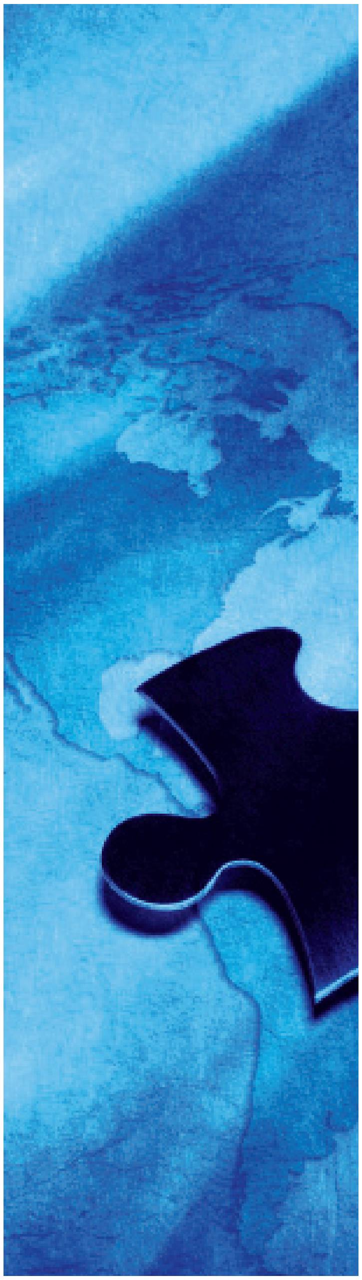
POLICY BRIEF



Addressing Leakage in a Greenhouse Gas Mitigation Offsets Program for Forestry and Agriculture

Prepared by the Nicholas Institute for Environmental Policy Solutions, Duke University

W. Aaron Jenkins
Lydia P. Olander
Brian C. Murray

April 2009

Duke
NICHOLAS INSTITUTE
FOR ENVIRONMENTAL POLICY SOLUTIONS

NI PB 09-03

MITIGATION BEYOND THE CAP

A Series of Briefs on Expanding Climate Mitigation Opportunities

Addressing Leakage in a Greenhouse Gas Mitigation Offsets Program for Forestry and Agriculture

W. Aaron Jenkins
Lydia P. Olander
Brian C. Murray

Leakage is the phenomenon through which efforts to reduce emissions in one place simply shift emissions to another location or sector where they remain uncontrolled or uncounted. It occurs "whenever the spatial scale of the intervention is inferior to the full scale of the targeted problem."[1] The potential for leakage arises when rules, regulations, and incentives for action affect only part of the potential pool of participants or emissions sources.[2] As complete coverage by a policy is difficult, leakage is a problem common to many policies.

Within climate change policy, a germane example is the concern about competitiveness-driven leakage from industrial sectors. Carbon constraints could cause some producers to incur costs that competing producers do not. That would bring about the leakage of emissions (along with economic production and jobs) from certain sectors in a country with stringent policy to other countries not covered by similar mandatory policies. Although negative leakage like this is most frequent, positive leakage can also occur, such as when a policy induces emission reductions outside of the targeted area.[*]

Leakage can be classified as either *on-site* or *off-site*. The former involves the unanticipated increase in greenhouse gas (GHG) emissions within a project or program coverage area; in the latter, emissions shift to a place or sector outside of the coverage area. We assume that on-site leakage will be dealt with through accounting, and do not discuss it further.[†] Off-site leakage is the focus of this brief and can take place at different spatial scales depending on the policy extent. *International* leakage transpires when emissions shift from a country with mandatory emissions reductions, such as a cap-and-trade regime, to a country without such restrictions. *Subnational* leakage can occur when a country adopts a binding program at the national level that leaves some sectors outside of the cap. Here, emissions may be displaced from a capped source (e.g., cement production) to an uncapped one (e.g., timber harvesting), particularly when one product of the emissions can substitute for another. Another avenue for sub-national leakage is voluntary inclusion in an emission reduction program. For example, in an offsets program, an uncapped entity can take on an emission reduction project (e.g., turning agriculture lands into forest); however, a similar uncapped entity may also increase its emissions (turning forest into farm land) in response to the demand shifted from the initial project.[‡] Box 1 provides a descriptive example of leakage.

