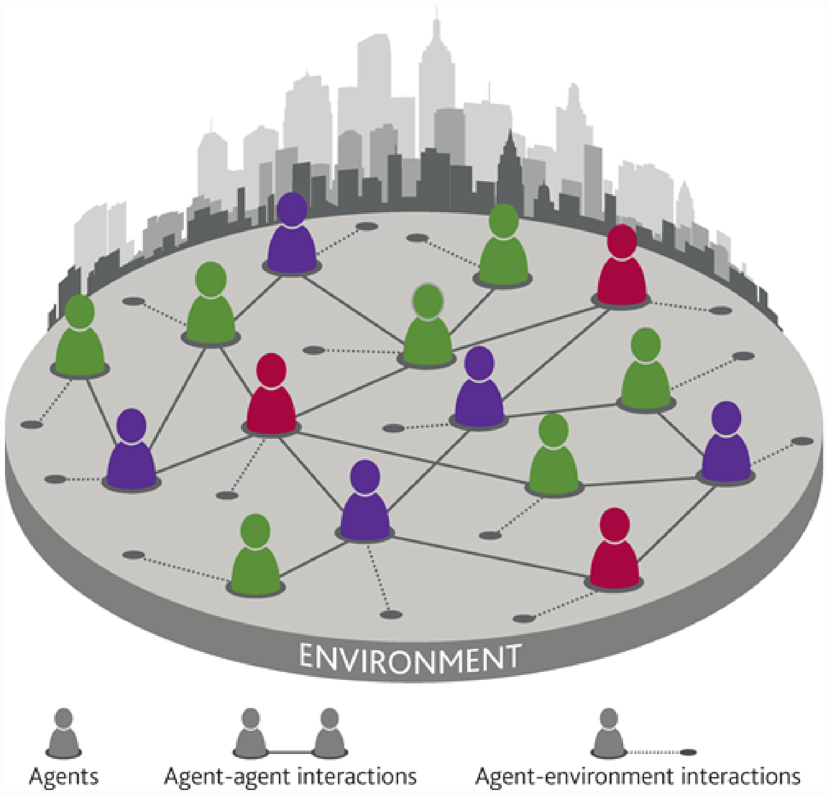

agent based modelling @ cnz

lessons from modelling the GB target of 600,000 heat pumps by 2028 using an ABM

🌍 slides by ryan || 𝕏 @ryancjenkinson

👋 hey, i'm ryan

👇 about me 👇

- 📈 data science @ krakenflex
- 🧠 works on domestic asset optimisation - heat pumps [hp], electric vehicles [ev], solar & storage (batteries)
- 🤝 worked @ cnz before

CNZ Report: Hitting the target

📌 **Goal:** *what combination of policy interventions are required to meet the UK target of 600,000 HPs by 2028?*

Agenda

1. What is an agent based model?
2. How did we build the model?
3. What did we learn?
4. Any questions?

Agenda

1. **What is an agent based model?**
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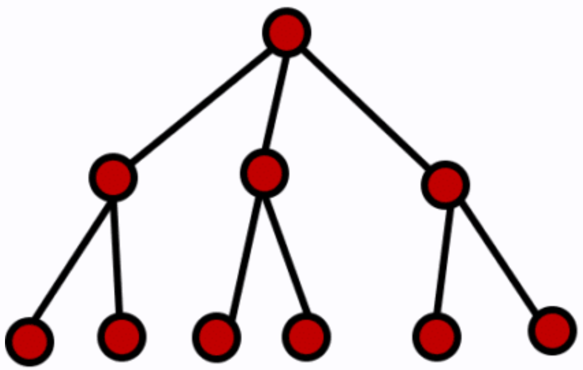
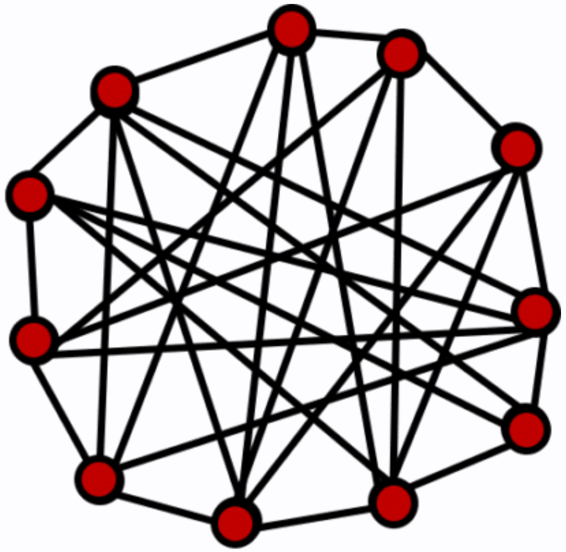
What is an agent based model (ABM)?



“Top-down”



