Forecasting the Diffusion of Residential Photovoltaic Systems in Austria: An Agent-Based Modeling Approach

Seif Marji, Kagan Yüksel, Reinhard Madlener

IAEE 2025, June 17, 2025
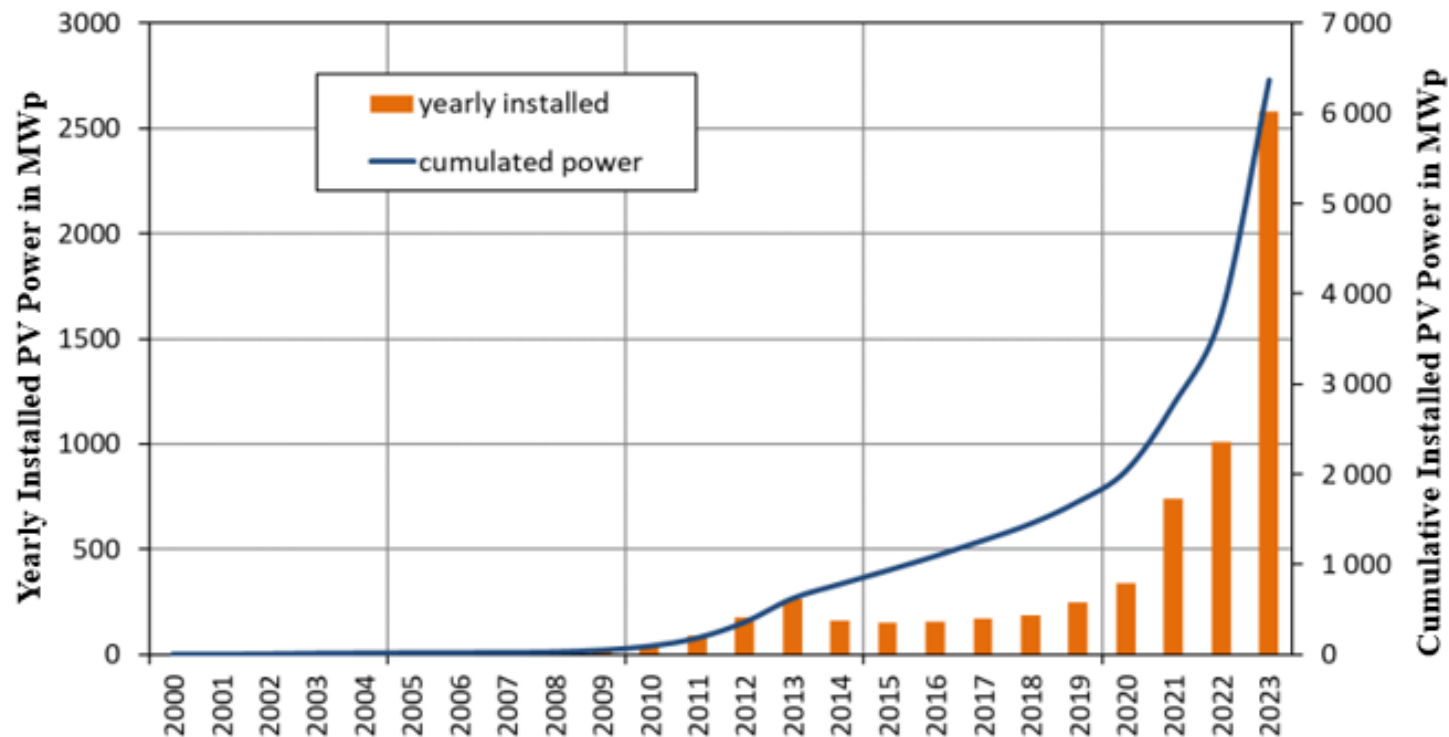
FCN | Future Energy Consumer Needs and Behavior

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Agenda

1. Introduction

2. Theoretical Background and Technical Specifications

3. Methodology

4. Results and Scenario Analysis

5. Conclusion and Outlook

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Introduction

Yearly and Cumulative Installed PV Power in Austria
Source: Biermayr (2023)