Box 1. An example of leakage in an offsets program.

A common type of offset activity is an afforestation project in which trees are planted on crop or pasture land and carbon is sequestered in tree biomass and the soil as the forest stand grows. For example, imagine that trees are afforested on 1,000 acres of crop land in one area, which will capture 100,000 metric tons of CO_2 ($MtCO_2$) over the life of the forest stand. Leakage results as trees are cleared from 200 acres in another area in order to plant crops to meet the demand for agricultural products left unfilled by the afforestation project. The tree clearing generates 20,000 $MtCO_2$ emissions, resulting in a leakage rate of 20%.

Proposed cap-and-trade policies to address climate change do not generally include the agriculture and forestry sectors under the cap, though they would allow those sectors to participate through voluntary projects. GHG mitigation projects in Agriculture, Land Use Change, and Forestry (AgLUCF) involve contracts between farmers/landowners (sellers) and other parties (buyers) to reduce GHGs below some baseline level or to increase carbon sequestration above some baseline level. The buyers may use these credits to meet compliance obligations under a GHG cap-and-trade program or as part of a voluntary obligation to reduce GHGs. These AgLUCF projects can create real reductions to offset emissions elsewhere in the system and include activities such as avoided deforestation, forest management, tillage management, afforestation/reforestation, and changes in practices to reduce emissions of nitrous oxide (N_2O) and methane

* For example, a U.S. domestic policy could provide incentives to spur the development of a new technology for energy efficiency. That technology could then be transferred to other countries and its implementation could result in GHG emission reductions in those countries. In this way, the U.S. policy could lead to positive leakage.

† Under entity-wide accounting, if an entity planted trees on 75 acres of cropland but also cleared trees on 25 acres elsewhere on its land holdings, then the GHG reductions from the afforestation project would need to be adjusted down to account for the deforested acres (i.e., the on-site leakage).

‡ An offsets program allows an entity covered in a cap-and-trade policy to offset its own emissions by using a reduction in emissions or increase in GHG sequestration produced by an entity outside of the compliance cap.

(CH_4). The projects can take place at both the national and international level.*

In contrast to biophysical phenomena in land use change, there are no special sensors that detect leakage. Leakage is not directly observable. Rather, it is a market phenomenon that must be estimated using economic data and models. Leakage can be estimated before policy implementation (*ex ante*) with predictive simulations, or after the policy has been implemented (*ex post*) using observed market data from a past period. Estimates should be adjusted by a time discounting approach to reflect when emission shifts occur, since leakage closer to the present is more damaging than that in the more distant future. Published leakage values range from 0% to 92% (see Table 2 in the Appendix)—in other words, there is considerable variability surrounding leakage rates and significant uncertainty in the estimates. The variability comes from the context surrounding the offset project, which encompasses such factors as connectivity to markets, flexibility of consumers and producers to adjust to the market signals (prices), and numerous other factors (see section on leakage magnitude below). Leakage is reduced through a drop in demand, substitution to less GHG-intensive products, or gains in productivity per acre. It is important that policy solutions do not hamper or preclude these alternative outcomes. The scale of leakage also depends on the type of offset activity implemented; leakage will generally be more of a concern for land use change projects (avoided deforestation and afforestation) than for projects that manage within a given land use (e.g., methane capture within agriculture). Overall, leakage can be minimal, or it can be a serious issue requiring attention in the design of any offset policy structure.

Along with additionality and permanence, leakage is a key concern for offset projects because it is essential to determine whether an emission reduction is genuine. If present, leakage erodes the GHG benefits, and hence the offset value, of a project. Thus, it has the potential to undermine a cap-and-trade regime that allows offsets.