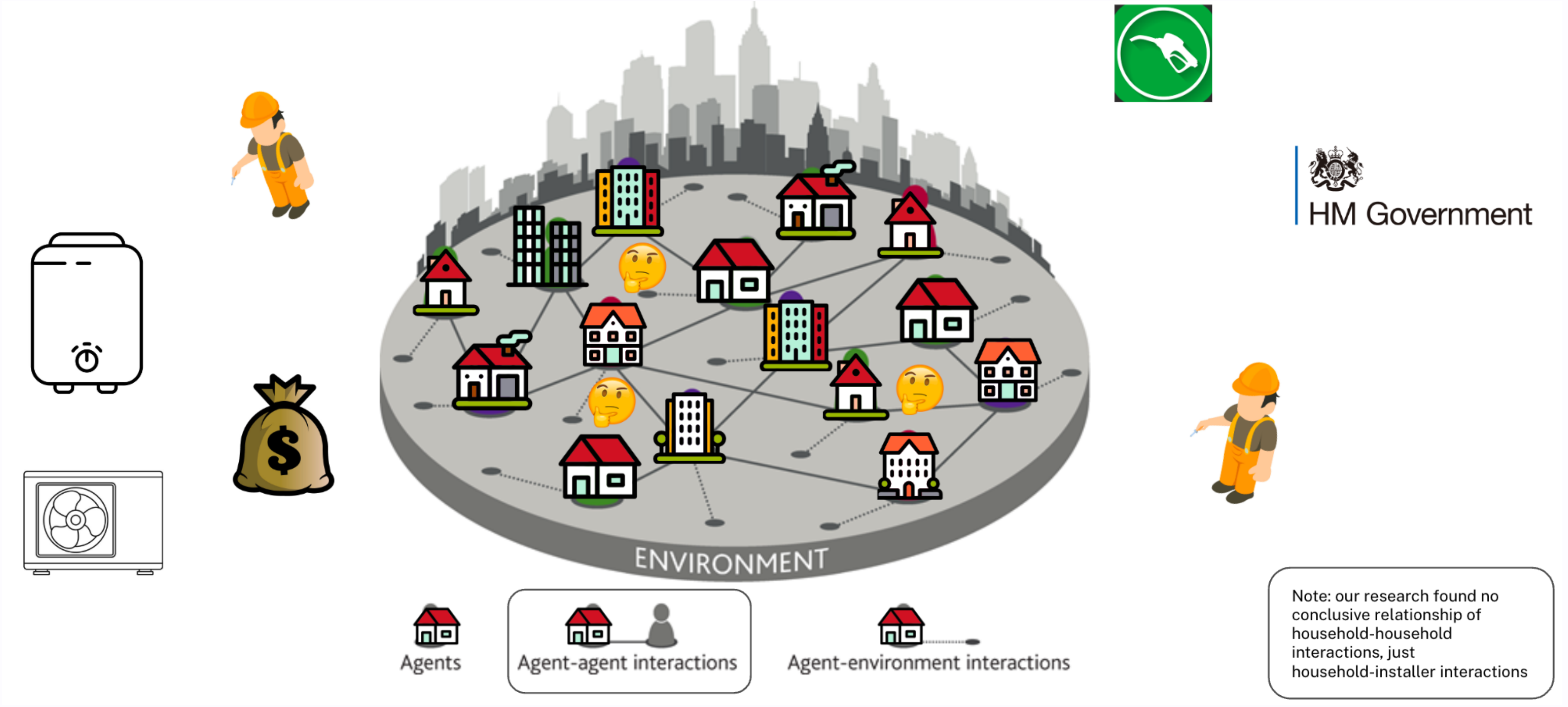
“Bottom-up”

An agent based model needs

1. `Agent` s, which we considered to be a `Household`
2. `Environment` , which dictates *costs*, *incentives* etc
3. `Rules` , for how the agents *interact with each other and the environment* at each timestamp

At each timestep, the environment evolves according to the rules, and the agents respond to the environment.

Our approach centred on households as the key decision maker



Note: our research found no conclusive relationship of household-household interactions, just household-installer interactions

like code? same :)

This is what an agent looks like in the code.

You can make them with

```
agents = [Household(**household) for household in households]
```

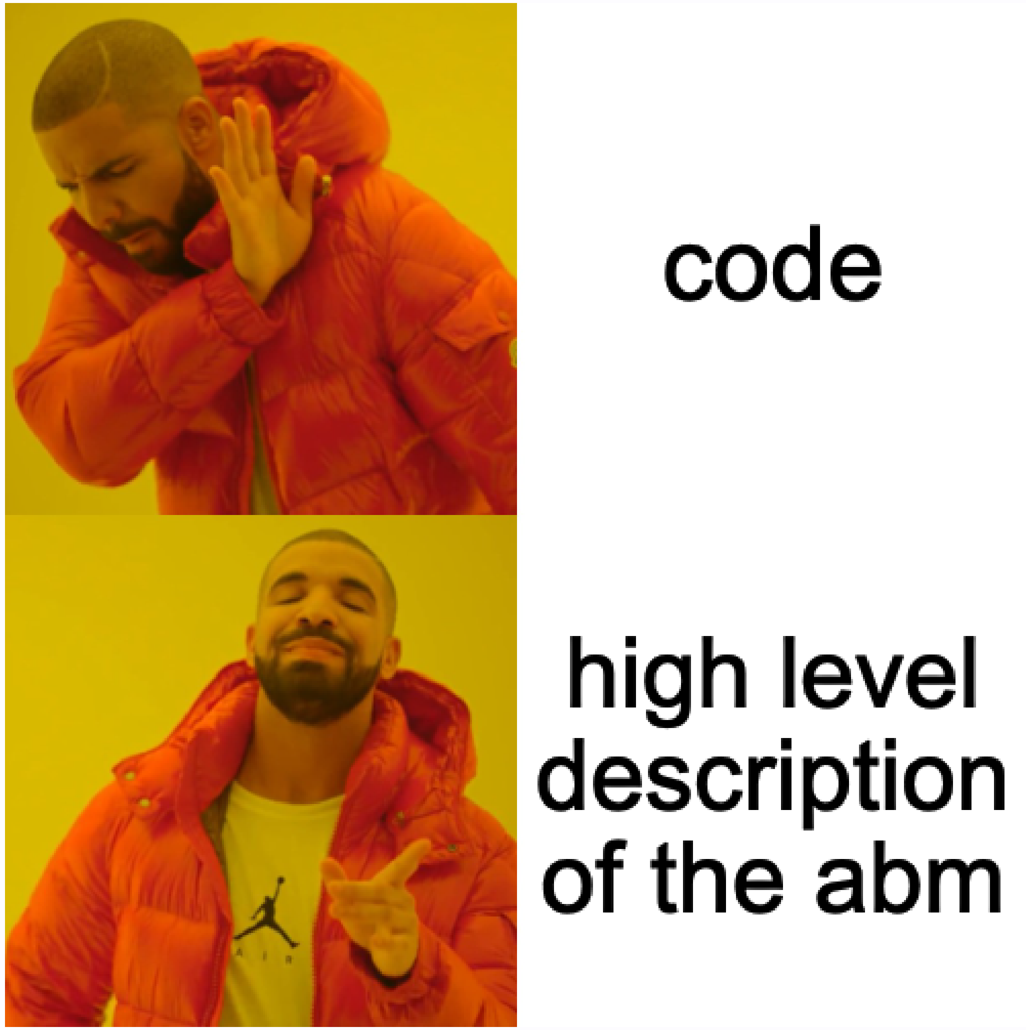
and then add them to the environment

```
class Household(Agent):
    def __init__(
        self,
        id: int,
        location: str,
        property_value_gbp: int,
        total_floor_area_m2: int,
        is_off_gas_grid: bool,
        construction_year_band: Optional[ConstructionYearBand],
        property_type: PropertyType,
        built_form: BuiltForm,
        heating_system: HeatingSystem,
        heating_system_install_date: datetime.date,
        epc_rating: EPCRating,
        potential_epc_rating: EPCRating,
        occupant_type: OccupantType,
        is_solid_wall: bool,
        walls_energy_efficiency: int,
        windows_energy_efficiency: int,
        roof_energy_efficiency: int,
        is_heat_pump_suitable_archetype: bool,
        is_heat_pump_aware: bool,
    ):
```