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Technological Diffusion & Agent-Based Modelling
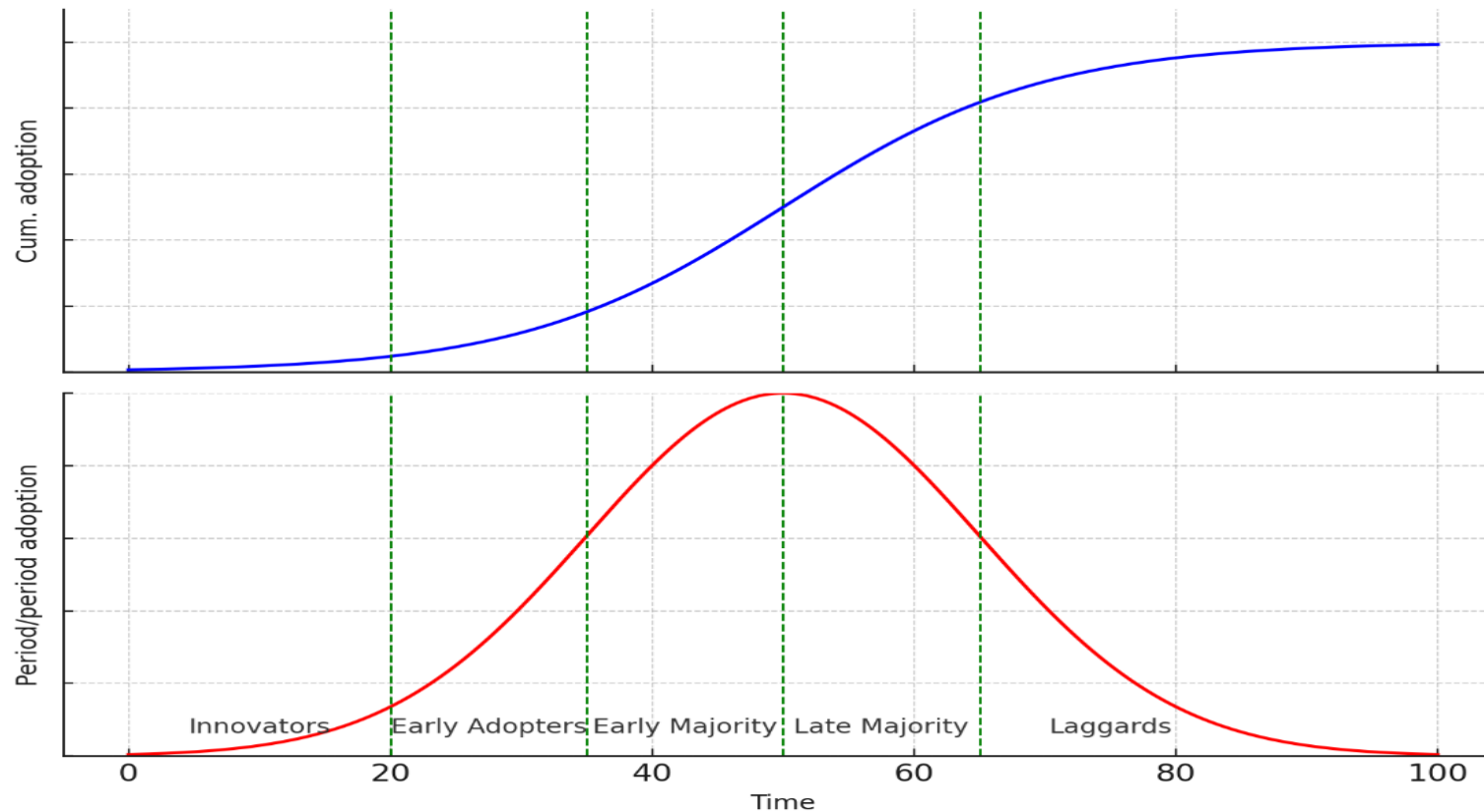
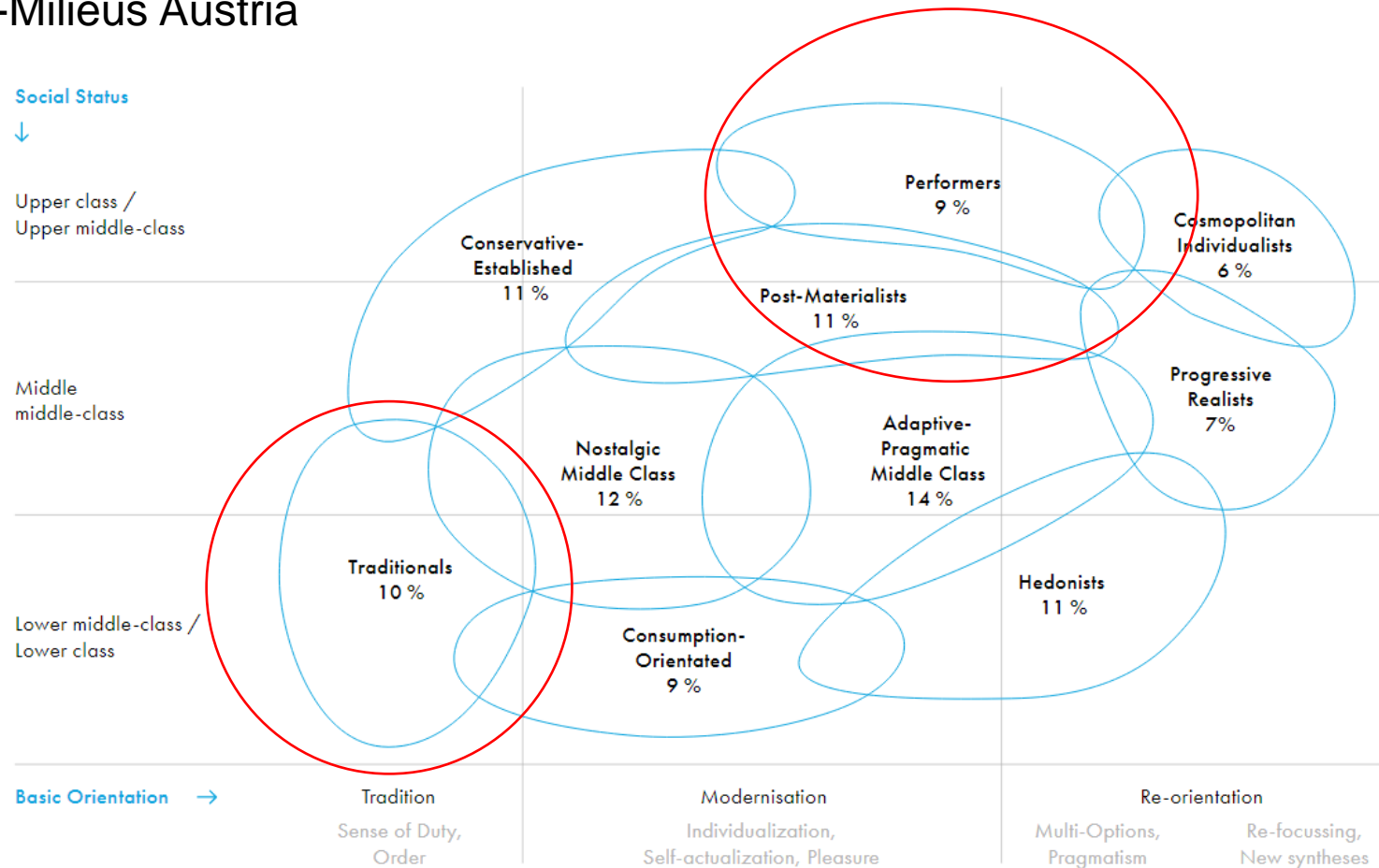**Diffusion of Innovation Theory**
Source: Own Illustration based on Rogers (1962)

Sinus-Milieus Austria

Sinus-Milieus of Austria
Source: Sinus-Milieus Austria (2022)

Solar Photovoltaics Policy in Austria – Summary of Recent Developments

Year	Feed-in-Tariff [€-cents/kWh]	Average Wholesale Electricity Selling Price [€-cents/kWh]	Capital Grants for PV systems [€/kWp]		Capital Grants for Batteries [€/kWh]
	5-10 kWp		< 5 kWp	5-10 kWp	
2008	39.99	7.28	2800	0	0
2009	39.98	4.72	2500	0	0
2010	38.00	4.66	1300	0	0
2011	38.00	5.66	1100	0	0
2012	27.60	4.87	800	0	0
2013	18.12	4.02	200	200	0
2014	12.50	3.53	200	200	0
2015	12.50	3.23	200	200	0
2016	8.24	2.70	275	375	0
2017	7.91	3.33	275	375	0
2018	7.91	4.45	250	250	500
2019	7.67	5.10	250	250	500
2020	7.67	3.99	250	250	200
2021	0.00	7.80	285	250	200
2022	0.00	33.43	285	285	200
2023	0.00	16.87	285	285	200

Sources: PV Austria (2024), IG Windkraft (2020), E-Control (2024), Klimafonds (2019)
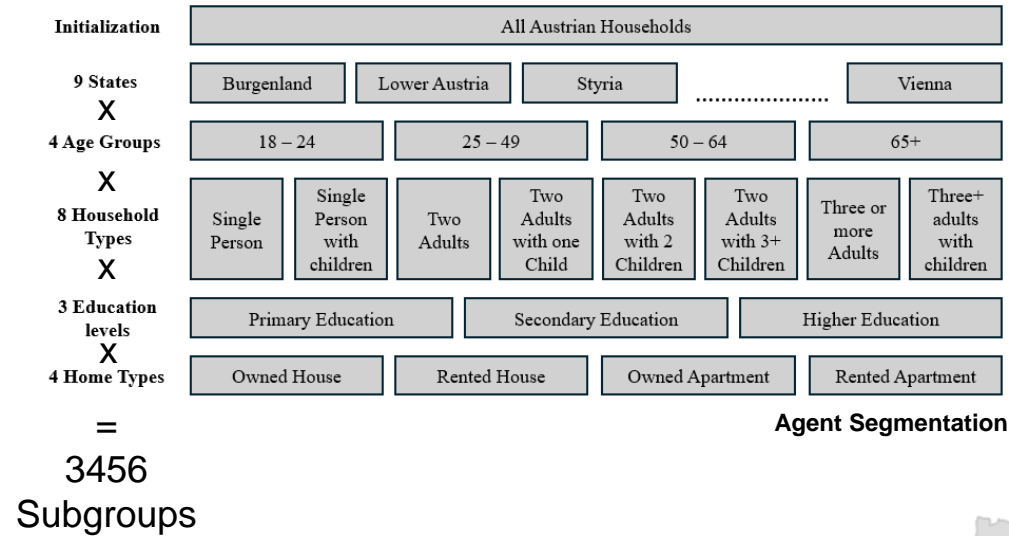
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Multi-Agent Segmentation