Economic foundations of leakage

Economic processes underlie the phenomenon of leakage. For example, deforestation usually happens when people clear land for agricultural production, mining, or other uses. If these actions are stopped or significantly curtailed, the underlying question is, How will the demand be met for the goods and services that would otherwise be produced on that land? It is reasonable to expect that in some cases, the demand will be met by simply shifting the emitting activity elsewhere. If it is shifted to a place that remains outside the purview of the policy, the emissions will go unaccounted for and undermine the policy.

First, society places demands on the goods and services produced by land, but the amount of land available to produce them is fixed. Policy-targeted changes on land use can cause a reallocation of that land use unless specifically and effectively prohibited by the policy.[3,4]

Second, agriculture and forest commodities produced on land are likely to be traded in markets that operate on local, regional, national, and often global scales. Therefore, market forces may translate changes in the supply of commodities promoted by policies in one location into changes in the demand for and supply of commodities in other, distant locations. Markets tend to expand the spatial impact of seemingly local actions. Even without well-integrated markets, parties can shift activities and emissions locally in response to restrictions in one place and the need to meet basic needs (e.g., shifting subsistence agriculture). This, too, is a matter of allocating scarce land resources.

Third, the timing of the induced land use changes matter. Suppose forests are established in one place to sequester carbon but lead to forest clearing elsewhere. The induced leakage is immediate and large, while the direct sequestration benefits take time to accrue. This shifting of impacts over time has implications for the climate benefits of the project (nearer-term mitigation is generally more valuable than farther-term), which complicates leakage estimation.

Leakage drivers

As discussed above, leakage is largely the result of economic processes. In the case of AgLUCF projects, land, agricultural, and timber markets are probably the most significant leakage venues. Within the U.S., land markets encompass activities in real estate development, whether expansion of the suburban fringe or exurban building. Land prices increase in response to development pressures, often resulting in the displacement of lower-return

* International offsets transacted between developed and developing countries have predominately taken place through the Clean Development Mechanism (CDM), a voluntary, incentive-based program established by the Kyoto Protocol. CDM projects can occur in most emitting sectors, but thus far have been limited to afforestation and reforestation in the AgLUCF sector. Going forward, there is substantial interest in also including reduced emissions from deforestation and degradation (REDD) into the UNFCCC post-Kyoto climate agreements and in U.S. legislation.

agricultural or forestry activities. Prices in agricultural and timber markets also wield substantial influence over land management decisions. The potential for leakage grows as those prices rise relative to a carbon price, triggering actions in other locations to satisfy unmet demand for food or forest products. Taking land out of production, however, does not necessarily lead to leakage, as demand can drop in response to higher prices or supply can be maintained through yield enhancements. In Table 1, we identify the main types of AgLUCF offset projects and their particular leakage drivers.

Land, forestry, and agricultural markets are major drivers in both developing and developed countries, but economic activity is often more segmented and localized in developing countries. As a result, local-level drivers may also play a role, and a potentially greater one than the broader-scale markets. For instance, subsistence (e.g., slash-and-burn) farming and local needs for fuelwood are more common factors in developing countries than in developed countries. While capital and labor typically move rapidly in the developed world, their degree of mobility in the developing world varies greatly. Also, population and employment pressures tend to be more significant issues in the developing context. Policy designed to deal with leakage will need to identify the most important drivers in the targeted areas to maximize effectiveness.

Conditions affecting leakage magnitude

Although empirical studies of leakage are few, an understanding of markets and leakage drivers allows some generalizations about conditions influencing the rate of leakage. The magnitude of leakage impacts will vary according to the particular circumstances of the markets, regions, and/or countries targeted by the policy intervention, as well as by the extent of the policy coverage. In general, the less complete the policy coverage (e.g., emitting activities or countries included), the greater the potential for leakage.

