Building insulation and renovation in climate change mitigation pathways

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Buildings: Problem Definition

Energy Use

- Transport: 28%
- Other industry: 31%
- Construction industry: 6%
- Buildings: 30%
- Other: 5%

Residential: 22%
Non-residential: 8%

Emissions

- Transport: 22%
- Other: 9%
- Other industry: 30%
- Construction industry: 11%
- Buildings: 28%

Residential (direct): 6%
Residential (indirect): 11%
Non-residential (direct):...
Non-residential (indirect):...

Aberel et al. (2017)
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Rogelj et al. (2018)

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Rogelj et al. (2018)
However…

• Buildings energy demand has been increasing
  \[ \rightarrow 1.3\% \text{ per year} \text{ (2000-2018, globally)} \]

• Expected to increase further
  \[ \approx 0.9\% \text{ per year} \text{ (WEO, 2019 – Stated Policies)} \]
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- Economic growth
- Floor space
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- Economic growth
- Floor space

- Behavioural change
- Technology Performance
- Fuel switching
- **Insulation Improvement**
Model Context

Buildings in IMAGE

- Demand for energy functions
- Urban/rural
- Five Income quintiles
Model Context

Buildings in IMAGE

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So Far: Building efficiency was an exogenous parameter assuming changes in heating or cooling intensity

\[ \text{Scenario parameter} \]

Model unable to represent the choices which govern this change
Modeling Improvements in Building Insulation

Driven by Scenario Parameters

- Building stocks

Socio-economics:
- Economic growth_{R,Q}
- Population growth_{R,Q}

Floorspace_{R,Q} (m²) → New Floorspace_{R,Q}

Subscripts:
R: Region
Q: Urban/Rural Quintile
Modeling Improvements in Building Insulation

Driven by Scenario Parameters

- **Building stocks**
- **Heating/Cooling Demand**

**Socio-economics:**
- Economic growth$_{R,Q}$
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**Subscripts:**
- $R$: Region
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**Floorspace$_{R,Q}$ (m²)**

**Heating & Cooling Demand$_{R,Q}$**

**New Floorspace$_{R,Q}$**

**Heating Degree Days (HDD)$_R$**

**Cooling Degree Days (CDD)$_R$**
Six insulation levels ranging *minimal* to *passive-house equivalent*

Investments in Efficiency based on relative costs

- Resultant Fuel Costs
- Insulation Capital Costs

→ Consumer discount rates

**Models:**

- Heating Degree Days (HDD)$_{R}$
- Cooling Degree Days (CDD)$_{R}$

**Socio-economics:**
- Economic growth$_{R,Q}$
- Population growth$_{R,Q}$

**Subscripts:**
- $R$: Region
- $Q$: Urban/Rural Quintile
- $I$: Insulation (Efficiency) Level

**Floorspace**$_{R,Q}$ ($m^2$)

New Floorspace$_{R,Q}$

**Insulation Levels (6)**
- Efficiency$_{I}$
- Discount Rates$_{R,Q}$

Cost (fuel + Capital)$_{R,Q,I}$

→ Market Shares$_{R,Q,I}$

Learning$_{I}$
Build Stock model can track efficiency levels

- **Renovation**
- **Households Benefit from**
  - Economic growth
  - Cost decreases

### Socio-economics:
- Economic growth
- Population growth

### Subscripts:
- $R$: Region
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**Floorspace**

- $\text{Floorspace}_{R,Q}$
  - (m²)

**New Floorspace**

- $\text{New Floorspace}_{R,Q}$
  - $t+1$

**Existing Floorspace**

- $\text{Existing Floorspace}_{R,Q}$

**Decommissioned at end-of-life**

**Insulation Levels (6)**

- Efficiency
- Discount Rates

**Market Shares**

- $\text{Market Shares}_{R,Q,I}$

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Heterogeneous Representation

- Urban/Rural Quintiles
- Climate characteristics
- Efficiency levels
- Stock accounting

Socio-economics:
- Economic growth\(_R,Q\)
- Population growth\(_R,Q\)

**Subscripts:**
- \(R\): Region
- \(Q\): Urban/Rural Quintile
- \(I\): Insulation (Efficiency) Level

Modeling Improvements in Building Insulation

Heating Degree Days (HDD)\(_R\)
Cooling Degree Days (CDD)\(_R\)

Heating & Cooling Demand\(_R,Q\)

Insulation Levels (6)
- Efficiency\(_I\)
- Discount Rates\(_R,Q\)

Cost (fuel + Capital)\(_R,Q,I\)

→ Market Shares\(_R,Q,I\)

Floorspace\(_R,Q\)
(m²)

NewFloorspace\(_R,Q\)

ExistingFloorspace\(_R,Q\)

Decommissioned at end-of-life

Learning\(_I\)
Results: Insulation uptake

- Economic growth leads to large increase in global floorspace
- Baseline Improvements: Increasing GDP, fuel prices, cost reductions
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- Urban households have higher uptake
  → Higher incomes

i.e. for the Mitigation Scenario in 2100:

Households with “Insulation Level 6”

Urban: 8%
Rural: 3%

But outcome is unequal

Richest Urban Quintile: 14%
Median Urban Quintile: 7%
Results: Insulation uptake

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Households with “Insulation Level 6”

Urban: 8%
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But outcome is unequal

Richest Urban Quintile: 14%
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Results: Energy

Insulation uptake in baseline

All results normalized to 2010
Results: Energy

Insulation uptake in baseline

Developing regions see growth in heating/cooling demand nonetheless
Results: Energy

Mitigation Scenario:
Colder regions see improvements in heating/cooling intensity

All regions see improvements in energy demand…
Results: Energy

What is the effect of improved Insulation?

“No Insulation improvement” counterfactual: Insulation causes ≈50% of demand decrease

Rest is from increased fuel use efficiency (fuel switching)
Results: Emissions

**Baseline** emissions increase with energy demand.

**Mitigation** scenario sees complete decarbonization of heating & cooling fuels.
Results: Emissions

Baseline emissions increase with energy demand.

Mitigation scenario sees complete decarbonization of heating & cooling fuels.

Limiting Insulation Improvement does not affect this.
Discussion

Weakness: very data intensive

- Existing building stocks and insulation levels
- Building types and characteristics

Sensitivity

- Results very sensitive to assumptions on building characteristics (shape, wall/window ratios)
- Not sensitive to costs or building lifetimes

Some limitations....

- Tennant – Landlord barrier ignored
- Inefficient use of efficient buildings
Conclusions

Improved insulation important in both Baseline and Mitigation scenarios

- Driven by increased household income and increased fuel prices
- Actively adopted in mitigation scenarios
  - Particularly in colder regions
  - Less in warmer regions because cooling costs are lower

Effect on energy demand and emissions

- 45% reduction in heating/cooling demand globally
  - Colder regions
- Limited effect on emissions (in mitigation scenario)

Interaction with fuel switching

- Carbon content of fuels decreases heavily in mitigation scenario
- Fuel switching cheaper than the most expensive insulation measures (according to the model)
- Reduces the incentives for very high efficiency levels
Moving forward…

Improved model can be used to

• Assess the impacts of inequality on transition pathways
• Test the effectiveness of targeted policies aiming at insulation and improvement
• Investigate lifestyle changes with consumers preferring high insulation buildings
• Project scenarios of material demand
Thank you

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