Agent Segmentation

= 3456 Subgroups

Example Agent

General Attributes:
- State: Vienna
- Age class: 25-49
- Household type: Two Adults
- Education level: Secondary Education
- Home type: Rented House
- Year: 2015

Individual Attributes:
- Sinus Milieu: Post Materialist
- Household Income: 31,000 €/a
- Electricity Consumption: 3500 kWh/a
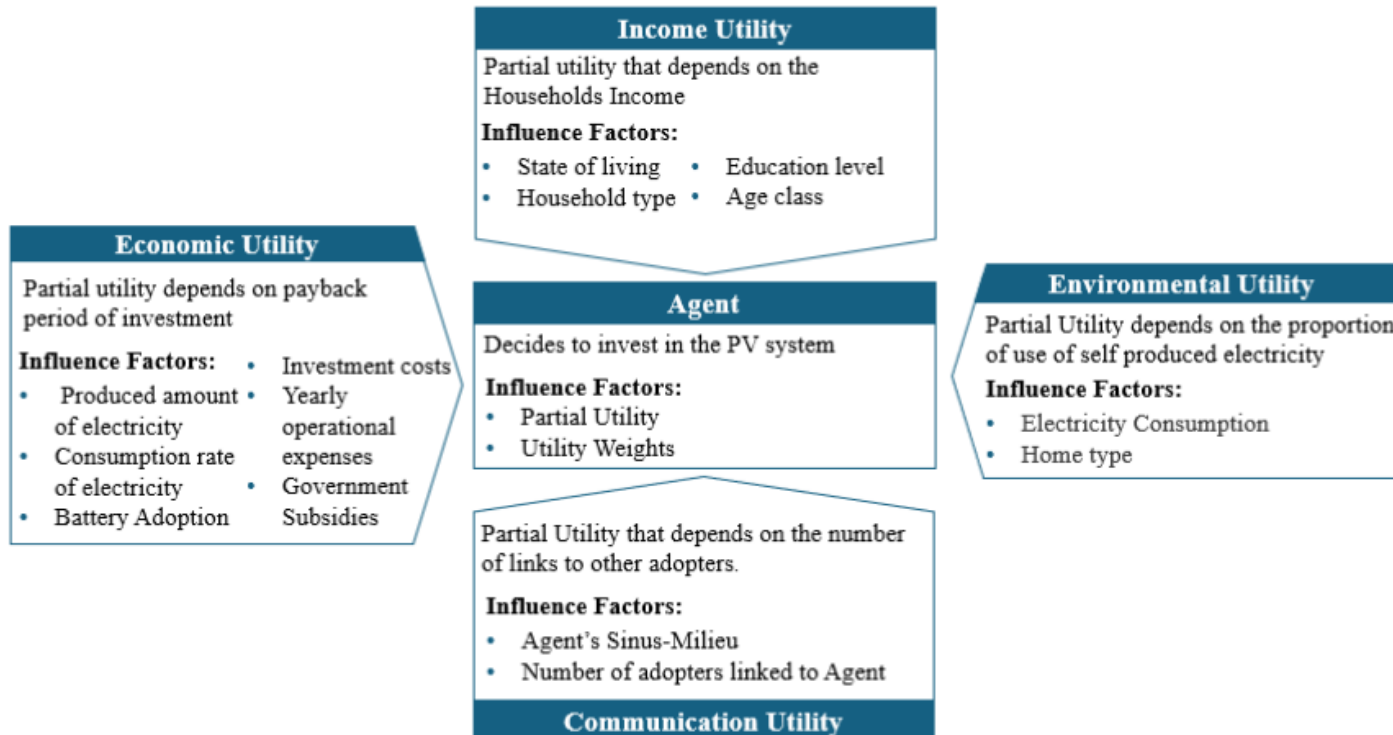- Electricity Production: 3000 kWh/a

Example Agent Attributes

Agent Adoption Decision

$$U_j = w_{econ}(sm_j) \cdot u_{econ}(j) + w_{com}(sm_j) \cdot u_{com}(j) + w_{inc}(sm_j) \cdot u_{inc}(j) + w_{env}(sm_j) \cdot u_{env}(j)$$

Where:

$$\sum_k w_k(sm_j) = 1 \; for \; k \in K:\{econ, com, inc, env\} \quad \textbf{and} \quad w_k(sm_j), U_j \in [0,1]$$

Income Utility

Partial utility that depends on the Households Income

Influence Factors:
- State of living
- Household type
- Education level
- Age class

Economic Utility

Partial utility depends on payback period of investment

Influence Factors:
- Produced amount of electricity
- Consumption rate of electricity
- Battery Adoption
- Investment costs
- Yearly operational expenses
- Government Subsidies

Agent

Decides to invest in the PV system

Influence Factors:
- Partial Utility
- Utility Weights

Environmental Utility

Partial Utility depends on the proportion of use of self produced electricity

Influence Factors:
- Electricity Consumption
- Home type

Partial Utility that depends on the number of links to other adopters.

Influence Factors:
- Agent's Sinus-Milieu
- Number of adopters linked to Agent

Communication Utility

Partial Utilities and their Influence on Agents
Source: Own Illustration, inspired by Palmer et al. (2015)