The following key conditions inform both the primary question of whether there will be leakage when an offsets program is implemented, and the secondary question of how much leakage will occur:

Connectedness of output and land markets

To the extent that markets are competitive and integrated across scales, leakage may be more likely as producers can expand into areas not under policy purview. This effect has been asserted with the USDA's Conservation Reserve Program (CRP) in which land retired via CRP has been shown to induce non-cropland acres elsewhere to go into crop production. One study shows a slippage rate of about 20% on CRP land, but subsequent research suggests a much smaller effect, which is negligible in some regions.[5,6] Segmented, localized markets will

Table 1. Offset project types and their associated leakage drivers.

Offset project type	Description	Leakage drivers
Afforestation/reforestation	Planting trees on current cropland, pasture land, marginal lands, or urban landscapes to increase carbon content of biomass and soil	Agricultural markets Land markets Timber markets
Conservation tillage	Modifying conventional tillage practices to increase soil carbon content (with possible tradeoff of productivity decline)	Agricultural markets
Grassland conversion	Converting cropland or marginal lands to pasture or other grassland to establish permanent biomass and increase soil carbon content	Agricultural markets Land markets
Forest management	Increasing stocking, lengthening harvest rotations, and applying reduced-impact logging to increase the carbon density of forests over time	Timber markets Land markets
Avoided deforestation	Maintaining current forest stands and the carbon they hold through formal conservation or reformed land use policies	Agriculture (subsistence & markets) Timber (local needs & markets) Fuel wood (local needs & markets) Population pressures (land & labor markets)

be more common in the developing world and could dampen leakage impacts there.

Mobility of labor and capital

The higher the mobility of capital and labor, the higher the probability that emitting activities will flow to other locations. This factor can vary greatly across developing countries, implying that leakage will be more variable there than in developed markets characterized by high mobility.[7]

Consumer flexibility

Consumers' willingness and ability to purchase and use alternatives, which depends upon the availability and cost of alternatives, determines the elasticity of demand in the commodity market affected by the policy. Inelastic (less flexible) demand implies that the market will be inclined to seek supplies from any sources that will provide them rather than cut consumption or switch to other commodities. This exacerbates the market forces that lead to leakage and is equally likely in domestic and international circumstances.

Producer flexibility

Leakage should be greater when supply is fairly elastic. This is the case when producers can easily step into the void and replace any lost supply that may have resulted from competing producers reducing supply as part of a project-based action.

The following additional factors primarily inform the secondary question of how much leakage will occur:

Availability of alternative lands for production

The leakage rate may be greater if alternative locations for emitting activities are nearby, unoccupied, unprotected, low-cost, and/or have suitable soils. This factor is most relevant for the developing world due to greater availability of frontier lands that often have less clarity or enforcement with regards to property rights.

Ability of producers to change their emissions profile without modifying production

When producers are flexible with the technology they can profitably use and some of the profitable technologies also have lower emissions, this may cause less market shifting and leakage. An example might be when improved fertilization or use of new cultivars does not diminish—and possibly enhances—productivity.

Relative emission potential

Where carbon losses per unit of output are greater in the areas not covered by policy than in the policy areas, leakage may be enhanced. For example, in the context of simulating the impacts of regional policies in the U.S., leakage would likely be higher if forest offset projects were primarily implemented in the South-central United States (SC) and diverted forest loss and timber production to the west side of the Pacific Northwest (PNWW), because PNWW forests are much more carbon-dense than SC forests, and carbon losses from expanding harvests there are greater, all else equal.[8]

Market share

When the scale of activity displaced has a small impact in the national or global market, the reduction in supply is easily replaced by increased supply elsewhere, thereby resulting in higher rates of leakage. In other words, minor market disruptions have little effect on market prices because the rest of the market can quickly fill the supply gap (i.e., leakage) when that supply is only a small share of the market.

Policies to address leakage

Although leakage is caused by economic factors, it is essentially an accounting problem—market forces cause the activities and emissions to shift, but it is only when it shifts into territories where it is unaccounted for that it becomes leakage. Therefore addressing leakage often involves making the accounting more comprehensive, either through better emissions monitoring, discounting, or expanding policy coverage. If none of these seem sufficient, the use of offset credits can be excluded from GHG policy compliance and outside-the-cap activities funded through other means. Lastly, the offsets market could just ignore leakage and accept the error in the system. These options are categorized into the six policy approaches discussed below.

