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Conceptual agent-based model of neighbourhood-level building retrofits based on Energiesprong approach

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Outline of the presentation

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- Introduction
  - Motivation
  - Background: Energiesprong & Agent-based modelling
  - Research aim
- Conceptualisation
  - Techno-economic sub-model
  - **Agents' decision-making**
  - Scenarios and policy interventions
  - Performance indicators
- Outlook

Motivation
Need to incentivise retrofitting better

- Despite numerous policy incentives [1], the rate of energy-efficient renovation/retrofitting (EER) in Europe is very low (0.4-1.2%) [2]. **Deep renovations**[1] in the EU28 is only around 0.2% [2].
- Barriers to EER at different points in the value chain: **initial decision to EER->** financing -> completion [2].
- Renovation decisions ~ many factors (financial, personal, contextual) [1]:
  - ~ **ownership/tenure type** in buildings (owner-occupier, privately rented, social rent) [2,3].
  - Gap in formalisation of building owner's decision-making
- Previous models of energy-efficient renovation has predominantly focused on:
  - only owner-occupiers (i.e. 70% of all owners)
  - macro-scale decisions (i.e. homogeneous, aggregate agent)
  - conventional way of EER (i.e. contractor-supplier).

[1] ~50-60% primary energy reduction, concerns the whole building

[1] Wilson et al (2015). Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. DOI: 10.1016/j.erss.2015.03.002
[2] European Commission. (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. www.navigant.com
[3] Liang et al. (2016). Making incentive policies more effective: An agent-based model for energy-efficiency retrofit in China

State-of-the-art in Industry

Deep renovation: Energiesprong approach

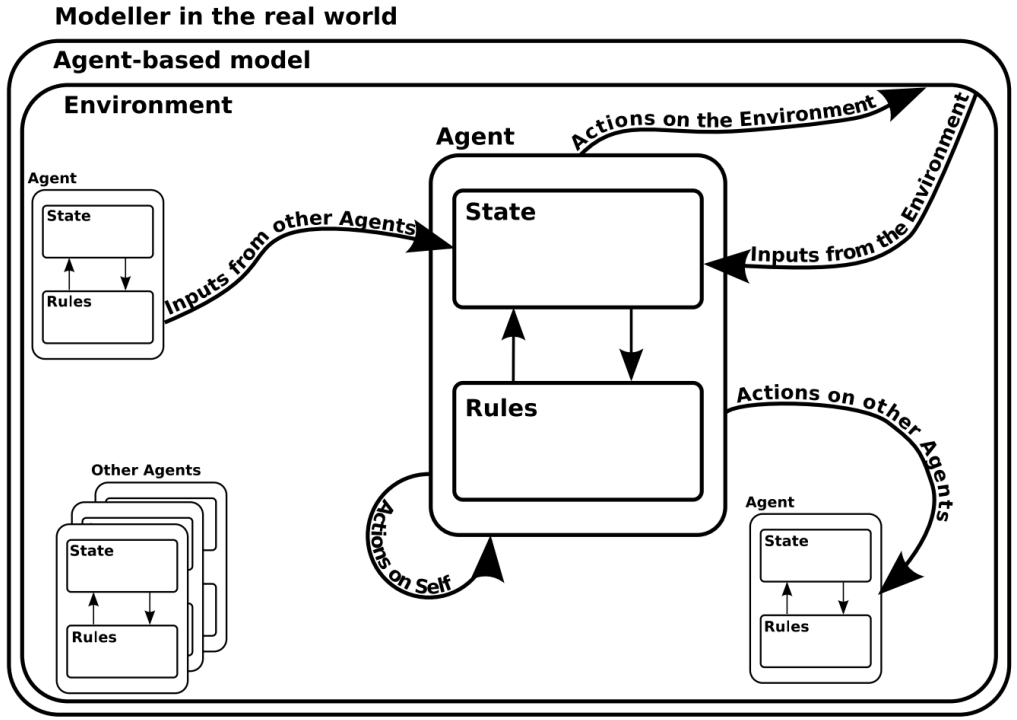
- Standardized facade and roof systems designed and prefabricated by a consortium of innovators → Retrofitting package/bundle or integrated solution
- Net-zero performance guarantee
- Little disruption to occupants
- Cost reduction due to collective/group purchase - pooling (e.g. social housing is a good target sector)
- New actors: Intermediary agent coordinating the process, retrofitting solution provider (e.g. VolkerWessels)

