US Residential Energy Use Affected by the Principal Agent Problem

Jayant A. Sathaye
Senior Staff Scientist
Lawrence Berkeley National Laboratory
Berkeley, CA, USA

Barriers to Energy Efficiency: Quantifying the Costs
15-17 March 2006, Sydney, Australia

Principal Agent (PA) Problem

- **A principal agent (PA) problem arises**

  —Where one person, the principal, hires an agent to perform tasks on his behalf, but cannot ensure that the agent performs them in exactly the way a principal would like

  — Efforts of the agent are impossible or expensive to monitor

  —Incentives of the agent differ from those of the principal.

  —The principal agent relationship is one which is characterized by asymmetric information, i.e., information concerning a transaction which is unequally shared between the two parties to a transaction

- PA problem arises in <u>two separate transactions</u> in the end-use of energy
  - —<u>First transaction</u> is between the seller and purchaser of the end-use device
    - Transaction may result in the installation of the least-first-cost device rather than the most cost-effective energy-efficient one
  - —<u>Second transaction</u> is between the owner and user of the device
    - User may use the device wastefully if he/she does not directly pay fuel or electricity cost of the device
- In either case, the <u>response</u> to a <u>price signal is masked and/or delayed</u>

End-User	Chooses Technology	Does not Choose Technology
Pays Energy Bill	Case 1: No Problem	Case 2: Efficiency Problem
Does not Pay Energy Bill (Utilities incl. in rent or flat fee)	Case 3: Usage and Efficiency Problem	Case 4: Usage Problem

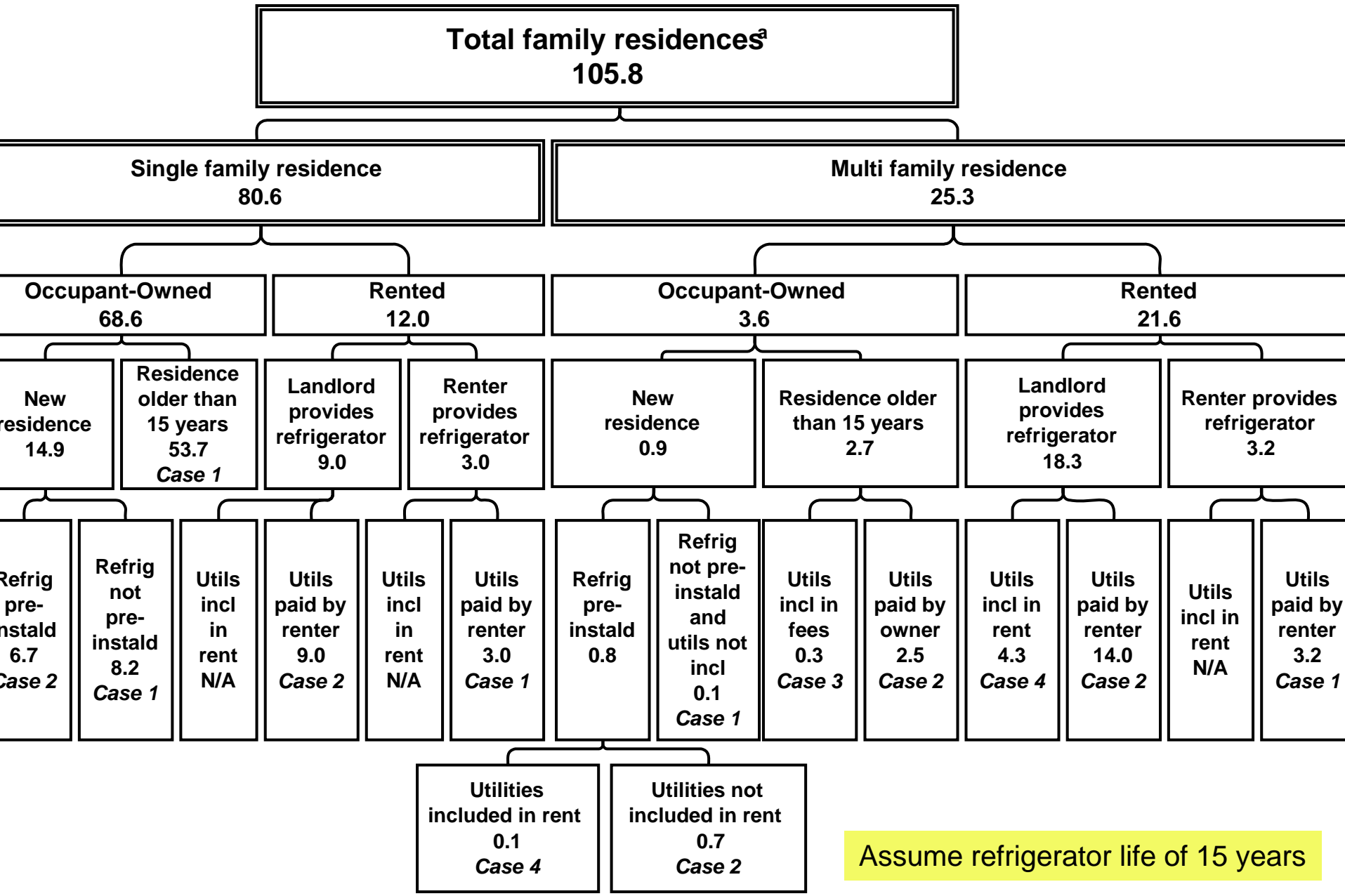|	Refrigerators	Water Heating	Space Heating	Lighting	Total
Site Energy					
Site Energy, (Million GJ)	532	1,680	4,657	343	7,212
Share of Site Total Residential Energy	5%	17%	47%	3%	73%
Primary Energy					
Primary Energy (Million GJ)	1,560	2,390	5,375	1,007	10,332
Share of Primary Total Residential Energy	9%	14%	31%	6%	59%