Local efforts

Improve monitoring. At the project scale, some leakage can be handled simply by expanding the monitoring system to capture emissions outside the project boundary. Certain project accounting standards (e.g., Voluntary Carbon Standard) now call for this by tracking localized "leakage belts" surrounding the project area. But in principle, leakage can go far beyond the local area through market-driven shifting, so this alone is unlikely to be sufficient in most cases.

Minimize through project design. By concentrating offsets on activities with demonstrated low leakage potential, overall leakage can be managed. One way to minimize local leakage is through contracts with other local actors who may be sources of potential leakage. While also likely to be insufficient in most applications, this option, together with improved monitoring, could have some success in areas that are separated from commodity markets operating at larger spatial scales (regional, national, global). Thus, developing countries or regions within those countries characterized by disconnected markets may be target areas for these local policy efforts.

Discounting

Discount credits to account for leakage. Given that full policy coverage is difficult, it is assumed that some leakage will remain in the system. The discounting option involves basing estimates of leakage on a project level on predictive estimates that could be specific to activity type and region. The estimated leakage can then be used to discount crediting for project-based reductions. A disadvantage is that big discounts would lower the offset value to the seller, reducing the marginal value and thereby discouraging participation of some of the more additional activities. Discounting can also seem unfair, since there is little the project actor can due to prevent leakage occurring on other people's land.

Ignore leakage discounts once a threshold participation level is achieved. An alternative would be to establish a minimal participation requirement, wherein leakage discounts are no longer applied if global or sectoral participation rises above some level (e.g., participants account for more than X percent of total forest-related emissions or emissions potential).[9] This approach would not burden the offset transactions with discounts for leakage once coverage is large enough. In some sense this is similar to the rules that made the Kyoto Protocol binding once a certain share of the world's emissions was covered through national ratification. Since leakage rates decline as participation increases, this ensures a base level of environmental certainty.

Alternative discounting actions. Instead of having the value of offset credits discounted, project developers could be given the option to pre-empt leakage by putting a percentage of project acreage into high-yield sustainable agricultural or timber production. The percentage would correspond to the expected amount of leakage from the project, using the same estimates as the discounting approach. In the developing world, this option could address sustainable livelihoods goals by instituting some type of sustainable business adjacent to and as part of an offset project. This would seemingly be more appealing for the developer since the sustainable production would generate income from that land, whereas under the crediting discount option, the discount for leakage would basically be income transferred from the project developer to some producer elsewhere. If technical assistance could be offered gratis or at a reduced rate to the project developer to help implement the high-yield sustainable production, that would sweeten the option further. One potential pitfall of this approach is that once the high-yield production techniques are well understood, there may be incentives to convert land in offset projects to commodity production, since that would likely be a higher-return use. Another downside is that it could lead to additional fragmentation of the landscape, undermining conservation objectives.

System-wide accounting

Expand the scale and scope of accounting to sector/national level. Requiring national-level accounting and accountability for activities (e.g., avoided deforestation) allowed in the offsets program will directly address the problem of national-level (within country) leakage for that activity. As such, any emissions transferred within the country will be captured in the national accounting even if they are not tracked in an offset project. If all emissions get counted, and adjustments are made to reconcile differences between the sum of projects and the national accounts, then leaks can be plugged. Broadening coverage even further to include all activities (e.g., all forestry) in the sector, and perhaps related sectors where leakage is likely to move, will reduce the scope for emissions leaking from counted to uncounted activity.[10] If forestry were the sector of interest, this means that all emissions associated with forestry—afforestation, reforestation, forest management, degradation, and deforestation—would need to be tracked (in essence, this would be national accounting for the forest sector). This is similar to international and U.S. policy proposals to include incentives for avoided deforestation and other international forest carbon activities in GHG mitigation policies using national accounting of the forest sector.[*] National accounting does not necessarily imply national coverage, but it can be used to reconcile differences in project and national accounts to address leakage as discussed below.

