them into three categories — current, probable and possible 'adopters'. Current and probable adopters have climate-change policies that are similar in scope to Kyoto's recommendations; possible adopters may have targets commensurate with the Kyoto recommendations, but to be included in this category only pledges to reduce emissions are needed. Our analysis, which includes contributions by different states, counties and cities (for details, see supplementary information), indicates that the current adopters represent about 24% of the US population and contribute about 27% of the gross domestic product (GDP) (Table 1).

AP PHOTO/C. PIZZELLO

Downtown Los Angeles: California is one state driving emission cuts.

There are several limitations to climate-change policies that operate at the sub-national level, including a lack of mechanisms for enforcing such small-scale initiatives. The Kyoto agreement is now legally binding, but it too could be undermined if targets are continually postponed and if the threat of exclusion from a trading system that is not yet proven[4] turns out to be ineffective. Nonetheless, many Kyoto signatories are taking real steps towards compliance. In the United States at the sub-national level, compliance will be a challenge even for current adopters, who have increased their carbon dioxide emissions on average by 14% since 1990 (ref. 5).

There is also the problem of carbon leakage (the process of moving high-emission activities across political borders), which affects Kyoto-ratifying countries as well. Carbon leakage from countries required to cut emissions to those countries without targets has been estimated to be 6–25% (ref. 6), although more recently it has been suggested that carbon leakage under Kyoto could be greater than 100% (ref. 7). Comparable leakage could occur as a result of California's plan to become better connected to electrical grids with coal-burning states such as Utah and Nevada.

Although sub-national climate-change policies may suffer from limitations similar to those of the Kyoto Protocol, they could be more adaptable to regional heterogeneity in creating site-specific plans for reducing greenhouse-gas emissions. For example, US states have strong control over land use and agricultural policy, and moderate control over electrical systems, all of which are effective tools for mitigation of greenhouse gases[8]. Individual states could also help in reducing transportation emissions, although scant attention has been paid to this so far. In many states (including all the current adopters), transportation is the greatest contributor to greenhouse-gas emissions, and this issue will need to be addressed before directives can become properly effective.

The sub-national movement analysed here is an important deviation from US federal policy in that it acknowledges the need for climate-change policies and for setting targets. Pledges may be broken and adopting policies does not necessarily change behaviour. But it is encouraging that targets set over the past few decades to achieve environmental goals have been effective in driving change[9] and have already helped to identify easy and inexpensive routes to emission reductions[10].

Given that the US delegation to the next international climate conference may be excluded from many sessions[11], it is important that sub-national efforts persist. Even our lower-bound estimate of the amount of US

Table 1 | Sub-national contributors to greenhouse-gas reduction

	Population (millions)	Percentage of US population	Gross product in 2003 (US$billions)	Percentage of US GDP
Current adopters				
California*	35.484	12.19	1,446	13.26
Connecticut†	3.483	1.20	172	1.58
Maine†	1.306	0.45	41	0.38
Massachusetts†	6.433	2.21	297	2.73
New Hampshire†	1.288	0.44	49	0.45
New Mexico‡	1.875	0.64	57	0.52
New York†	19.190	6.59	822	7.53
Rhode Island†	1.076	0.37	40	0.36
Vermont†	0.619	0.21	21	0.19
Subtotal	70.755	24.31	2,945	26.99
Probable adopters				
New Jersey	8.638	2.97	397	3.64
Oregon	3.560	1.22	120	1.10
Washington	6.131	2.11	245	2.24
Subtotal	18.329	6.30	763	6.99
Possible adopters				
25 US municipalities	12.774	4.38	1,673	15.34
Total	101.859	34.99	5,381	49.32

Percentage population figures are calculated for individual states with respect to the total US population of 291 million; the contribution of each state to the national economy is also shown, and is calculated from the 2003 value of the gross domestic product (GDP) of the United States ($10.9 trillion). For details, see supplementary information.
*Pledged to reach 1990 levels by 2020. †Pledged 10% reduction below 1990 levels by 2020. ‡Pledged 10% reduction below 2000 levels by 2020.

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GDP being pledged towards significant reductions (27%; Table 1) represents 9% of the global economy; the upper bound represents 16.7%, which is slightly larger than the GDP of Japan, the world's second largest economy.

Although there is no US federal cooperation with Kyoto, the implementation of climate-change policies by lower levels of government are widespread and governed by pledges that are not dissimilar from the targets adopted in Kyoto. These pooled efforts will ultimately be gauged by the real reductions in emissions that they achieve.