Source: https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/steckbrief-pilotprojekt-hameln/

State-of-the-art in Research

Agent-based modelling (ABM) of retrofitting

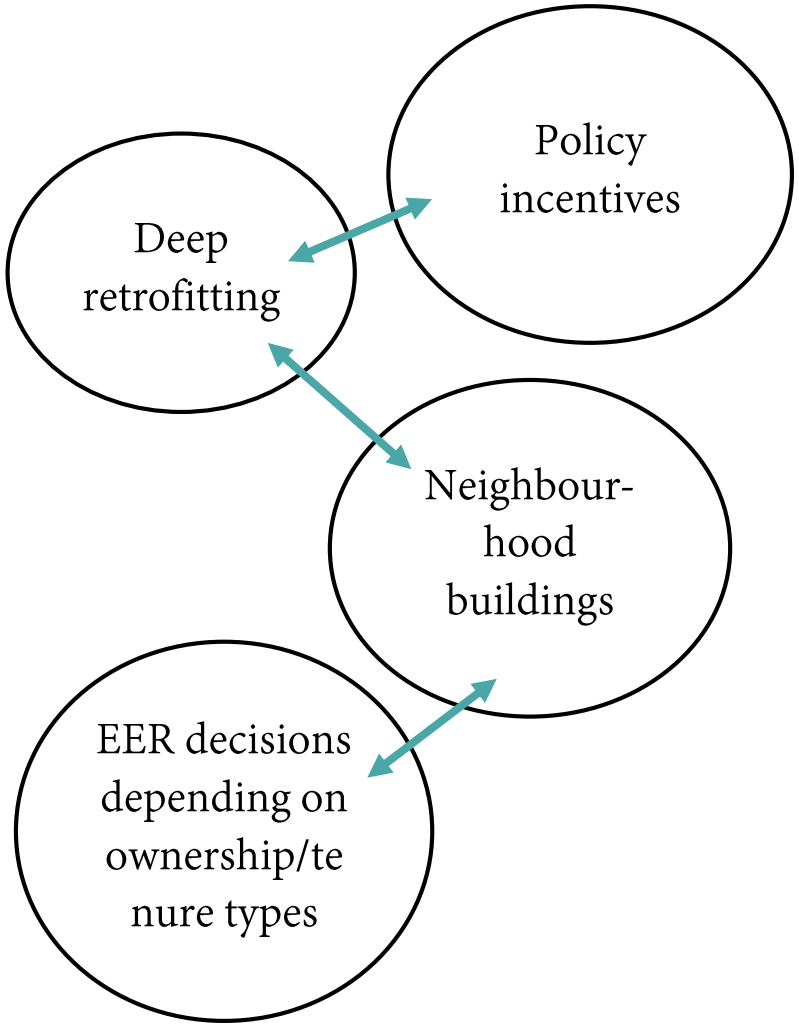
- ABM is becoming more applied in policymaking for energy transition: can give "emergent" insights that remain unobserved in aggregate-scale techno-economic modelling.
- Allows testing various "what-if" questions while considering building owners' decision-making, heterogeneity and interactions with intermediary actors.
- Previous ABM of retrofitting decisions:
  - Moglia et al. (2018). An Agent-Based Model of Residential Energy Efficiency Adoption
  - Liang et al. (2019). Making incentive policies more effective: An agent-based model for energy-efficiency retrofit in China.
  - Friege, J. (2016). Increasing homeowners' insulation activity in Germany: An empirically grounded agent-based model analysis



van Dam, K.H., Nikolic, I., and Lukszo, Z. 2013. Agent-Based Social Systems Volume 9 Editor in Chief : Series Editors : ABSS – Agent-Based Social Systems

Aim
Conceptual agent-based model of EER diffusion

- To develop a conceptual agent-based model(ABM) that will explore policy interventions for stimulating the adoption of retrofitting packages by building owners.
  - **Decision of the building owner(s) and interaction with intermediary actor**
  - **Neighbourhood-level:** (a) Interest in co-benefits of neighbourhood & district-level initiatives, e.g. Positive Energy Districts, energy communities; (b) Buildings with different ownership types; (c) Micro-scale for agent-based model
- What **policy interventions** and **socio-techno-economic conditions** enable the integrated net-zero retrofitting of existing neighbourhoods?
  - *Techno-economic*: costs of retrofitting packages, energy prices
  - *Social*: mix of income levels, social connectedness, awareness/information level
  - *Policy interventions*: introduce intermediary agency for active promotion of renovation, increase carbon taxes.