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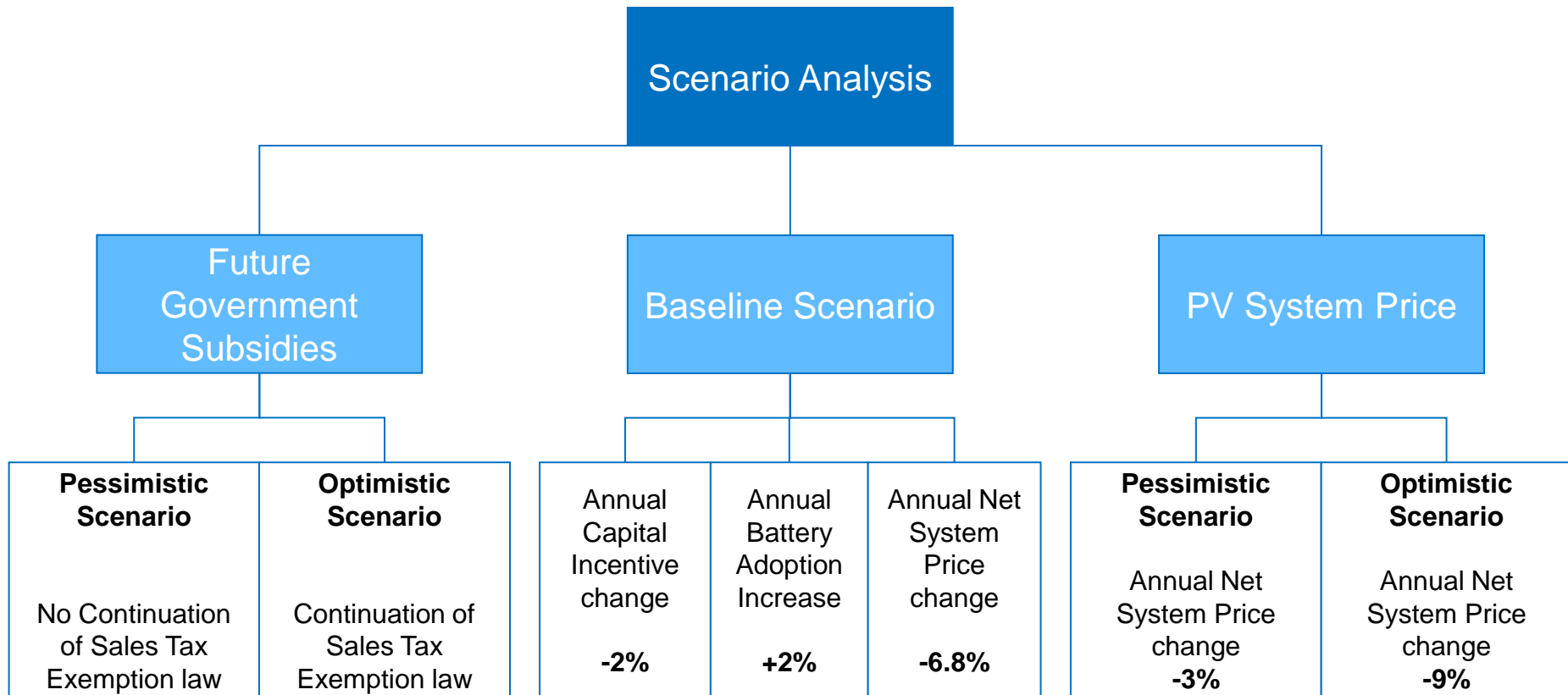## Proportion of Adopters per Sinus Milieu (Model Calibration)
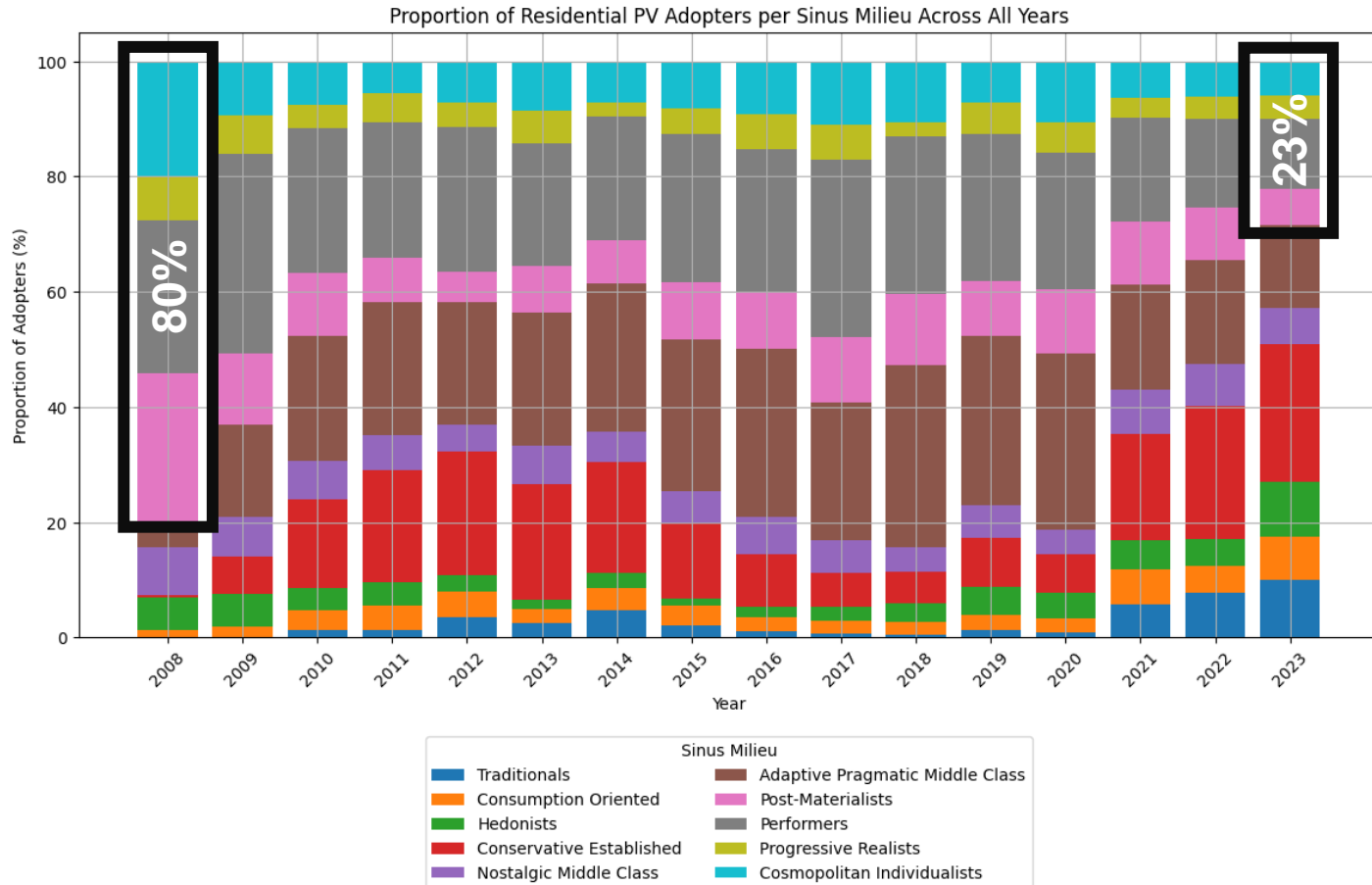
Proportion of Residential PV Adopters per Sinus-Milieu