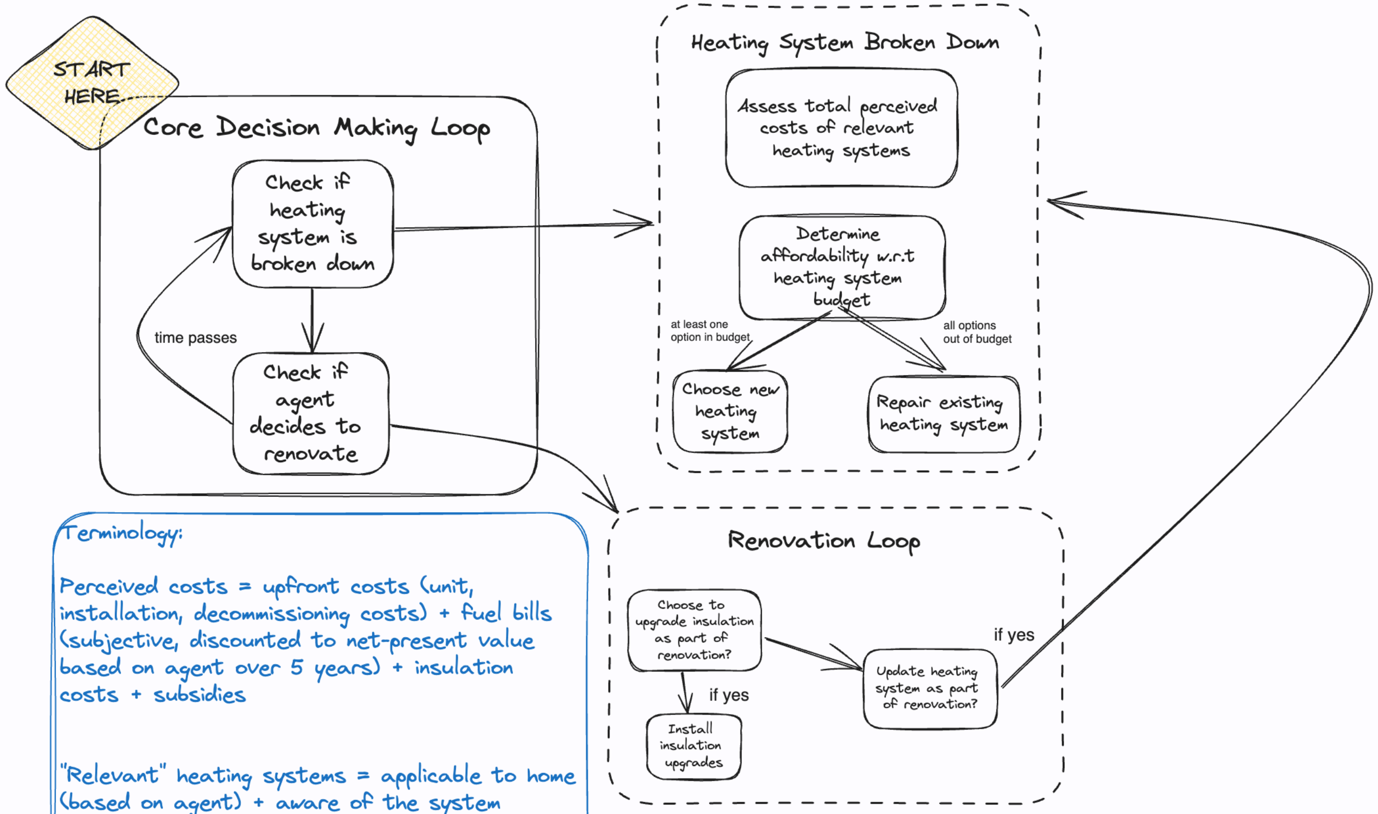
the `Environment` was similar

```
class DomesticHeatingABM(AgentBasedModel):
    def __init__(
        self,
        start_datetime: datetime.datetime,
        step_interval: relativedelta,
        # ... some other stuff ...
        interventions: Optional[List[InterventionType]],
        # ... some other stuff ...
        price_gbp_per_kwh_gas: float,
        price_gbp_per_kwh_electricity: float,
        price_gbp_per_kwh_oil: float,
        air_source_heat_pump_price_discount_schedule: Optional[
            List[Tuple[datetime.datetime, float]]
        ],
        heat_pump_installer_count: int,
        heat_pump_installer_annual_growth_rate: float,
        annual_new_builds: Optional[Dict[int, int]],
    ):
```

We made assumptions globally about how the "world model" evolved. These were parameters, so we could change them and run lots of scenarios.


code
high level description of the abm

Agent decision making loop



Terminology:

Perceived costs = upfront costs (unit, installation, decommissioning costs) + fuel bills (subjective, discounted to net-present value based on agent over 5 years) + insulation costs + subsidies

"Relevant" heating systems = applicable to home (based on agent) + aware of the system

"Choose" or "Check" = based on a probability distribution function, that depends on variables inherent to the agent