System-wide true-up. Under this option, net changes in emissions (sequestration) would be measured on a national basis and used to reconcile project and national accounts to account for leakage outside the project system. Buffer accounts can be set aside at the project and/or national level to facilitate these adjustments over time. The benefits are that leakage adjustments would be based on real measurements and that incentives for projects would be improved by shifting liability from individual projects to the system as a whole since leakage is not the fault of projects, per se, but the result of incomplete policy coverage. Project viability could be further enhanced if funding for the buffer account could be provided from an external source, such as auction proceeds from allowances or a strategic reserve, though clearly there will be substantial demand for those resources. A hurdle for this approach is the difficulty in separating out the leakage from natural variation and other factors that change carbon flux in the system.

Cap adjustment

Account for leakage indirectly by tightening the cap. The general concept here is to ratchet down the cap by the measured/anticipated amount of leakage. In its basic form, leakage would be estimated and then the cap would be adjusted accordingly. The quantification could be done retrospectively (as in the system true-up) or prospectively based on predictive leakage estimates. Major challenges loom as empirically measuring the leakage is no mean feat, and furthermore, there may be serious political opposition to this option as it ostensibly shifts the burden back onto the capped sectors. However, this burden may be more perception than reality since an offsets program hampered by leakage hurts the capped sectors as well if it results in restrictions on the use of offsets or deep discounts on them.

Expand cap coverage. The U.S. could expand regulatory coverage across all land use activities, for example by bringing them under the cap of a cap-and-trade policy. But would this option be logistically possible? Under the United Nations Framework Convention on Climate Change (UNFCCC), Annex 1 countries that include their land use sectors are required to conduct national accounting (land use, land-use change, and forestry [LULUCF]). This accounting, however, is often not done at the level of resolution necessary to link individual agricultural producers and landowners into a cap-and-trade program. New Zealand plans to apply a cap that incorporates forestry from the beginning and brings in agriculture later.[*] Its efforts will furnish some lessons, though feasibility will remain an issue seeing that the U.S. is much larger, more economically diverse, and has more widely dispersed land ownership than New Zealand. The other question is whether it would be politically possible to include agriculture and forests under the cap? The domestic agricultural sector will already face higher fuel and fertilizer costs under a climate policy, and thus are concerned that layering on compliance requirements for their net emissions would place too high a burden and raise food prices even higher. Resistance to inclusion under the cap could be quite strong given that the default approach now is to exclude it. The cap could also be expanded by additional countries taking on mandatory caps or mitigation targets which would help to reduce international leakage.

Decouple

Exclude offset compensation from GHG target compliance. If leakage concerns remain too high to be ignored or "swept into" the system, one option is to prohibit the use of offset credits for GHG compliance in capped countries/sectors. With compliance no longer driving demand, some other means, such as a "fund approach" or an allowance revenue allocation approach, would need to account for activities otherwise included as offsets. This option may be primarily used to minimize potential damage to the cap-and-trade system. There are a few other variations on this theme. A partially decoupled approach could involve a strategic reserve which is used for cost containment by some U.S. policy proposals. Offset credits that have some level of perceived risk could be purchased by the government for the reserve and would only be released into the market if prices went above a set price. This would provide financial support for whatever offset types are purchased for the reserve with temporary separation from the market. Another variation, which has been named a "dual markets" approach, creates a separate market for offsets that is linked to the primary market through its commitment to sourcing a certain proportion (or fixed quantity) of its GHG reduction target from the offsets market.[11]

"Forgive and forget"

Ignore the leakage. This option would mean simply disregarding the leakage generated by various projects in the offsets program and accepting inherent error in the system. This would be advantageous for projects if they no longer have to discount the value of their GHG reductions for potential leakage. Perhaps more importantly, it could be negative for the system as a whole since leakage would impair the effectiveness of the offsets program and the cap-and-trade system to which it is linked, undermining the environmental objectives. In many ways this just acknowledges the reality that GHG policies are, for the time being, incomplete in global and sectoral coverage and that there are many imperfections that need to be worked out by applying a broader, more comprehensive global approach. But ignoring leakage, without some compensating attention to the overall stringency of the GHG targets over time, will ultimately lead to a weaker policy.