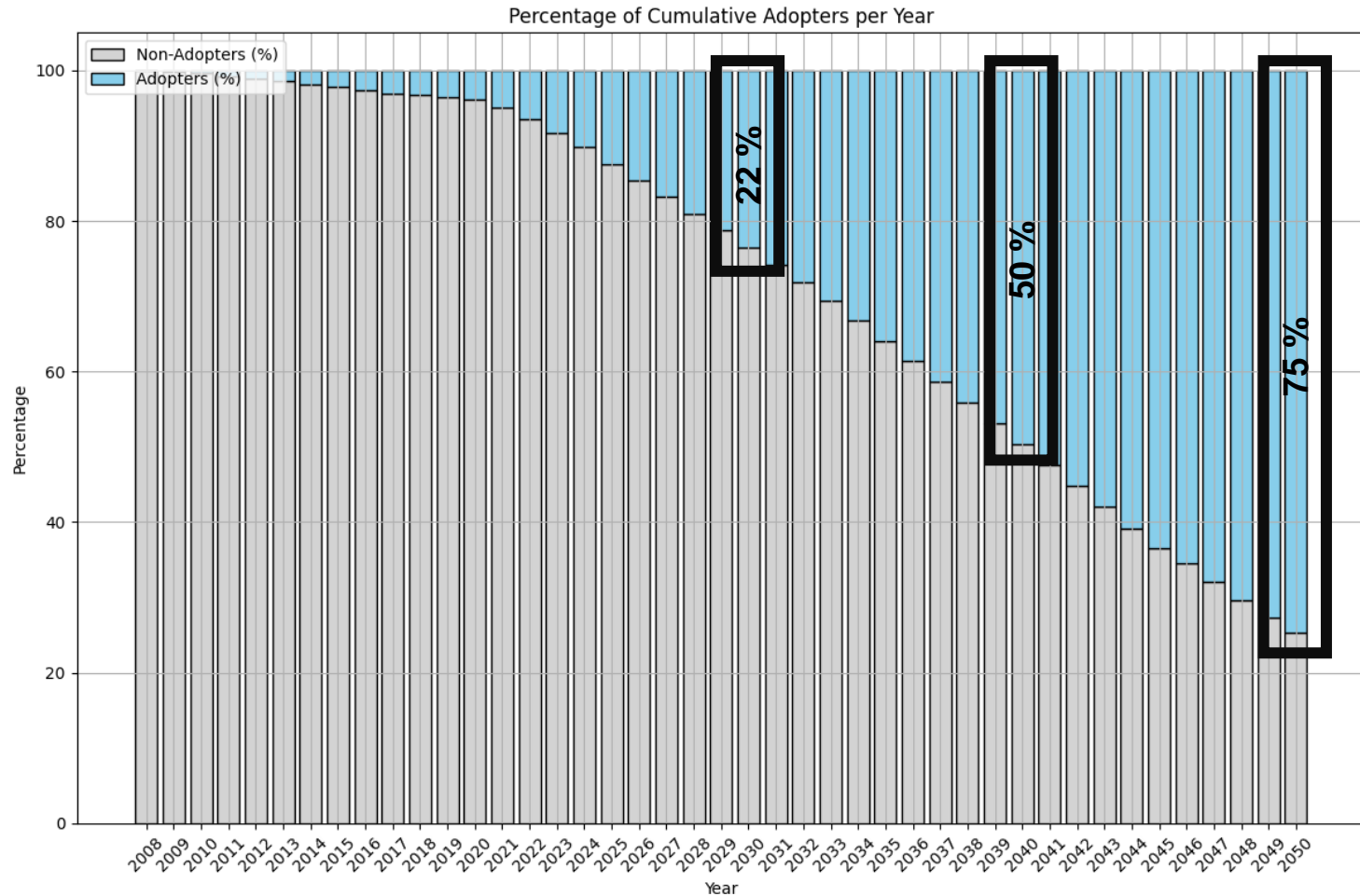Forecasting the Diffusion of Residential Photovoltaic Systems in Austria: An Agent-Based Modeling Approach | Chair of Energy Economics and Management | Institute for Future Energy Consumer Needs and Behavior | S. Marji, K. Yüksel, R. Madlener | IAEE 2025 – June 17, 2025

Results and Analysis

Forecasting Future Household PV Adoption – Scenario Analysis

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Projected Future Adoption – Baseline Scenario

Percentage of Cumulative Adopters per Year

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Influence of Partial Utility on Adoption Over Time – Baseline Scenario

Proportion of Each Utility by Year (Normalized)

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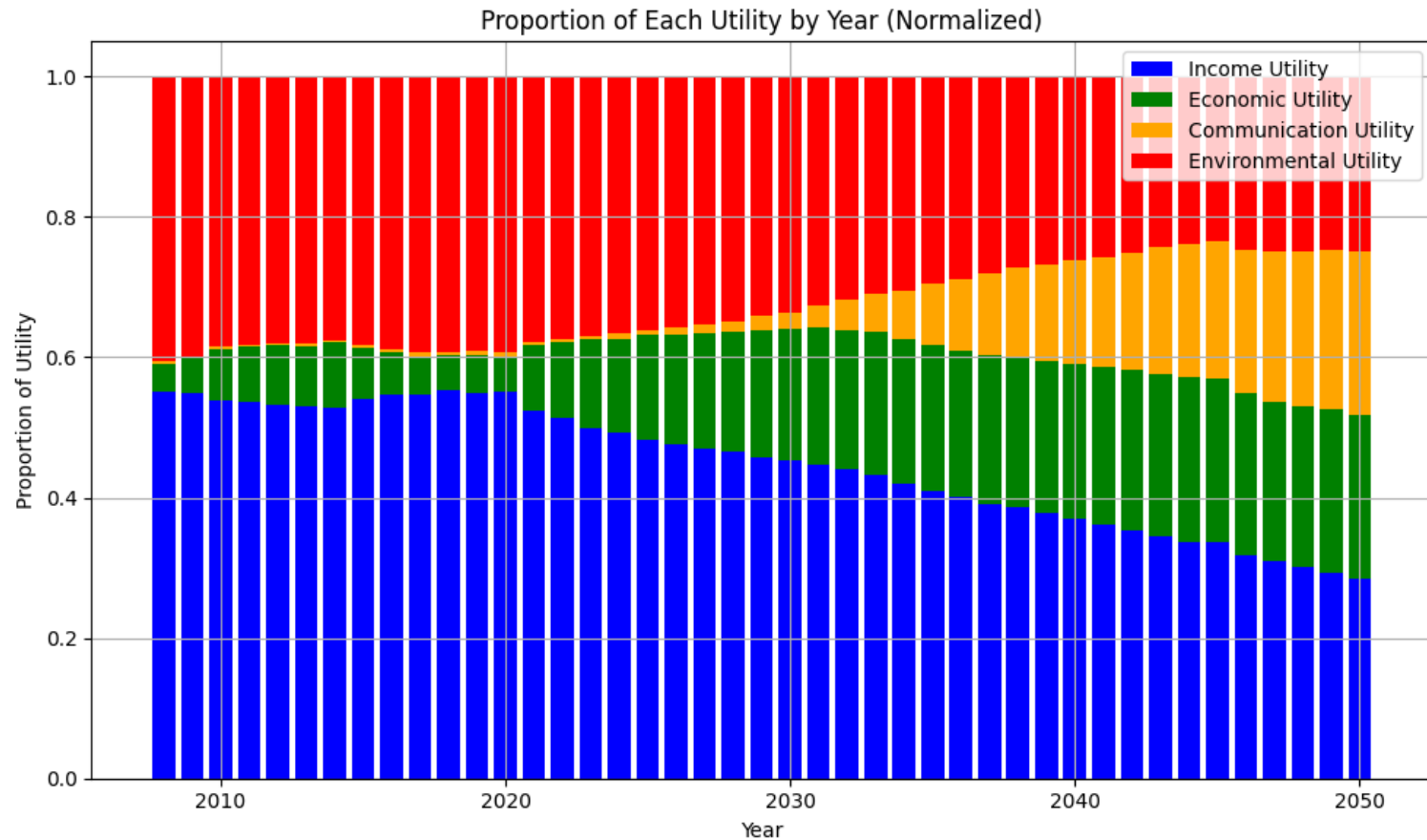
Cumulative Adoption per State – Baseline Scenario