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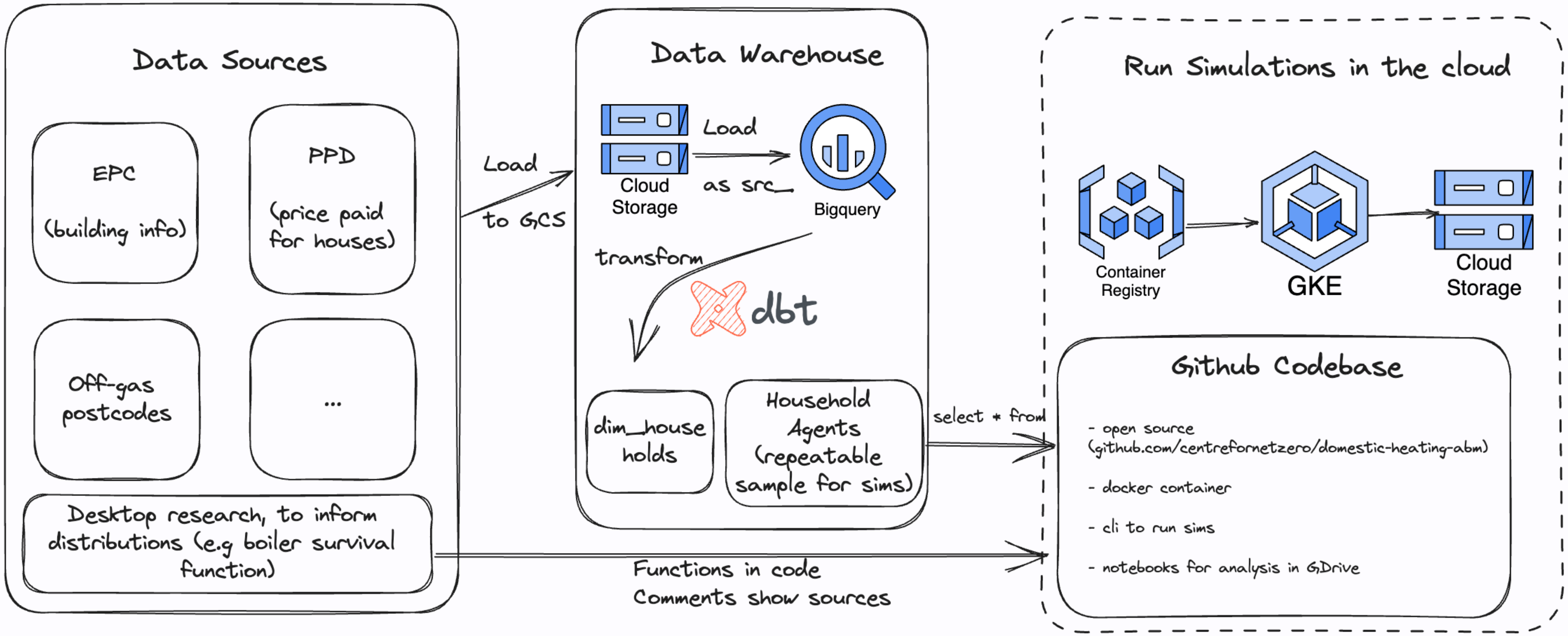
ABM Architecture Diagram



Development pipeline

- ~~We~~Dani did a literature review of the "key" behaviours we want to model. As you'll see later, only worry about the big stuff.
- **Test-driven development**: write the *test of expected behaviour* then add the feature as code.
- Check how it impacted our *key metric* (HPs installed)
- Sensitivity analysis (see later)
- Run a notebook of graphs to check results against scenarios

Technical: The model is sensitive to awareness and upfront costs

	Default value	Minimum value	Maximum value
Heat pump awareness (%)	0.25	0.2	1
Annual renovation rate	0.1	0.05	0.33
Lookahead years (years)	3	1	5
Hassle factor	0	0	0.2
All agents heat pump suitable	False	False	True
Gas price (£/kWh)	0.0465	0.02325	0.06975
Electricity price (£/kWh)	0.2006	0.1003	0.3009
Oil price (£/kWh)	0.0482	0.0241	0.0723
Heat pump price discount (%)	30	0	60
Heat pump installer annual growth (%)	48	0	100

Table 9: Default parameter values and minimum and maximum values used for sensitivity analysis.

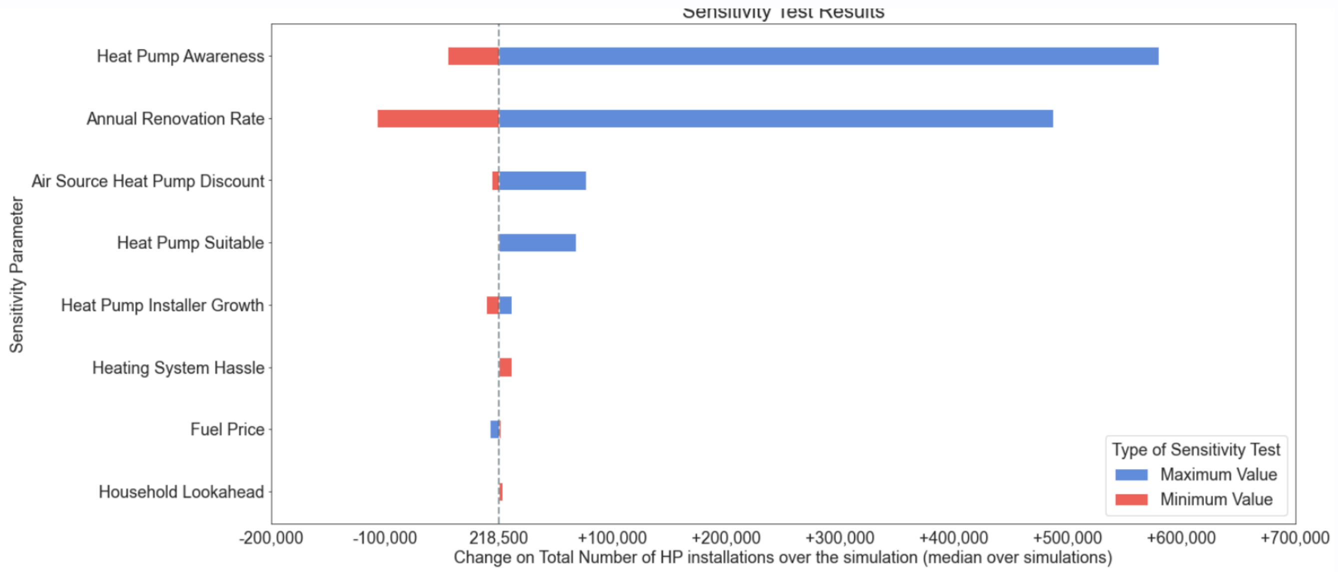


Figure 34: Tornado chart showing the variation in total heat pumps installed over the simulation when parameters are changed to levels shown in Table 9

Technical: How we calibrated and validated the ABM

Show that you can recreate a historical dataset with default parameters. We used RHI uptake from 2010 - 2021.