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Conceptual Model

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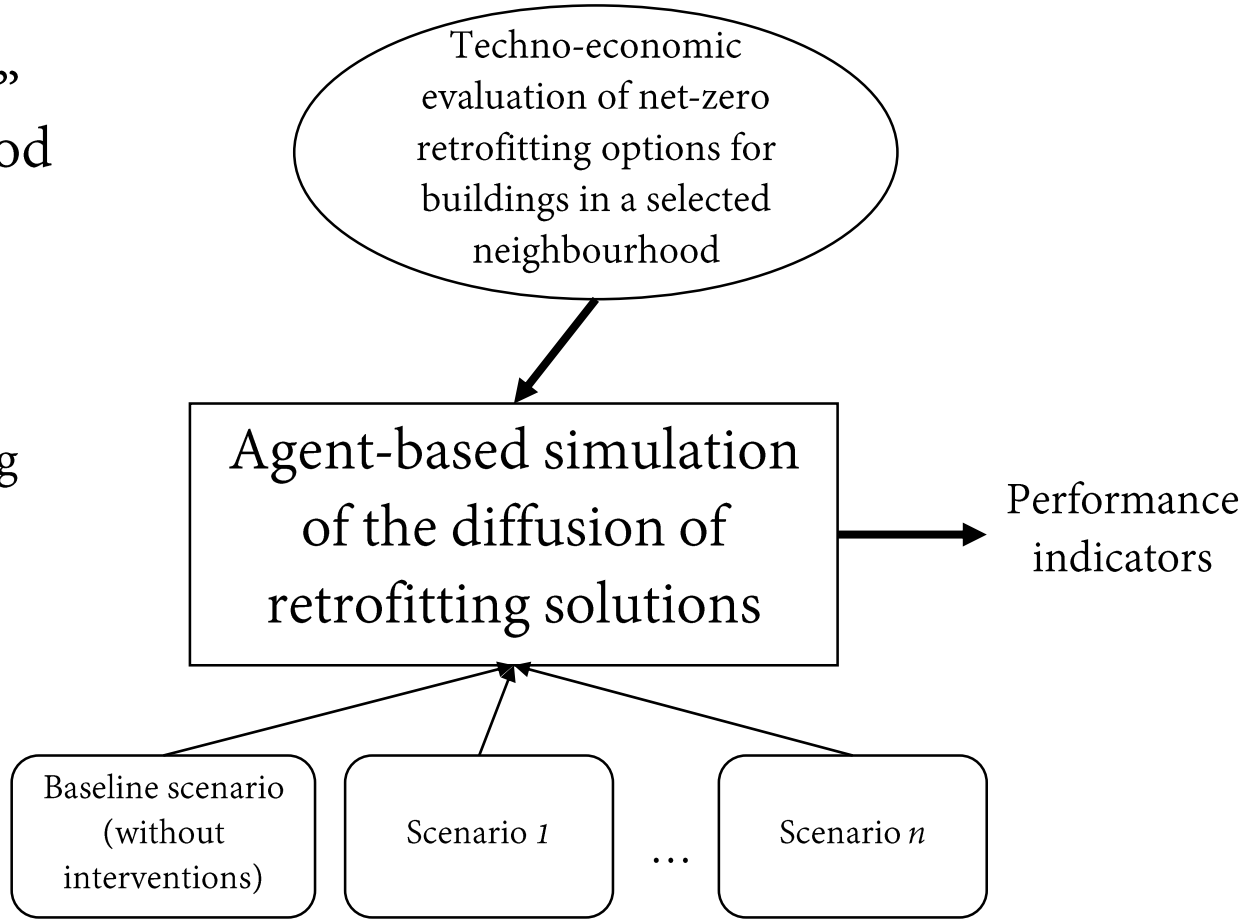
General model framework

- Agent-based simulation of the "diffusion" of retrofitting packages in a neighbourhood consisting of the following steps:
  - **Techno-economic evaluation sub-model:** determining retrofitting options for the building archetypes in the given neighbourhood and calculating their costs
  - **Agent decision-making framework:** building owners decide (a) whether they want to renovate; and, if yes, (b) choose a suitable retrofitting package
  - **Simulating several scenarios (i.e. policy interventions):** e.g. scenario when an intermediary agency approaches the neighbourhood's building owners; modifications to rent policy; energy costs increase.