Cumulative Residential PV Adopters per State

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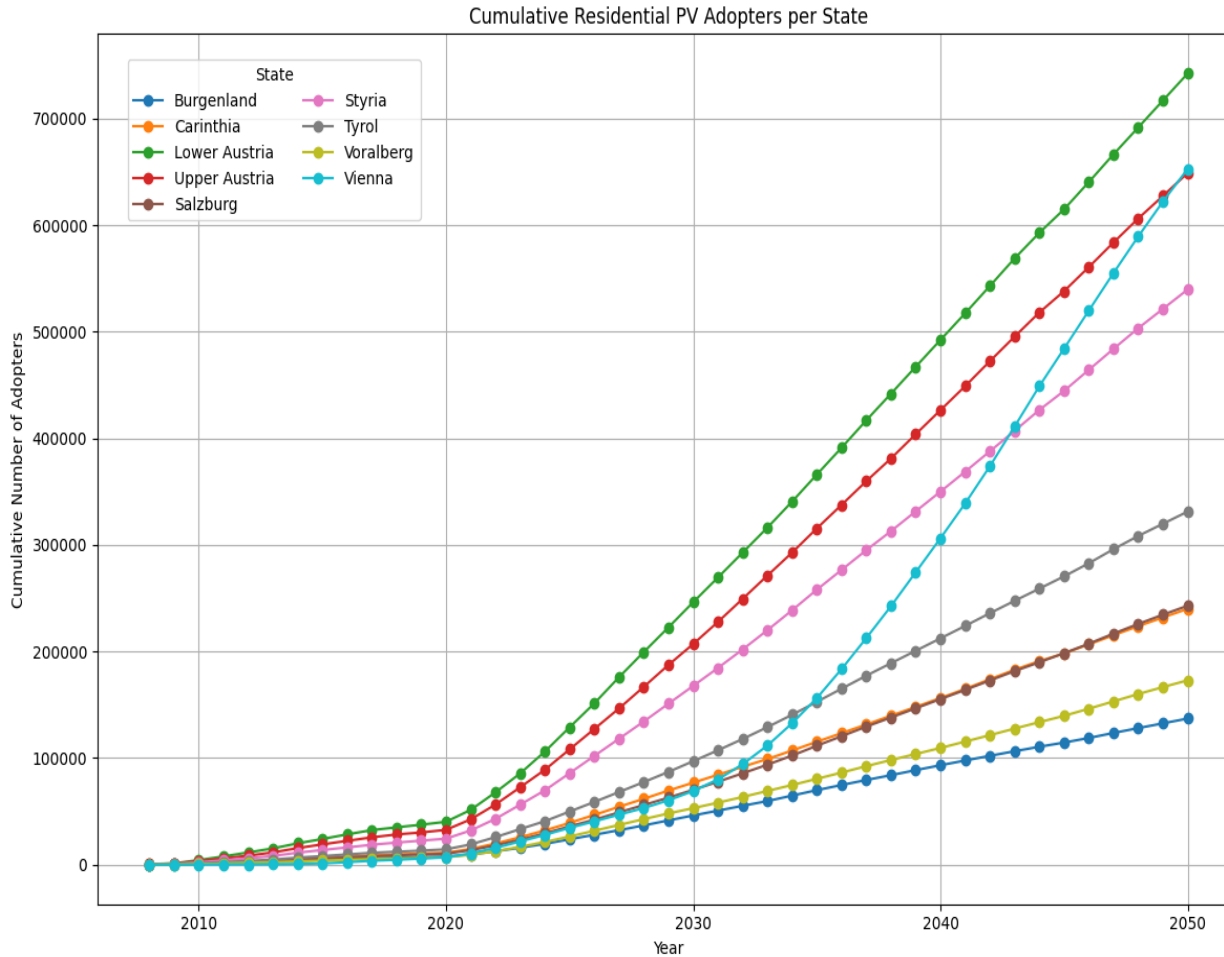
Adoption per Home Type in Different Federal States – Baseline Scenario

Upper Austria
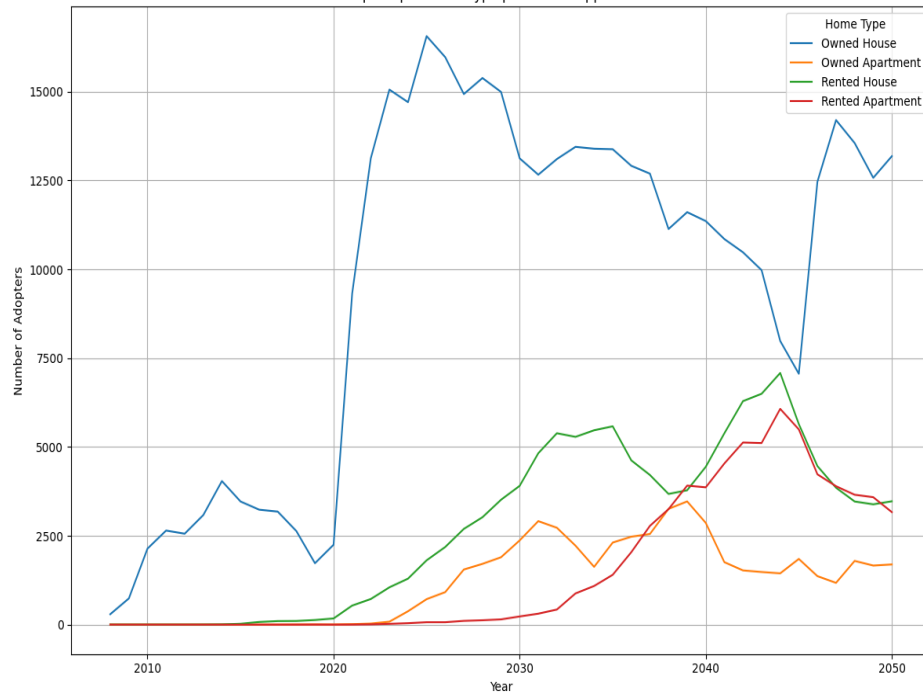
Vienna
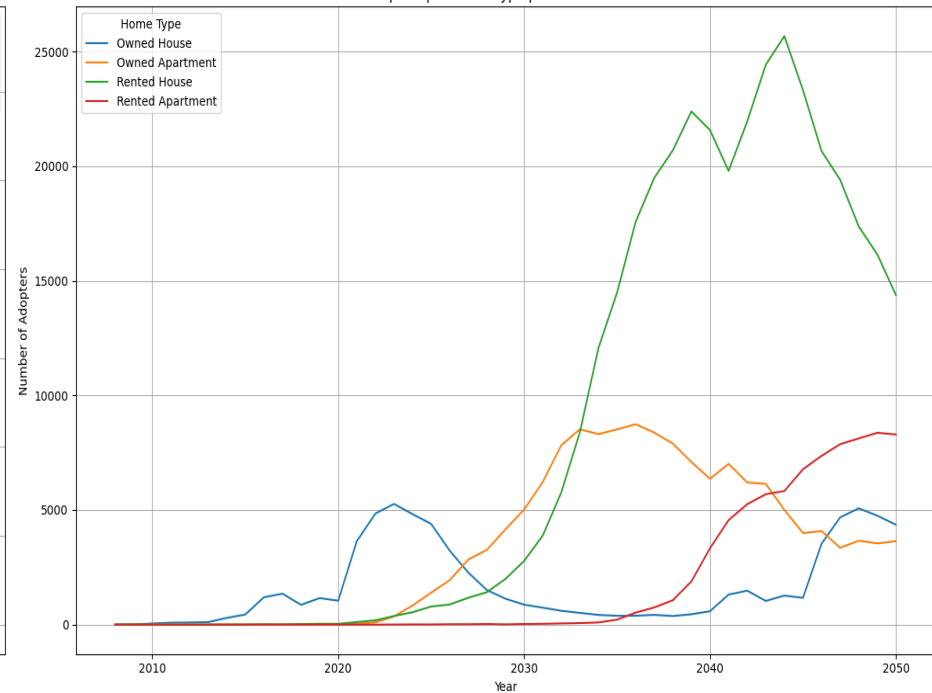
Projected Future Adoption – PV Regulation Developments