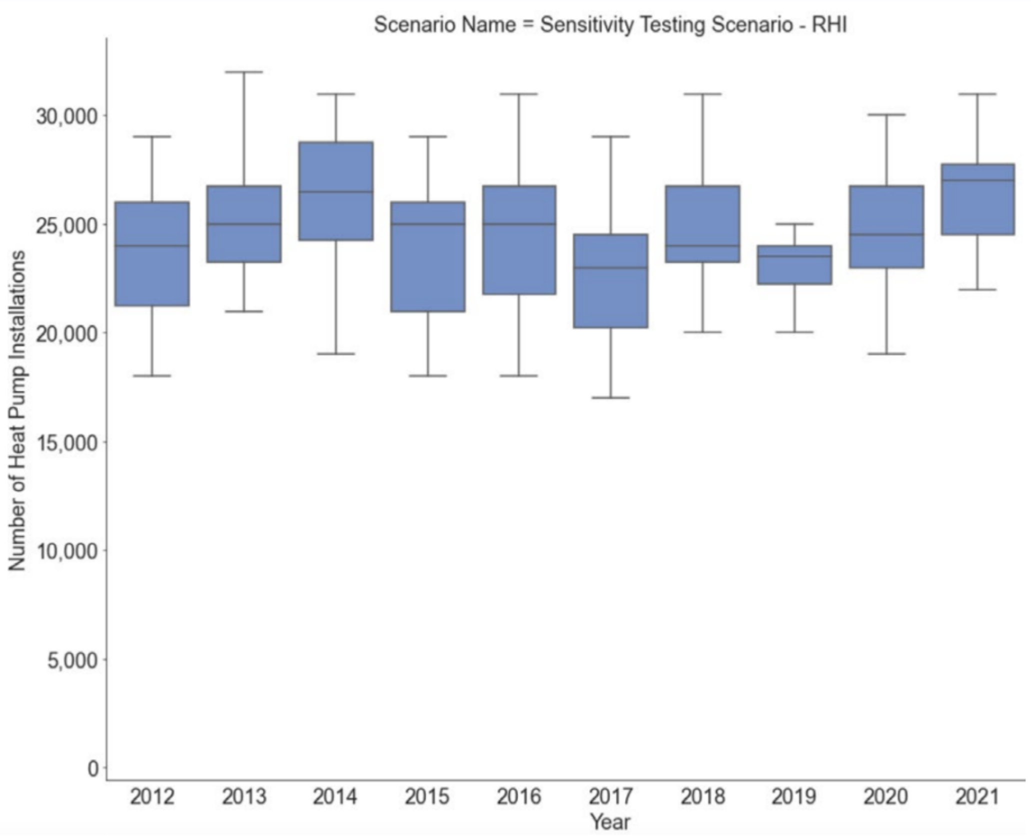


Figure 33: Box and whisker plots chart showing annual heat pump installations under the RHI scenario from 2012-2021 for calibration purposes. Each box shows the median, 25% and 75% percentiles across 10 simulation runs, with the whiskers showing maximum and minimum values across these runs.

Scenarios were agreed with our policy team

		No interventions	BUS	BUS + Policy Costs		Maximum Government Interventions (BUS + Policy Costs + 2035 Boiler Ban)			Industry Interventions (Cost Reductions, Removing Hassle, Removing Heat Pump Installer Constraints)	
Scenario Number		1	2	3a	3b	4a	4b	4c	5a	5b
Intervention Event	Boiler Upgrade Scheme	N	Y	Y	Y	Y	Y	Y	N	Y
	Ban Announcement	N	N	N	N	Y-2025	Y-2025	Y-2030	N	Y-2025
	2035 Fossil Fuel Boiler Ban	N	N	N	N	Y	Y	Y	N	Y
	Policy Costs	N	N	Y	Y	Y	Y	Y	N	Y
Simulation Parameter	Awareness	25%	25%	25%	50%	50%	50%	50%	50%	50%
	Hassle Cost of Heat Pumps	10%↑	10%↑	10%↑	10%↑	10%↑	10%↑	10%↑	0	0
	Heat Pump Suitability	65%	65%	65%	65%	65%	65%	65%	100%	100%
	Heat Pump Prices	70% by 2023	70% by 2023	70% by 2023	70% by 2023	70% by 2023	70% by 2023	70% by 2023	40% by 2025	40% by 2025
	Heat Pump Installer Constraints	None	None	None	None	None	48% YoY Growth	48% YoY Growth	None	None