A 3-step process:

1. <u>Allocate all households</u> to the four cases of the principal-agent typology <u>using housing data</u>

    - This depends on factors such as tenancy status, age, whether the end use feature is pre-installed, and whether energy costs are individually billed

2. Within each case, <u>disaggregate households by important end-use characteristics</u> such as fuel or type of heating/cooling system

3. <u>Estimate energy use</u> considering factors such as housing unit type (SFR, MFR, mobile home) and end-use characteristics

Data Sources: Refrigerators

- American Housing Survey, 2003
  - Number of housing units by unit type, year of completion, ownership status, and whether utilities are included in rent

- National Assoc. of Home Builders, 2005
  - Number of single-family and multi-family units completed in 2003 with refrigerators pre-installed

- American Assoc. of Home Appliance Manufacturers, 2003 Fact Book
  - Refrigerator shipments and average shipment-weighted energy use

- Residential Energy Consumption Survey (RECS), US EIA, 2001
  - Number of refrigerators in the stock and energy consumption for refrigeration

Total family residences[a]
105.8

Single family residence
80.6

Multi family residence
25.3

Occupant-Owned
68.6

Rented
12.0

Occupant-Owned
3.6

Rented
21.6

New residence
14.9

Residence older than 15 years
53.7
Case 1

Landlord provides refrigerator
9.0

Renter provides refrigerator
3.0

New residence
0.9

Residence older than 15 years
2.7

Landlord provides refrigerator
18.3

Renter provides refrigerator
3.2

Refrig pre-instald
6.7
Case 2

Refrig not pre-instald
8.2
Case 1

Utils incl in rent
N/A

Utils paid by renter
9.0
Case 2

Utils incl in rent
N/A

Utils paid by renter
3.0
Case 1

Refrig pre-instald
0.8

Refrig not pre-instald and utils not incl
0.1
Case 1

Utils incl in fees
0.3
Case 3

Utils paid by owner
2.5
Case 2

Utils incl in rent
4.3
Case 4

Utils paid by renter
14.0
Case 2

Utils incl in rent
N/A

Utils paid by renter
3.2
Case 1

Utilities included in rent
0.1
Case 4

Utilities not included in rent
0.7
Case 2

Assume refrigerator life of 15 years

nd-user	Chooses Technology	Does not Choose Technology
ays nergy ill	**_Case 1: No problem_** 70.8 million households [67%] 381.5 TBtu [72%] *Owned residences:* Most newer ones (55%) Those older than 15 years [a] *Rental units:* Those with no refrigerator included	**_Case 2: Efficiency problem_** 30.4 million households [29%] 134 TBtu [25%] *Owned residences:* Some newer ones (45%) *Rental units:* Most of these units
oes not ay nergy ill	**_Case 3: Efficiency and usage problem_** 0.3 million households [< 1%] 0.9 TBtu [< 1%] *Condominiums:* Small number *Rental units:* Small number	**_Case 4: Usage problem_** 4.4 million households [4%] 14.6 TBtu [3%] *Condominiums:* Small number *Rental units:* Significant number[b]

[a] Assumes original refrigerator has been replaced by owner.