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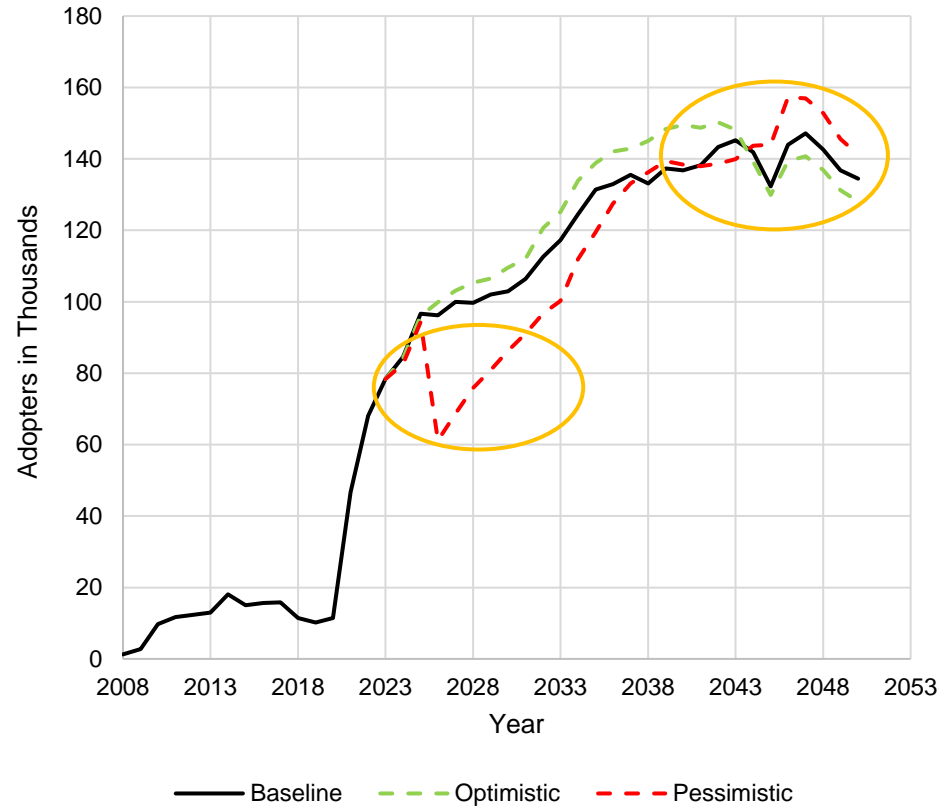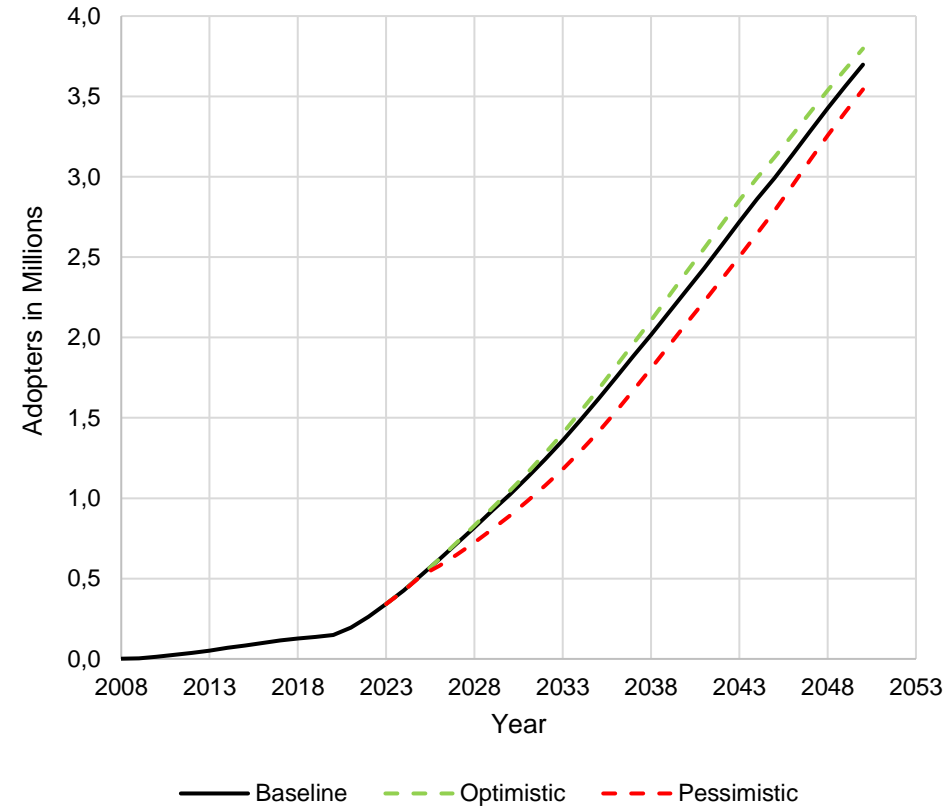
Projected Future Adoption – PV System Price Scenarios