Techno-economic evaluation sub-model

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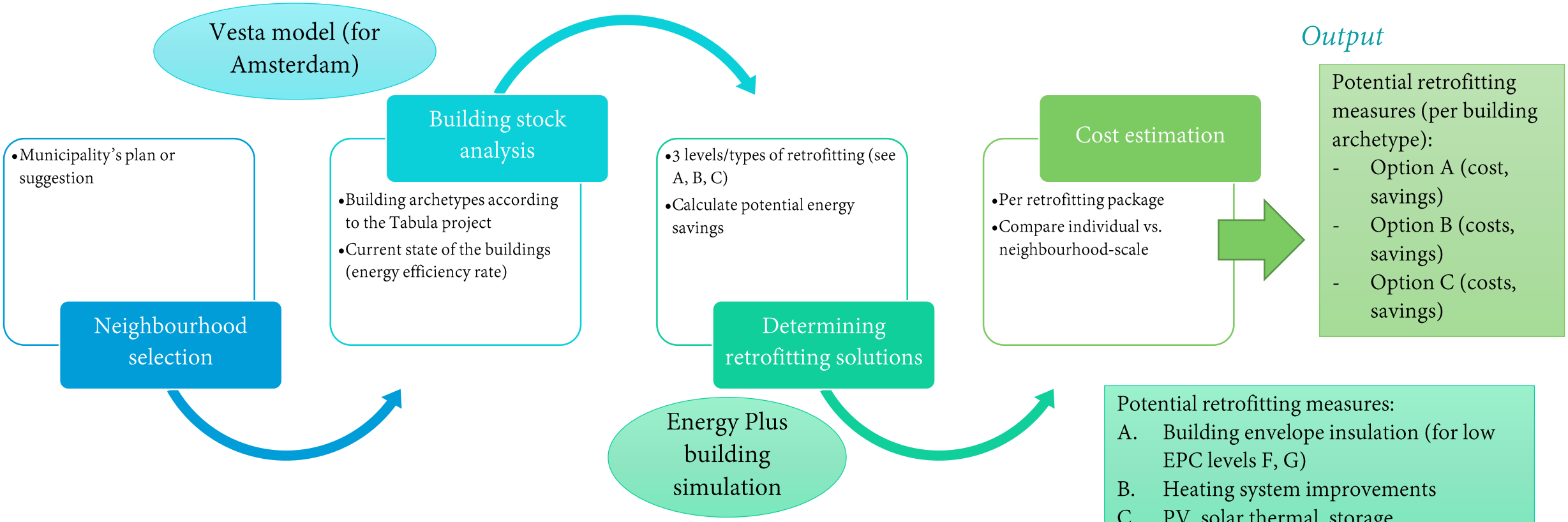
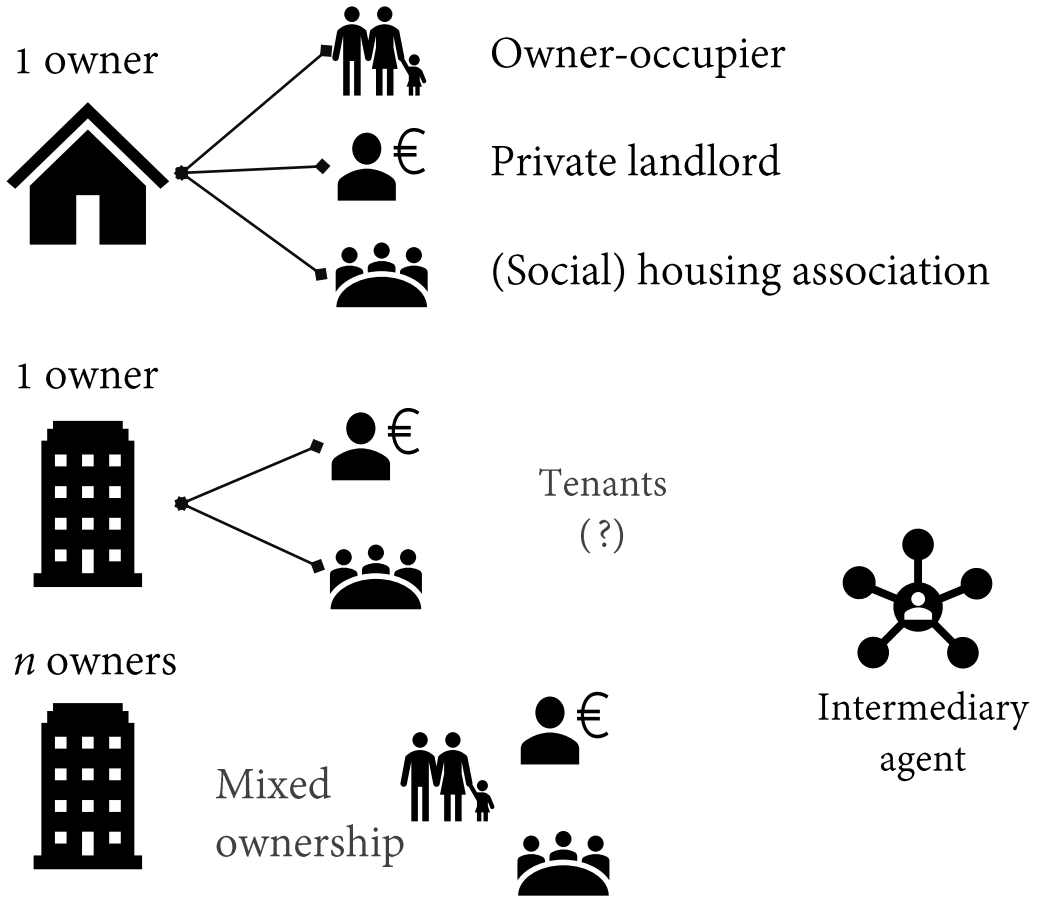
"Proxy" for retrofitting providers



