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Who Captures the Value of Residential Retrofit? The Benefit-Transmission Gap in China and Beyond

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THE MISSING POST-RETROFIT STEP

Residential retrofit is usually judged by predicted or realized energy savings. Yet physical savings do not automatically reduce household expenditure. In northern China's district-heating systems, lower heat demand or supply costs may leave household charges unchanged when billing settlement and household charge apportionment are weakly linked to measured consumption.^{1,2} In an individually metered dwelling, the pathway is often more direct. The difference is institutional as well as technical.

Teece's distinction between value creation and value capture provides a useful map.³ The retrofit creates the capacity to save; meters, data systems and billing platforms are complementary assets that make the saving verifiable; and tariff, tenure, subsidy and contract rules form the institutional arrangements that allocate its value. Households, landlords, property managers, utilities, energy-service companies (ESCOs) and public budgets may therefore capture different shares.

The benefit-transmission gap complements, rather than renames, established research. A split incentive is primarily an ex-ante investment problem: the actor paying for a retrofit may not receive the expected benefit. Energy performance contracts explicitly divide verified savings between a client and an ESCO. The benefit-transmission gap is an ex-post accounting question: after realized savings have been identified and monetized, how much of their value reaches households through lower bills or energy-related service charges? Principal-agent models explain why contractual incentives may be misaligned before investment; The Benefit Transmission Ratio (BTR) audits the realized distribution after investment, whether or not the relationships fit a landlord-tenant dyad. It can therefore be applied to publicly financed and owner-occupied programmes as well as rental housing. The contribution is a common accounting lens across these arrangements, not a claim that benefit sharing has been overlooked.

WHY CHINA MAKES THE GAP VISIBLE

China makes this distinction visible because efficiency programmes combine public finance, utility investment and household equipment replacement. System-level avoided investment and operating costs can offset much of the cost of urban building efficiency, while the actors funding improvements may differ from those receiving the saving.¹

Northern district heating is the clearest mediated pathway. Apartment position, heat transfer, outages and limited user control complicate household measurement.² Building-level savings may lower a heating company's operating cost or a government's subsidy requirement without reducing household charges, especially where charges remain area-based. Building-level metering with a transparent household charge-apportionment rule may therefore be more credible than treating each apartment as thermally independent.

In individually metered regions, technical savings can enter electricity or gas bills more directly, but household value must still be visible. A survey of 413 homeowners in six Anhui cities found limited recognition of retrofit energy and financial benefits; clearer benefit and service information was associated with stronger cooperation.⁴

The same issue arises beyond China. European rental and social-housing programmes show that rent recovery, third-party finance and EPC contracts can determine who receives savings. In France, social landlords may recover part of energy-cost savings from tenants. In Reggio Emilia, Italy, a social-housing EPC allocated verified savings between tenants and an ESCO.⁵ These are deliberate allocation rules, whereas opaque or unreported allocation produces a transmission gap that households cannot assess. Similar physical retrofits can therefore yield different household outcomes: an area-based charge weakens automatic pass-through, a metered tariff makes it more direct, and a shared-savings contract makes the retained and transmitted shares explicit. This institutional comparison, rather than geographic coverage alone, motivates the "beyond" framing.

MEASURING BENEFIT TRANSMISSION

Three gaps should remain separate. An energy-performance gap is the difference between predicted and realized saving. Rebound and comfort takeback affect realized saving. The benefit-transmission gap begins after that saving has been measured and monetized. The gaps can interact because weak transmission in one project can reduce the credibility of promised benefits in the next.

At building or programme level, realized saving is the weather-normalized difference between post-retrofit use and the counterfactual: what would have occurred without retrofit at a comparable service level. Let $V_{E_{src}}^{src}$ be avoided expenditure at the source meter or supply contract under the price schedule that would otherwise have applied (the counterfactual tariff). Let ΔB_H be the attributable reduction in aggregate household bills or energy-related service charges over the same period. The Benefit Transmission Ratio is:

$$BTR = \frac{B_H}{V_{E_{src}}^{src}}$$

The denominator must represent value created where energy is purchased for the building or programme. It should not be constructed by multiplying saved energy by the same household per-unit price used for the numerator, which would make BTR approximately one by construction. Where a bill has a fixed connection charge and a per-unit charge (the marginal tariff), lower consumption reduces only the latter. Tariff changes, rebates and contract payments should be stated separately or incorporated through an explicit counterfactual. A practical calculation should align energy units, prices, population and time. Source expenditure and household bills should cover