Adoption Rate — X axis: Year (2008–2053); Y axis: Adopters in Thousands (0–180). Legend: Baseline, Optimistic, Pessimistic.
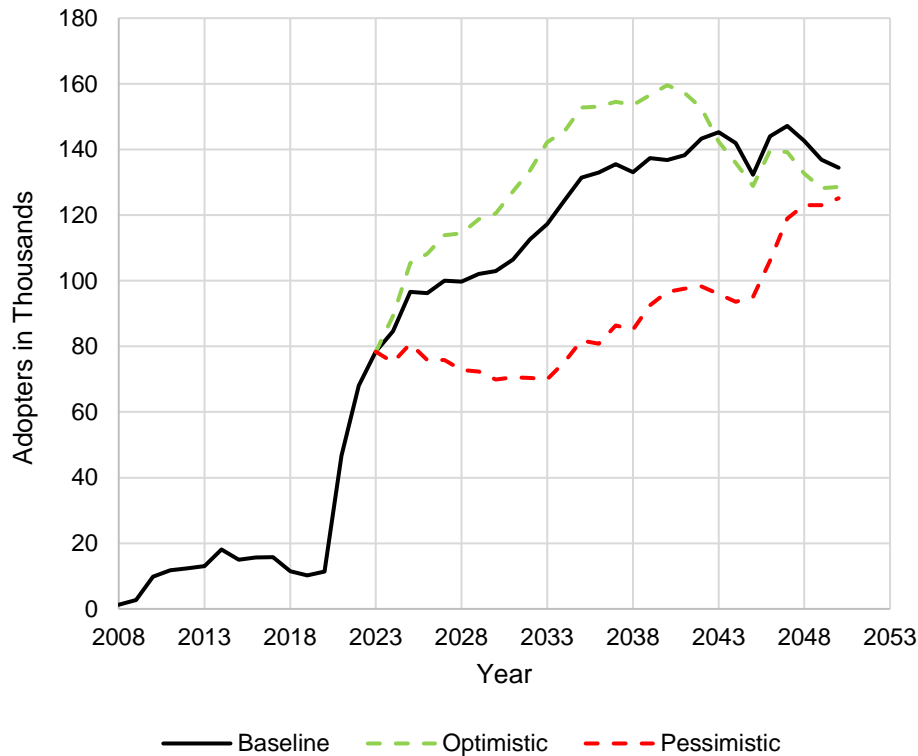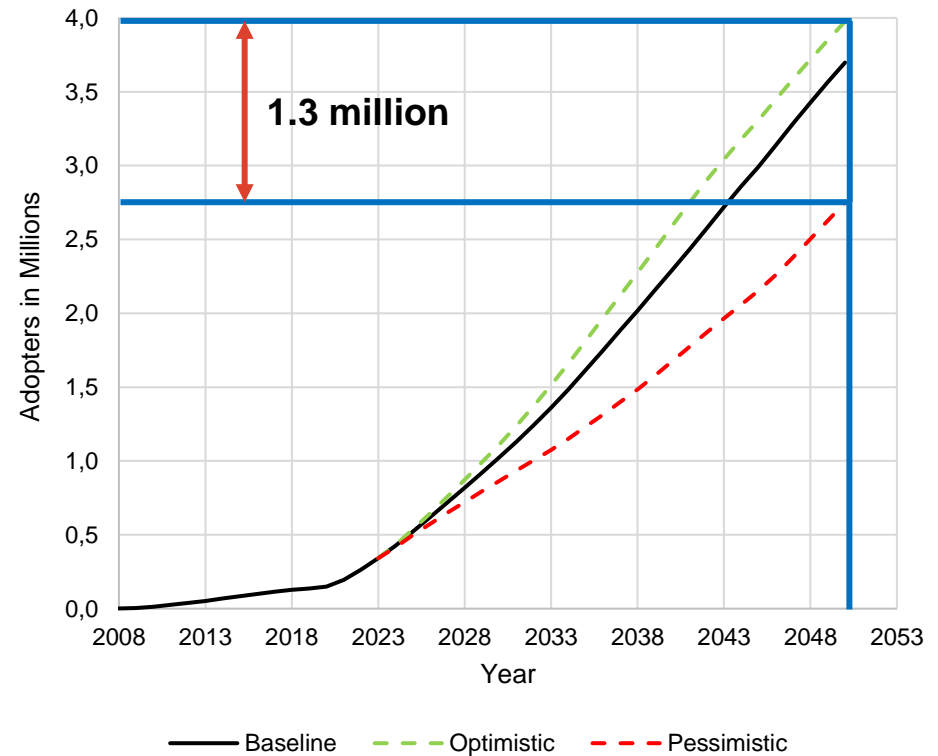
Cumulative Adoption — X axis: Year (2008–2053); Y axis: Adopters in Millions (0,0–4,0). Annotation: 1.3 million. Legend: Baseline, Optimistic, Pessimistic.

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Conclusion and Outlook

- The model, expanding on Palmer et al. (2015), provides useful and a disaggregated investigation of PV adoption dynamics in Austria.

- Utilizing multi-categorical data enables better understanding of (state-level) market diffusion of residential PV systems in Austria.

- Sinus-Milieus are useful to reflect the socio-cultural dimensions of the Austrian population.

- House ownership loses ground as a primary factor for PV adoption. States with lower rates of homeownership are expected to catch up (e.g. Vienna).

- Changing the PV system price leads to market saturation faster than the offered subsidies.

- Incorporating state and district level policy heterogeneity into future models could enhance the predictive accuracy of the model (work in progress).

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Work In Progress

■ "Zooming-In": **State-Level** Subsidy Investigation

State	Owned / Rented	Available Subsidy (< 5 kWp)	Available Subsidy (5 kWp ≤ x ≤ 10 kWp)	Combination with EAG?	Notes
Carinthia	Owned	€323 (per kWp)	€194 (per kWp)	YES	Maximum 50% of costs covered
Carinthia	Rented	€200 (per kWp)	€200 (per kWp)	YES	
Salzburg	Owned	0	€1,000 (per kWp) 40% of total PV system cost	YES	Systems under €500 are ignored
Styria	Owned	15% of total PV system cost	€300 (per kWp) 15% of total PV cost	YES	
Styria	Rented	15% of total PV system cost	€300 (per kWp) 15% of total PV system cost	YES	
Tyrol	Owned	0	€250 (per kWp)	YES	Minimum 7 kWp
Vienna	Owned	€250 (per kWp) 30% of total PV system cost	€250 (per kWp) 30% of total PV system cost	NO	Minimum 1 kWp

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■ "Plug-and-Play" Application for **Different Sustainable Residential Technologies**
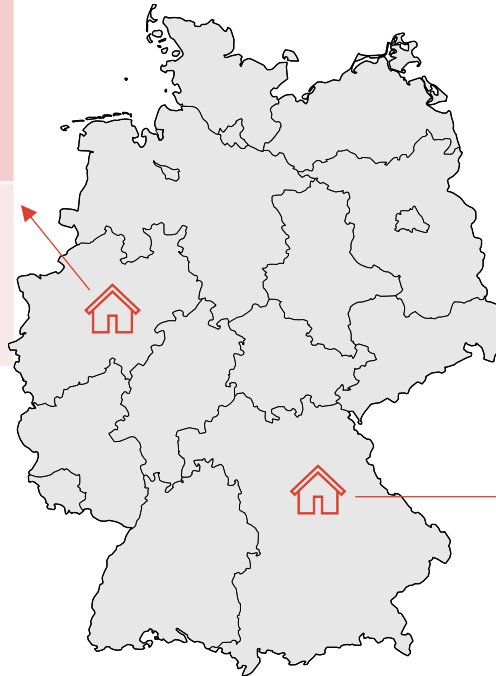

Example Agent 1

General Attributes:
- **Year:** 2022
- **State:** North Rhine-Westphalia
- **Age Group:** 25 to 49 years
- **Education Level:** Tertiary Education
- **Household Type:** Two Adults
- **Degree of Urbanization:** Cities
- **Parking Lot Type:** Shared Garage

Individual Attributes:
- **Household Income:** 45,824 €/a
- **Annual Driving Distance:** 12,500 km/a
- **Powertrain:** Electric Motor
- **Sinus Milieu:** Performer Milieu

Example Agent 2

General Attributes:
- **Year:** 2022
- **State:** Bavaria
- **Age Group:** 65+ years
- **Education Level:** Primary Education
- **Household Type:** Three Adults
- **Degree of Urbanization:** Rural Areas
- **Parking Lot Type:** Lot on Private Ground

Individual Attributes:
- **Household Income:** 20,712 €/a
- **Annual Driving Distance:** 18,500 km/a
- **Powertrain:** Combustion Engine
- **Sinus Milieu:** Traditional Milieu

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Thank you for your kind attention.
Any questions?

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