[b] For refrigerators, no efficiency problem exists assuming same agent (e.g. landlord) chooses technology and pays for energy. This may not be true in some newer buildings where electricity is included in rent if the developer selected refrigerators instead of the landlord.

Refrigerators: Sensitivity Analysis

Description of Assumptions Used	Counter-Assumptions	% Change Affected Energy
Rate of pre-installed refrigerators for 2003 was assumed to apply for all previous "new" stock in SFRs.	Previous years had either a much higher or lower rate of pre-installs than 2003 changing by ± 15%.	± 7.5%
Rate of pre-installed refs for 2003 MFRs applies to entire rental MFR stock.	Assume that on average 95% of MFR renters do not choose refrigerator	+ 5.4%
Most HH reporting a secondary refrigerator are SFRs. These refrigerators were divided proportionally among rental & owned SFRs based on their shares of the SFR stock.	Assume rentals greater or lesser than proportional share by ± 5%.	± 4.2%

- For incremental savings, determine how many units are purchased for affected households by
  - New rental units
  - New occupant-owned households, where end-use feature is pre-installed
  - Replacements for existing rental units
- Using data on efficiencies of shipped units, minimum standards, and Energy Star criteria estimate a reasonable efficiency improvement that could be expected from removing the PA barrier
  - Ideally, data would be available on efficiencies of units purchased by occupant-owners vs. units purchased for rental households
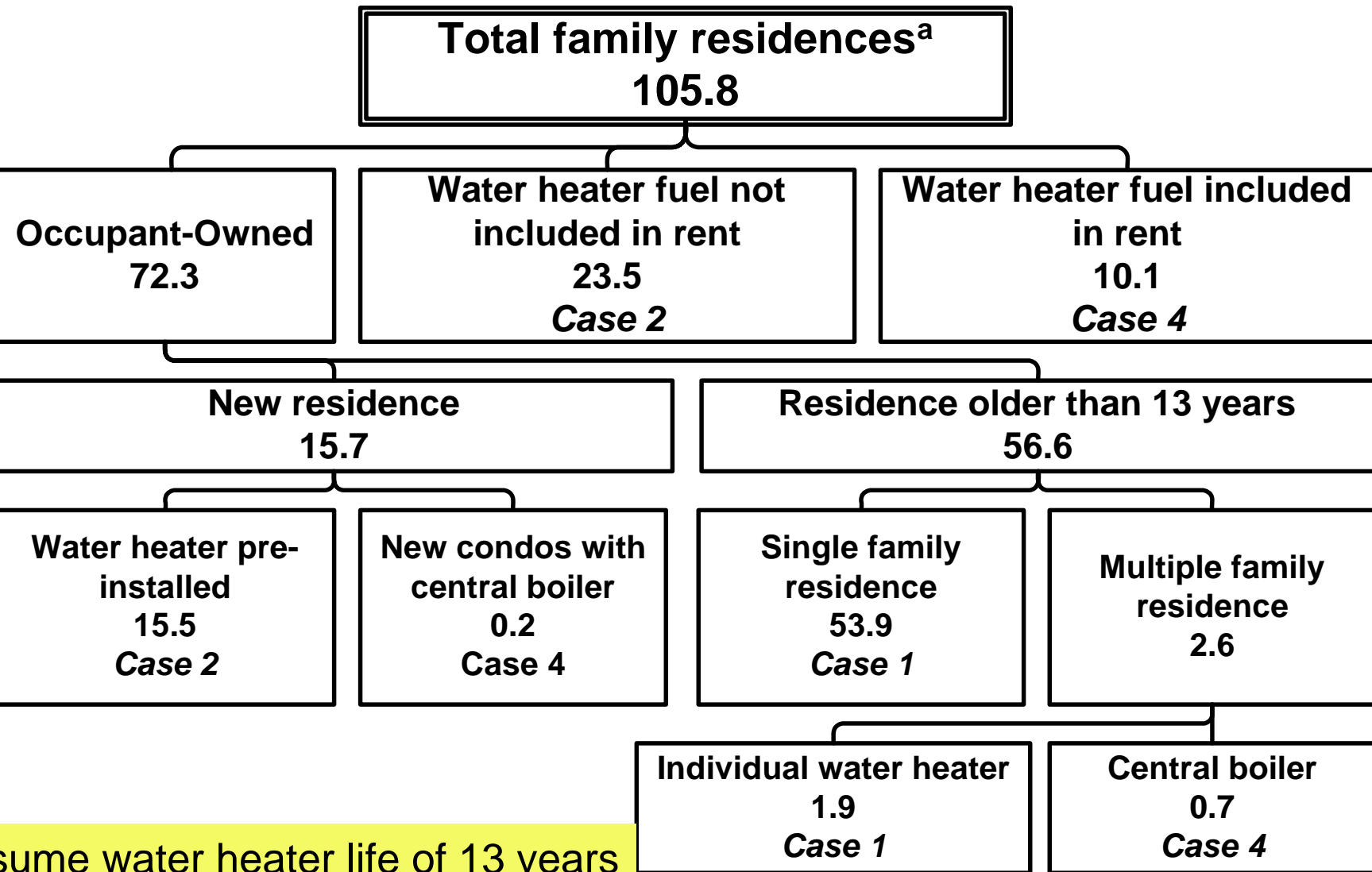
escription of Assumptions Used	Counter-Assumptions	% Change in Savings from One Year's Sales
hipment-weighted average for 2002 is 6% better than minimal standard.	Assume shipment-weighted average is closer to or better than minimum standard by $\pm 2\%$.	+ 19.7% / -21.5%