Agent-based diffusion of retrofitting

Agents

- Diffusion of innovation is commonly used in ABM
  - Agents choose or "adopt" a certain product based on their "decision-making framework" (i.e. "rules")
- "Decision-making" agents ("social subsystem" [3]):
  - **Owner-occupier:** owns the apartment or house where he lives
  - **Private landlord:** rents apartment(s)/building(s), but doesn't live there; profit-oriented
  - **(Social) housing association:** rents apartments(s)/building(s), but doesn't live there; not so profit-oriented
  - **Intermediary agent** (proxy for "One-Stop-Shop" or "market development team"): informs the owner agents about retrofitting in general; proposes retrofitting packages (link to retrofitting providers)



[3] van Dam, K.H., Nikolic, I., and Lukszo, Z. 2013. Agent-Based Social Systems Volume 9 Editor in Chief : Series Editors : ABSS – Agent-Based Social Systems

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Agent-based diffusion of retrofitting

Building owner agents' decision-making framework

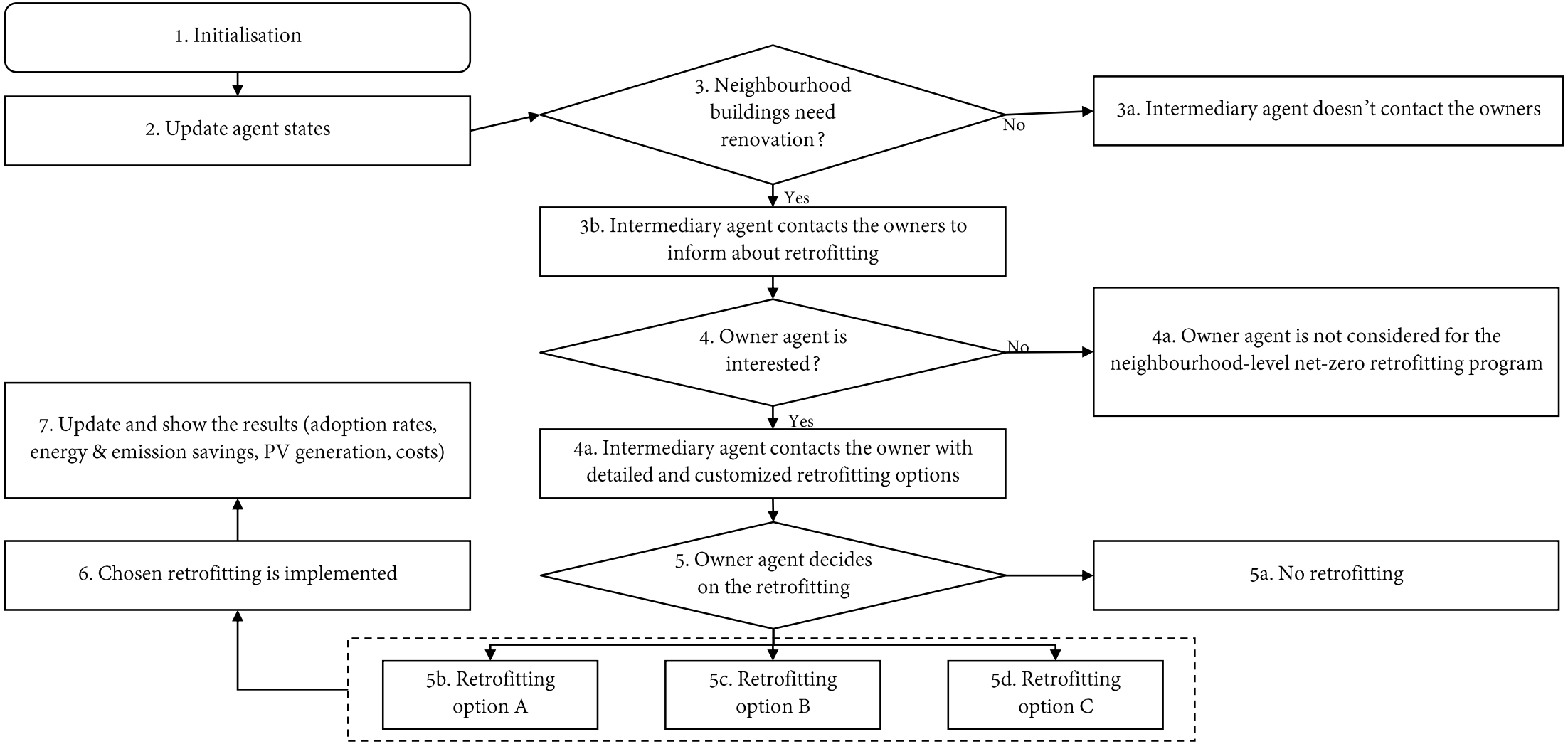
- In the initial version of the model, the decision to adopt the renovations is based on building owner agent's **utility** from a retrofitting option (i.e. overall satisfaction from the EER)
- Based on Liang et al (2019) – utility theory and cost-benefit analysis:
  - *Utility = Economic benefit*
  - *Economic benefit = (perceived) profit from EER = revenue – costs*
  - *Revenue = savings in energy bills + government subsidy + non-monetary benefits (e.g. satisfaction, comfort, aesthetics)*
  - *Savings in energy bills = (energy demand after – energy demand before)*area*energy price + renewable production*
  - *Costs = investment costs + non-monetary costs (e.g. effort, time)*
  - Choose Retrofitting option IF: *Utility > Threshold (static variable of an agent)*
- Possibility to gradually sophisticate the decision-making
- Differences between **owner types** are to be identified – different expectations of payback time, discount rate