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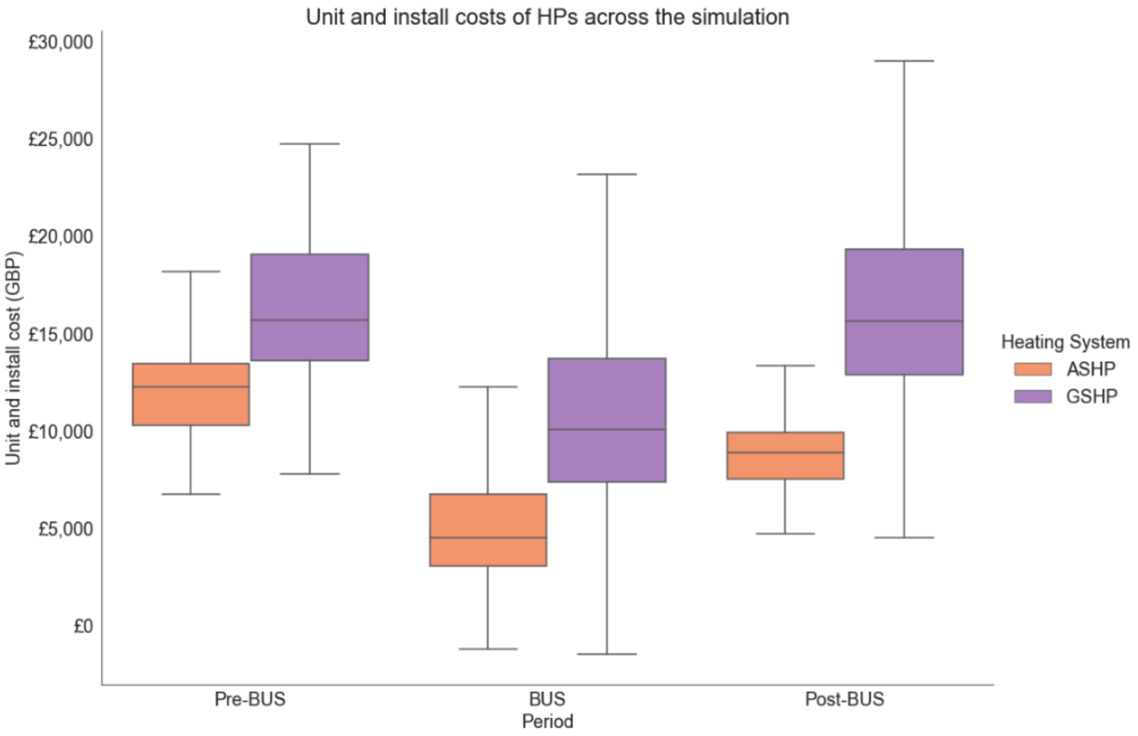
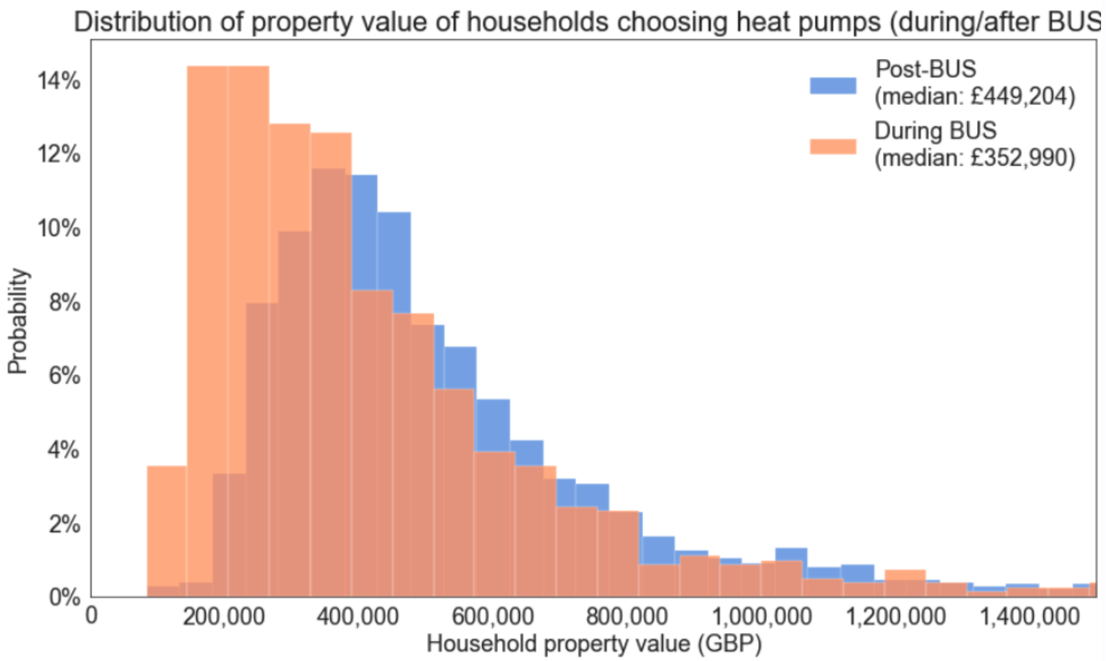
Our Findings

Area	Description of Finding
Upfront costs	Present the biggest barrier to adoption by our household agents. Even in our most ambitious projections, the upfront cost of a HP is still 1.5- 2 times more expensive than an equivalent boiler in the short-medium term.
Awareness	Our model is most sensitive to awareness and rate of renovation; changing these values leads to a large increase in the cumulative HP installations over the time period simulated.
Resolving Friction	Renovation is most important trigger for agents to purchase new heating systems. Resolving frictions a household experiences with changing heating system type in a ‘near-breakdown’ scenario, especially if property type and insulation are sufficient is important to meeting targets is important for avoiding lock-in to fossil fuel systems.
Boiler Ban	Of scenarios that enable us to reach the Government’s target, the early announcement of a fossil fuel boiler ban with a commencement date of 2035 is crucial to driving uptake.
Policy costs	Redistribution of policy costs does not materially change the number of HP installations since upfront costs outweigh the future running costs of a heating system in a household’s decision-making.
Training	Training more HP installers is necessary to meet demand in the short-medium term. Our simulations suggest 30,000 HP installers are required by 2028, a tenfold increase on today’s numbers and approx a quarter of existing Gas Safe installers. Failure to do so will lead to medium term capacity constraints in 2025/27.

Key Finding 1: The BUS alone doesn't go far enough

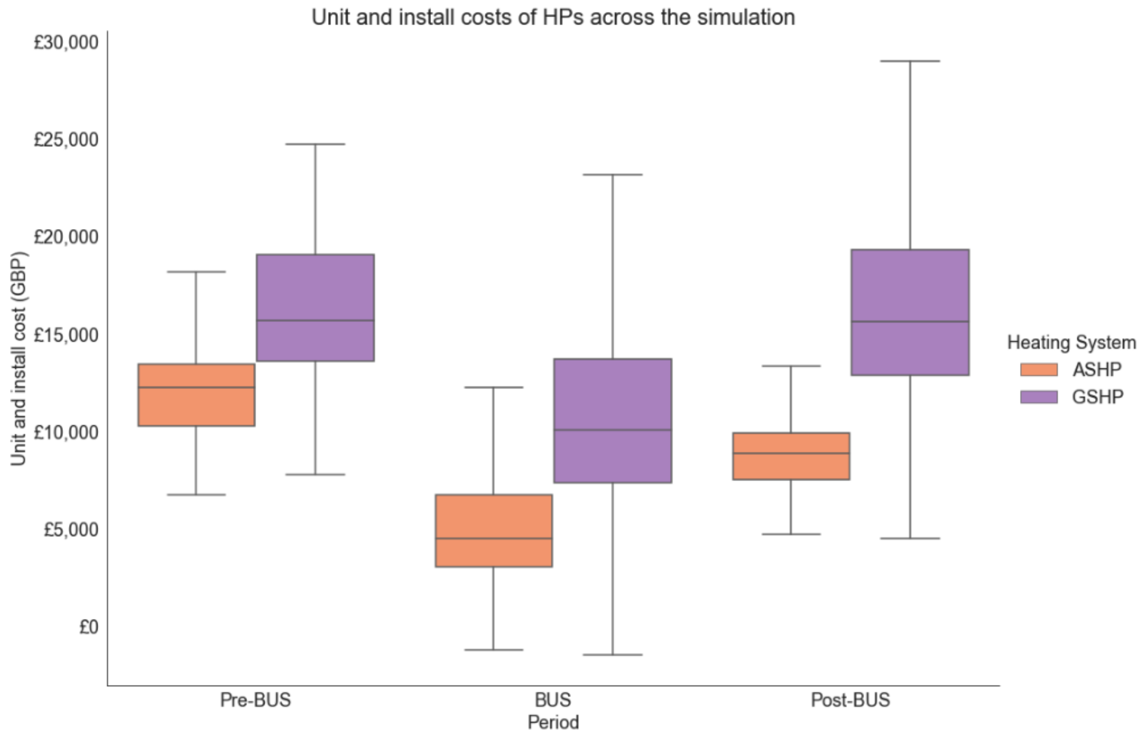
Grants such as the Boiler Upgrade Scheme enable less wealthy households to adopt heat pumps, but it **does not go far enough on its own** to meet the target