* The recent U.S. Senate cap-and-trade proposal by Boxer, Lieberman, and Warner (S. 3036), the draft legislation released by Rep Dingell and Boucher (2008), and the recently released proposal from the U.S. Climate Action Partnership (USCAP), a coalition of businesses and NGOs favoring cap-and-trade legislation in the U.S., all contain an international forest carbon provision calling for national accounting of forest sector emissions as part of the compensation scheme. The approach discussed here is just a domestic offset variation on that approach.

Rather than be wedded to only one approach, it will probably be most effective to employ hybrids of the options described above or to use more than one mechanism at a time. In general, the broader the scope of the policy, the better, but there will always be technical and logistical limitations. When an expansive policy is not workable, discounting for leakage, at least initially, can serve a useful purpose. In lands disconnected from markets (i.e., remote areas in developing countries), it may be sufficient to simply monitor the shifting of local activity. Finally, if leakage concerns are too great, they can be circumvented by decoupling offsets from cap-and-trade compliance.

Summary

Leakage has the potential to undermine the integrity of any offset program and, by extension, a cap-and-trade system that allows offsets. AgLUCF offset projects are particularly prone to leakage due to competition for a fixed land base and the multi-scale nature of agricultural and forestry commodity markets. The implementation of an offset program to reduce GHG emissions within a targeted area can result in the shift of emitting activities to locations outside of the policy coverage area. The principal cause of leakage is unmet demand for the goods previously produced in the policy area. Smart offset policy design can help to mitigate this inherent problem of incomplete coverage.

Leakage associated with AgLUCF projects tends to be driven by the need to meet land, agricultural, and timber demand. Due to often more segmented and less mature markets, developing countries may pose somewhat different challenges and opportunities for offset programs. The magnitude of leakage impacts will vary according to the particular circumstances of the markets, regions, and/or countries targeted by the policy intervention, as well as by the scope and scale of the policy itself. Assessing these circumstances, such as the mobility of labor and capital, can provide valuable information about whether to expect leakage and, if so, how much.

Policy approaches to address leakage fall into the five following categories:

- **Local efforts** that involve improving emissions monitoring or project design
- **Discounting** offset credits to account for leakage, at least until a participation threshold has been met
- **System-wide accounting** that allows for a more complete (sectoral, national) measure of net emission effects, which can be used to directly reconcile any subnational leakage effects
- **Adjusting the cap** by either tightening it in recognition of leakage deficiencies or by expanding the scope to encompass more activities so that fewer can leak
- **Decoupling** the offset program from GHG target compliance, either completely or partially
- **Ignoring leakage** and accepting inherent error in the system

Solutions to leakage will probably not be found exclusively within one of the above approaches, but rather through hybrids of the policy options or through the concurrent or sequential application of one or more options. Those solutions may vary across different sectors and between domestic and international contexts. Overall, leakage cannot be eradicated entirely, but it can be contained sufficiently to instill confidence in offsets programs and cap-and-trade systems associated with them.

* New Zealand's Emissions Trading Scheme (NZETS) will phase in different sectors from 2008 to 2013 with forestry being the first, effective January 1, 2008. It will be followed by stationary energy and industrial process sectors in 2010 and liquid fossil fuels in 2011. Agriculture, which is responsible for almost 50% of New Zealand's emissions, will enter the NZETS in 2013. Note that although the scheme passed parliament in October 2008 under the previous government, it is currently under review by a parliamentary committee set up by the new ruling coalition.

References

1 Wunder, S. 2008. How should we deal with leakage? In *Moving Ahead with REDD: Issues, Options and Implications,* ed. A. Angelsen, 65–75. Bogor, Indonesia: Center for International Forest Research (CIFOR).