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Supplementary information accompanies this communication on *Nature*'s website.
Competing financial interests: declared none.
doi:10.1038/438301a

ANT NAVIGATION

Priming of visual route memories

Ants travelling to and fro between their nest and a foraging area may follow stereotyped foodward and homeward routes that are guided by different visual and directional memory sequences[1–6]. Honeybees are known to fly a feeder-to-hive or hive-to-feeder vector according to whether or not they have recently fed — their feeding state controls which compass direction they select[7]. We show here that the feeding state of the wood ant *Formica rufa* also determines the choice between an outward or inward journey, but by priming the selective retrieval of visual landmark memories.

We trained the ants along a foraging route in which the appearance of a landmark differed on the ants' foodward and homeward paths. The ants ran 1 m from a start-pot to a drop of sucrose, both of which lay 20 cm from a black wall that was 2 m long and 20 cm high. They were guided by the remembered appearance of the wall[8], which was to their left on the way to food and to their right on the way home. (For methods, see supplementary information.)

To investigate the role of feeding state in priming visual memories for the foodward or homeward route, trained ants that had either been fed or left unfed were placed individually in a start-pot midway along the wall (Fig. 1a). Unfed ants walked so that they viewed the wall on their left (59 out of 63 paths from 23 ants); fed ants viewed the wall on their right (56 of 61 paths from 20 ants). The wall was regularly rotated during training and the visual scene was identical for fed and unfed ants. We conclude that the ants' feeding state, rather than the compass orientation or panoramic context, determines whether foodward or homeward memories are primed.

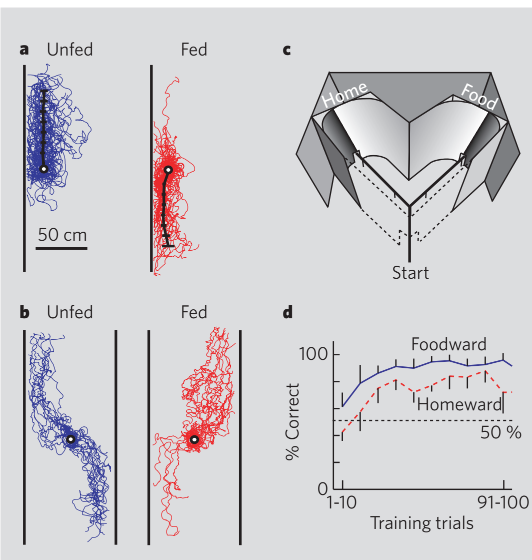

Figure 1 | Wood ants use feeding state to select visual memories for guiding routes towards food or the nest. **a,** Individual trajectories of unfed and previously fed ants released from a start-pot (white circle). Thick line indicates the mean path, with 95% confidence interval (CI) plotted every 10 cm. **b,** Trajectories of ants when the start-pot is placed midway between two walls. The exit from the start-pot is at the top of the figure. Fed ants left in the direction of the exit; unfed ants circled the pot before choosing a direction. **c,** Y-shaped maze (dotted lines indicate front wall) with different patterns for homeward and foodward routes (see supplementary information). Distance from Y junction to pattern, 33 cm. **d,** Ants' performance on foodward and homeward journeys in training, showing mean choices of 11 ants (95% CI).

Ants did not just learn fixed motor patterns (for example, to turn left when fed) as the paths were the same, irrespective of whether the exit from the ants' start-pot faced the wall (as in training) or faced away. Ants placed midway between two identical walls 80 cm apart (Fig. 1b) walked closer to the left wall when unfed (20 of 20 paths, 9 ants) and to the right wall when fed (22 of 22 paths, 9 ants), thereby matching the route-specific visual memory that was primed by their feeding state.

In a second experiment, ants learned a foraging route in which they ran twice through the same 'Y' maze, first to reach food and then to be returned to the nest. Each arm of the 'Y' led to a different visual pattern (Fig. 1c). One of the two patterns signalled the way to food, and the other the way home. Training patterns were frequently switched between sides. Ants learned to choose the foodward pattern when unfed and the homeward pattern after feeding (Fig. 1d).

In unrewarded tests, unfed or previously fed ants made two journeys through the maze. On both journeys, ants chose the foodward pattern when unfed (first journey, 41 out of 44 correct; second, 37 of 41 correct) and the homeward pattern when fed (first journey, 38 of 43 correct; second, 25 of 28 correct) (all $P < 0.0001$). We conclude that the ants' visual memories were primed by feeding state and not by the sequence of rewarded patterns.

Although ants are rigid in sticking to familiar routes, they are like honeybees in that they show flexibility in choosing between routes. The selective priming of visual and vector memories specific to a particular route is an important component of this flexibility[7,9–13].

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Supplementary information accompanies this communication on *Nature*'s website.
Competing financial interests: declared none.
doi:10.1038/438302a

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