- Need to be tuned by empirical data (survey and interviews are planned !)

Agent-based diffusion of retrofitting

Intermediary agents' decision-making framework

- Step 1: Intermediary agents inform and make certain number of building owners aware about retrofitting (N_{inf})
  - Certain proportion of people will answer and get interested (N_{int})
- Step 2: Offer concrete solutions to building owners who are interested
  - from techno-economic submodel
  - Several building owners will agree to retrofitting (adopters, N_{adopt})
- Intermediary agent's **utility (=benefits-costs)**
  - *Benefits* = *success rate* ~ N_{int}/ N_{inf}
  - *Costs* ~ N_{inf}
  - Becomes more convincing (skilful) as he/she convinces more and more building owners

Simulation narrative



Performance indicators

- Building owner agents' retrofit adoption rates
- And based on that:
  - Energy & emission savings
  - PV annual generation
  - Retrofitting spendings
- Intermediary agents' "costs" = "policy costs"

Scenarios and policy interventions

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- Responsibilities of Intermediary agents
- Energy prices, CO2-taxes
- Socio-economic characteristics of homeowners – age, income, environmental awareness, education, etc.
- Mix and proportion of agents (and buildings)
- Housing and rent regulations
- Legal framework of condominiums
- → Insights for policy-makers (complementary to techno-economic models)

Open Questions and Outlook

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- Techno-economic model: retrofitting solutions
- Agent decision-making rules and agent variables/attributes
- Define scenarios (cluster policy interventions, techno-economic conditions, socio-economic conditions)
- Implementation of the concept: a simple test case in Python (Mesa)
- Data collection: survey and interviews to define important parameters and “validate” model logic

Thank you for your attention !

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Questions ?

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