Data Sources: Water Heaters

- **American Housing Survey, 2003**
  - — Number of housing units by unit type, year of completion, ownership status, and whether utilities are included in rent

- **National Assoc. of Home Builders, 2005**
  - —Number of single-family and multi-family units completed in 2003 with water heaters pre-installed

- **GAMA --**
  - — Water heater shipments

- **Residential Energy Consumption Survey (RECS), US EIA, 2001**
  - — Number of water heaters in the stock and their energy consumption

BERKELEY LAB

```
                    ┌──────────────────────────────┐
                    │  Total family residencesᵃ     │
                    │           105.8               │
                    └──────────────────────────────┘
```

Total family residences[a]
105.8

Occupant-Owned
72.3

Water heater fuel not included in rent
23.5
Case 2

Water heater fuel included in rent
10.1
Case 4

New residence
15.7

Residence older than 13 years
56.6

Water heater pre-installed
15.5
Case 2

New condos with central boiler
0.2
Case 4

Single family residence
53.9
Case 1

Multiple family residence
2.6

Individual water heater
1.9
Case 1

Central boiler
0.7
Case 4

sume water heater life of 13 years

a Numbers in parent categories will not always equal the sum of subordinate categories due to rounding.

Water Heater Users by Number and Share of Households and Site Energy

End-user	Chooses Technology	Does not Choose Technology
Pays Energy Bill	Case 1: 55.9 million [53%] 963 TBtu [57%] *Owned SFRs* older than 13 years[a] *Owned MFRs,* older than 13 years, w/ individual water heaters, utilities not included in rent	Case 2: 38.9 million [37%] 560 TBtu [33%] Most *rental* units Newer *owned* units
Does not Pay Energy Bill	Case 3: Negligible Possibly a small number of *condos* older than 13 years w/ individual water heaters	Case 4: 11.0 million [10%] 157 TBtu [9%] Significant number of *rental* units *Condos* with central boilers *Newer condos* with utilities included

[a] Assumes original water heater has been replaced by owner.

Water Heating: Sensitivity Analysis

Description of Assumptions Used	Counter-Assumptions	% Change in		
		Affected Energy	**Savings from One Year's Sales**	**Savings from Entire Stock**
New SFR and condo buyers never specify the type of water heater installed.	Assume 20% of new SFR and condo buyers choose water heater.	- 7.5%		
Since the best performing units in 2003 were more efficient than the minimum standard by 20% for gas units and 10% for electric units, we assumed the efficiency gain from eliminating PA problem is half the difference, 10% for gas and 5% for electric.	The estimate of the savings may be high since information barriers are likely to play as large a role as principal-agent barriers. Assume efficiency gain is only 5% for gas and 2.5% for electric.		- 50%	
All rental MFR units reporting natural gas included in rent are accurate.	Only half of rental MFR units reporting natural gas included in rent are accurate.			- 33% site - 29% primary