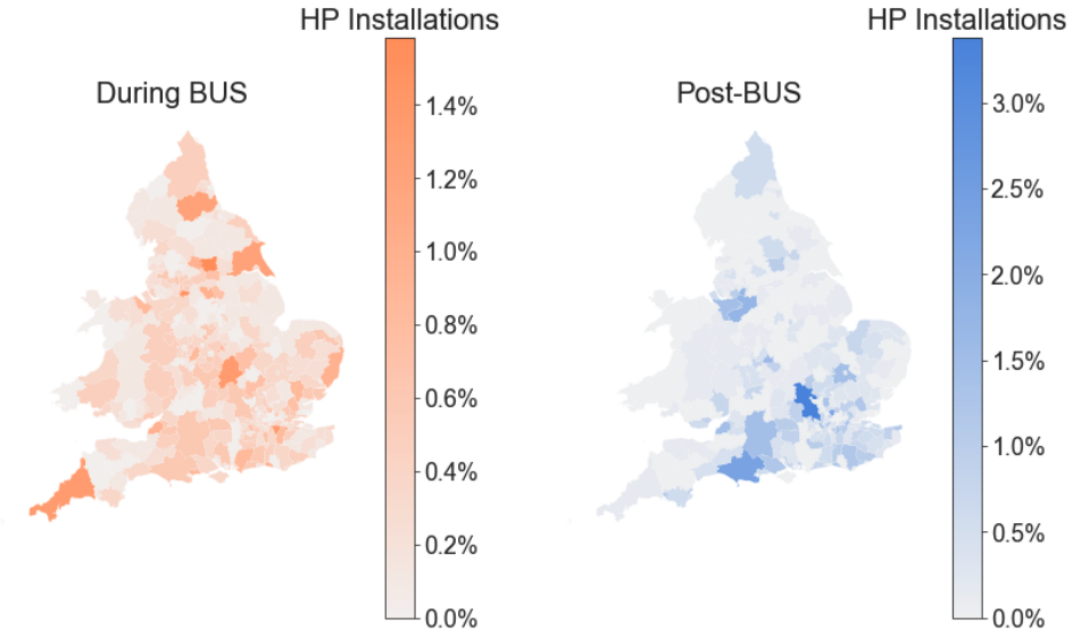




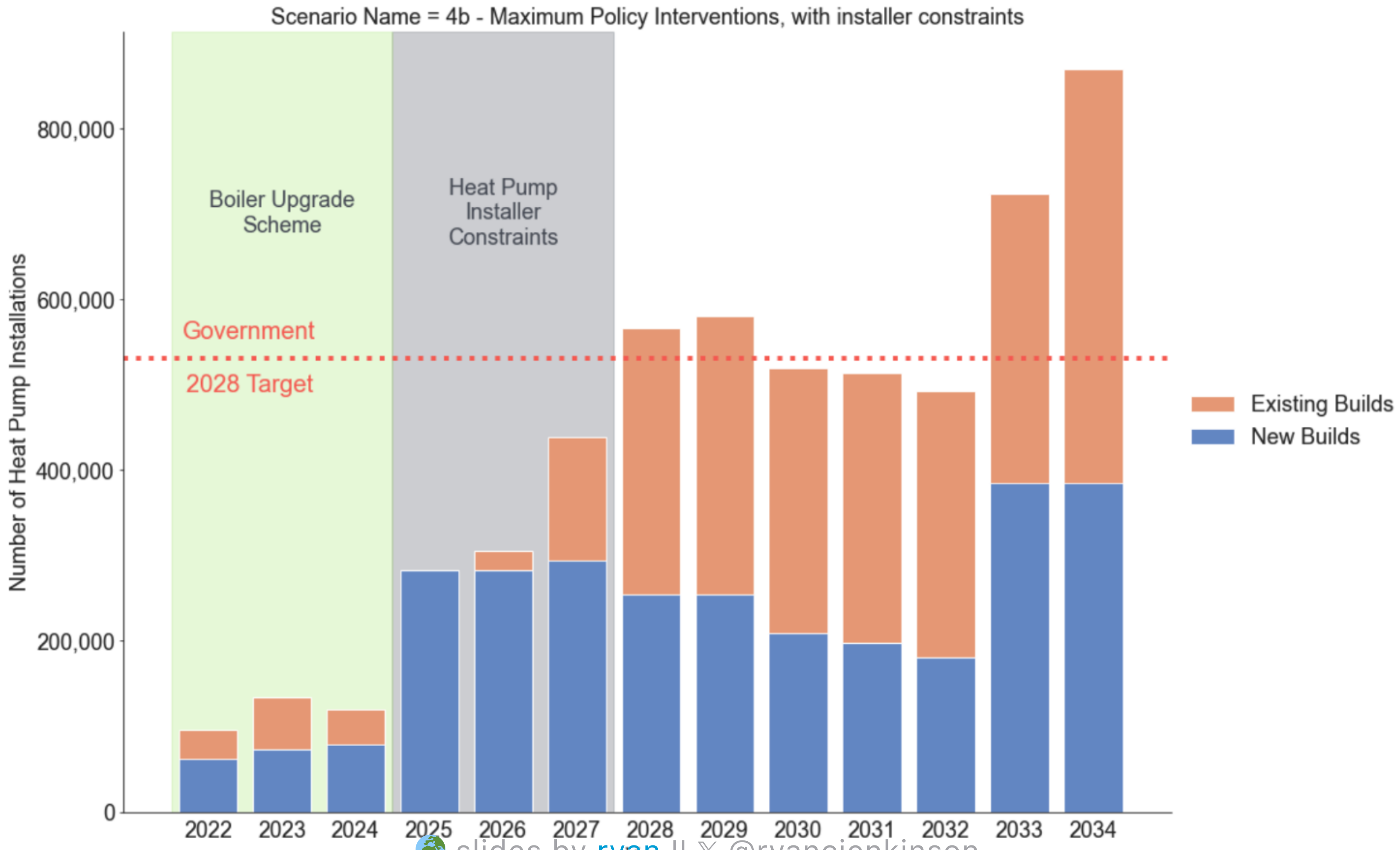
Key Finding 1: Upfront costs are the largest barrier to adoption