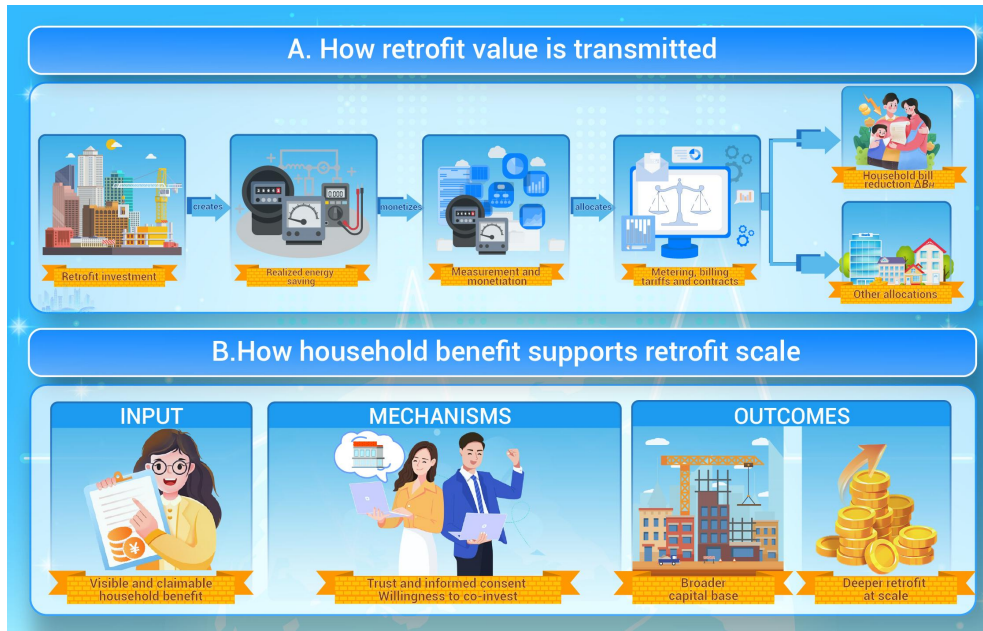


Figure 1. Benefit transmission and retrofit scale (A) Retrofit investment creates realized energy saving that is measured, monetized and allocated through metering, billing, tariffs and contracts to household bill reduction (ΔB_H) or other allocations. (B) Visible and claimable household benefit can support trust, informed consent and willingness to co-invest, broadening the capital base and enabling deeper retrofit at scale.

guards and protection for occupants of inefficient or disadvantageously located dwellings. Distribution should also be reported across tenure, income, building vintage and climate region; an acceptable average BTR may conceal weak transmission to households facing the greatest affordability risks.

Benefit transmission can also affect financing. Observable and claimable household value may strengthen consent, cooperation and willingness to co-invest, widening the capital base beyond public budgets and utility balance sheets (Figure 1). This is a financing condition,

the same buildings and billing period and use the same weather and service baseline. Analysts should report whether taxes, fixed charges, arrears, subsidies, rent adjustments and ESCO payments are included. Sensitivity ranges are preferable when counterfactual tariffs or attribution are uncertain.

A European Commission case illustrates the calculation. The Reggio Emilia social-housing EPC guaranteed a 50% energy saving over 12 years and allocated 60% of the savings to the ESCO and 40% to tenants, producing a reported 20% monthly bill reduction.⁵ Taking the contract's total monetized savings as V_E^{src} and the tenant share as ΔB_H gives $BTR = 0.40$. This calculation uses published contractual shares rather than primary bill microdata; the remaining 0.60 represents disclosed financing recovery rather than unexplained loss.

A BTR near one indicates that most measured source-side monetary saving appears in household charges; a value near zero indicates weak household capture. Values above one may reflect transfers, while negative values may arise if tariff or service-charge increases exceed the saving. Such cases require decomposition, not automatic ranking. BTR measures bill incidence – who receives the monetary effect – not total welfare. Comparison across programmes is most credible when boundaries are harmonized. A programme can report annual BTR and cumulative contract-period BTR because early savings may legitimately service capital while later savings flow more fully to households. Distributional results should accompany the aggregate ratio wherever billing data permit.

DESIGNING FOR HOUSEHOLD CAPTURE AND CAPITAL MOBILIZATION

Programmes should report a reconciled chain of energy and money: realized physical saving, avoided source expenditure, aggregate household bill or service-charge reduction, and the residual retained or reallocated among utilities, property managers, landlords, ESCOs and public budgets. The accounting boundary, period, weather adjustment, counterfactual prices and treatment of subsidies must be declared. The residual should be named rather than treated as leakage: debt service, maintenance, utility revenue stabilization, landlord recovery, ESCO remuneration and public-budget savings have different policy meanings. A reconciliation that does not sum should trigger a data-quality review.

Retrofit design, metering, pricing, contracts and social protection should be developed together. Consumption-based charging needs affordability safe-

not a sufficient cause: credit constraints, disruption, tenure, collective consent and trust in contractors remain important.

A low BTR does not necessarily mean that a retrofit has failed. Savings may repay capital, maintain infrastructure, stabilize tariffs or reduce subsidies. Comfort, health, property value, peak-load reduction and emissions benefits should be reported alongside BTR rather than folded into it. The requirement is transparency: households should be able to see what value was created, what share they received, and why the remainder was allocated elsewhere.

OUTLOOK

China is not an exception but a stress test of the assumption that energy saving automatically produces household benefit. Collective heating exposes billing and contractual transmission; individually metered regions expose whether benefits are visible and credible. European rental and EPC examples show the same question under different institutions. Retrofit evaluation should therefore ask not only whether energy was saved, but who captured its value and whether the allocation supports the next round of investment.

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DECLARATION OF INTERESTS

The authors declare no competing interests.