Space Heating: Number and Share of Households and Site Energy by Case

End-user	Chooses Technology	Does not Choose Technology
Pays Energy Bill	Case 1: 50.6 million [48%] 2,450 TBtu [53%] *Owned SFRs* older than 20 years[a] *Owned MFRs*, older than 20 years, individual space heaters, utilities not included	Case 2: 46.1 million [44%] 1,860 TBtu [40%] *Most rental units*, excluding where utilities included *Newer owned units*, excluding condos w/ central steam heating
Does not Pay Energy Bill	Case 3: Negligible Possibly a small number of *condos* older than 20 years w/ individual water heaters and space heating fuel included in rent	Case 4: 9.1 million [9%] 350 TBtu [8%] *Rental MFRs* and *mobile homes* with space heating fuel included in rent *Condos* with central boilers *Newer condos* with utilities included

[a] Assumes original space heater has been replaced by owner.

Description of Assumptions Used	Counter-Assumptions	% Change in Affected Energy
Housing units defined as "new" based on 20-yr furnace lifetime, resulting in 29% of units classified as new.	Adjust "new" units by ± 7%	± 11.1%
New SFR buyers never choose furnace, insulation, windows, etc.	20% of new SFR buyers choose space heating-related features.	- 13.5%

End-user	Chooses Technology	Does not Choose Technology
Pays Energy Bill	Case 1: 101.0 million [95%] 335 TBtu [98%] Owned and rented SFRs Most owned MFRs and mobile homes Most rental MFRs and mobile homes	Case 2: Negligible
Does not Pay Energy Bill	Case 3: 4.9 million [5%] 7.8 TBtu [2%] Some rented MFRs and mobile homes Small number of owned MFRs	Case 4: negligible

Lighting: Sensitivity Analysis

Description of Assumptions Used	Counter-Assumptions	% Change in Affected Energy
All rental SFRs with electricity included are misreports.	Only half of rental SFRs with electricity included are misreports.	+ 12.4%
All rental MFRs and mobile homes w/ electricity included are accurate.	Half of rental MFRs and mobile homes w/ elec. included are misreports.	- 45.0%
All owned mobile and MFRs w/ electricity included are accurate.	Half of owned MFRs with electricity included are misreports.	- 5.0%

	Refrigerators	Water Heating	Space Heating	Lighting	Total
Site Energy					
Site Energy, (Mn. GJ)	532	1,680	4,657	343	7,21
Affected Site, (Mn. GJ)	134	717	2,210	7.8	3,06
Affected Share of Site	25%	43%	48%	2%	43%
Affected Share of Site Total Residential	1%	7%	22%	Neg.	31%
Primary Energy					
Primary Energy (Mn. GJ)	1,560	2,390	5,375	1,007	10,33
Affected Primary Energy (Mn. GJ)	394	1,007	2,570	23	3,99
Affected Share of Primary	25%	42%	48%	2%	39%
Affected Share of Primary Total Residential	2%	6%	15%	Neg.	23%

End-User	Chooses Technology	Does not Choose Technology
ays Energy Bill	**Case 1: No Problem** Refrigerators: 72% Water Heating: 57% Space Heating: 53% Lighting: 98%	**Case 2: Efficiency Problem** Refrigerators: 25% Water Heating: 33% Space Heating: 40% Lighting: Negligible
oes not Pay nergy Bill Utilities included rent or user ays a flat fee)	**Case 3: Usage and Efficiency Problem** Refrigerators: <1% Water Heating: negligible Space Heating: negligible Lighting: 2%	**Case 4: Usage Problem** Refrigerators: 3% Water Heating: 9% Space Heating: 8% Lighting: Negligible

Summary and Conclusions

- Price signals alone may have a limited effect on inducing energy savings in the residential sector, because

    - Large share of energy is consumed by end users who have little or no control over the efficiency of energy-using equipment (Case 2)

    - End-users are shielded to some extent from the costs of their energy consumption (Cases 3 and 4)

- Split incentives and asymmetric information characterize these cases

- Information programs and metering could in principle solve both problems

- Are there less expensive approaches to eliminate or minimize asymmetric information problem?

    - Information and voluntary programs – Energy Star and Home Energy Rating System (HERS) ratings for new homes, appliance labels

    - Appliance standards and building codes is another way to address PA problems