2 Murray, B.C. 2009. Leakage from an avoided deforestation compensation policy: Concepts, empirical evidence, and corrective policy options. In *Avoided Deforestation: Prospects for Mitigating Climate Change*, eds. C. Palmer and S. Engel. Abingdon, UK: Routledge.

3 Wear, D.N. and B.C. Murray. 2004. Federal timber restrictions, interregional spillovers, and the impact on U.S. softwood markets. *Journal of Environmental Economics and Management* 47(2):307–330.

4 Wu, J. 2000. Slippage effects of the Conservation Reserve Program. *American Journal of Agricultural Economics* 82(4): 979–992.

5 Ibid.

6 Roberts, M.J. and S. Bucholtz. 2005. Slippage in the Conservation Reserve Program or spurious correlation? A comment. *American Journal of Agricultural Economics* 87(1): 244–250.

7 Sohngen, B. and S. Brown. 2004. Mitigating leakage from carbon projects in open economies: A stop timber harvesting project in Bolivia as a case study. *Canadian Journal of Forest Research* 34: 829–839.

8 Murray, B.C., B.A. McCarl, and H. Lee. 2004. Estimating leakage from forest carbon sequestration programs. *Land Economics* 80(1):109–124.

9 Murray, B.C. and L.P. Olander. 2008. A core participation requirement for creation of a REDD market. Short Policy Brief, Nicholas Institute for Environmental Policy Solutions, Duke University. http://www.nicholas.duke.edu/institute/pb-redd.pdf.

10 U.S. Environmental Protection Agency (U.S. EPA). 2005. Greenhouse gas mitigation potential in U.S. forestry and agriculture. http://www.epa.gov/sequestration/pdf/greenhousegas2005.pdf.

11 Ogonowski, M. et al. 2007. Reducing emissions from deforestation and degradation: The dual markets approach. Future Actions Dialogue Working Paper, Center for Clean Air Policy. http://www.ccap.org/docs/resources/69/FINAL_REDD_report.pdf.

Appendix

Table 2. Published leakage estimates from avoided deforestation, land retirement, and forest preservation setaside (stop logging) policies.

Region	Policy action	Estimated leakage magnitude (%)	Analysis approach	Source
Temperate, Pacific Northwest U.S.	Stop logging public lands	Within region: 43 National: 58 Continental: 84	ex post	Wear and Murray, 2004
U.S.	Land retirement via Conservation Reserve Program	20	ex post	Wu, 2000
Global	Reduce forest output at national and regional level	45–92	predictive estimates	Gan and McCarl, 2007
Temperate/ U.S. regional	Avoid deforestation and logging setasides on private lands (regional policies in isolation)	Avoided Deforestation Northeast: 41–43 Pacific NW: 8–9 Other regions: 0–92 Logging setaside Pacific NW: 16 South: 64	predictive estimates	Murray et al, 2004
Tropics/Bolivia	Logging setasides in national park	2–38	predictive estimates	Sohngen and Brown, 2004

Adapted from Sathaye and Andrasko, 2007, Special issue on estimation of baselines and leakage in carbon mitigation forestry projects, *Mitigation and Adaptation Strategies for Global Change* 12(6): 963–970.

The authors acknowledge the support of the Linden Trust for Conservation and the help of Aaron Jenkins and Paul Brantley from the Nicholas Institute.

the Nicholas Institute

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to engage with decision makers in government, the private sector, and the nonprofit community to develop innovative proposals that address critical environmental challenges. The Institute seeks to act as an "honest broker" in policy debates by fostering open, ongoing dialogue between stakeholders on all sides of the issues and by providing decision makers with timely and trustworthy policy-relevant analysis based on academic research. The Institute, working in conjunction with the Nicholas School of the Environment, leverages the broad expertise of Duke University as well as public and private partners nationwide.

for more information please contact:

Nicholas Institute for Environmental Policy Solutions
Duke University
Box 90335
Durham, North Carolina 27708
919.613.8709
919.613.8712 fax
nicholasinstitute@duke.edu