Grants such as the Boiler Upgrade Scheme enable less wealthy households to adopt heat pumps, but it **does not go far enough on its own** to meet the target



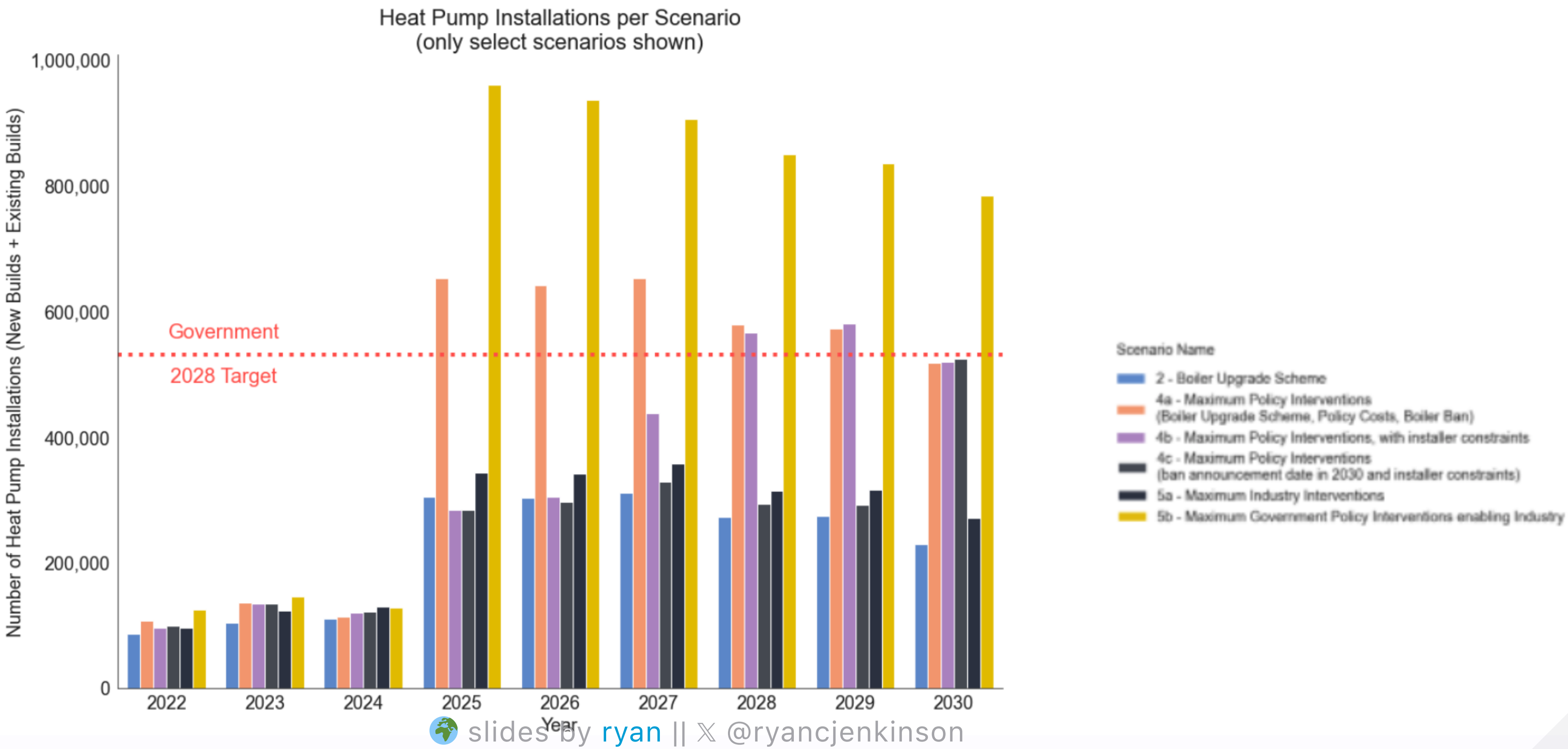


Key Finding 2: Lack of installer capacity could be a significant constraint on adoption even if demand is met



Key Finding 3:

Unambiguous ban announcement, consumer awareness raising and installer training together are key to reaching Govt target and beyond



Recommendations to Policymakers

1. Take a longer-term view of upfront costs
2. Launch a public awareness campaign on decarbonising home heating
3. Set an unambiguous time frame for the phase out of fossil fuel heating systems as early as possible
4. Prioritise efforts to grow heat pump installer numbers

Stuff we learnt

- Everything you add to the model is an assumption. **Add as little as possible**, because you'll have to justify everything and you want a model you can explain. You *can* have too many things going on.
- Writing ABM code is easy. Knowing what to add and running it at scale is hard. **Stand on the shoulders of giants, using data and techniques that already exist**.
- Orient yourself around a key question: what do you want to answer? What do you want to test?
- **Sensitivity analysis** is key towards seeing what would swing the output. Only focus on the big stuff (both inputs & outputs of a model).
- <Probably more stuff here!>

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