Nudging consumers
towards energy efficiency
through behavioural science

Intervening me Softly - Modeling Nudging Interventions to Change Electric Vehicle User Preferences (6-161-22)

Jonas Burkhardt[1], Dr. Matthias Kühnbach[1], Sabine Pelka[1, 2]
(sabine.pelka@isi.fraunhofer.de)
[1]Fraunhofer Institute for Systems & Innovation Research ISI, [2] Delft University of Technology

ECEEE Conference, 6-10/06/2022

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Nudging consumers
towards energy efficiency
through behavioural science

Simulations of rational decision-making on flexibility provision by electric vehicles vs. intuitive decision-making

In everyday life:

Decision-making on providing flexibility from electric vehicles based on… (Kahnemann 2003)

- Rational choices – e.g., cost-minimazation
- Intuitive choices – e.g., based on social interaction and provided information

Incentives for providing **more flexibility** from electric vehicles

- For rational choices: monetary incentives
- For intuitive choices: nudging interventions

Simulating everyday life in agent-based models:

Cost-minimisation optimisation

Our paper: social network simulation

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Research outline

Research question

- How do nudging interventions based on social interaction influence the flexibility provision by electric vehicles?

Research assumptions

- Flexibility provision by electric vehicles by minimizing the required final stage of charge (SoC)
- Nudging interventions based on social interaction in the network influence the SoC of the agents

Research objectives

1. Setting up the agent-based model based on a social network
2. Testing and demonstrating the model functionalities in two sub-steps:
    1. Influence of nudging interventions (and external factors) on the SoC (experiment)
    2. Influence of the agent settings on the results (sensitivity analysis)

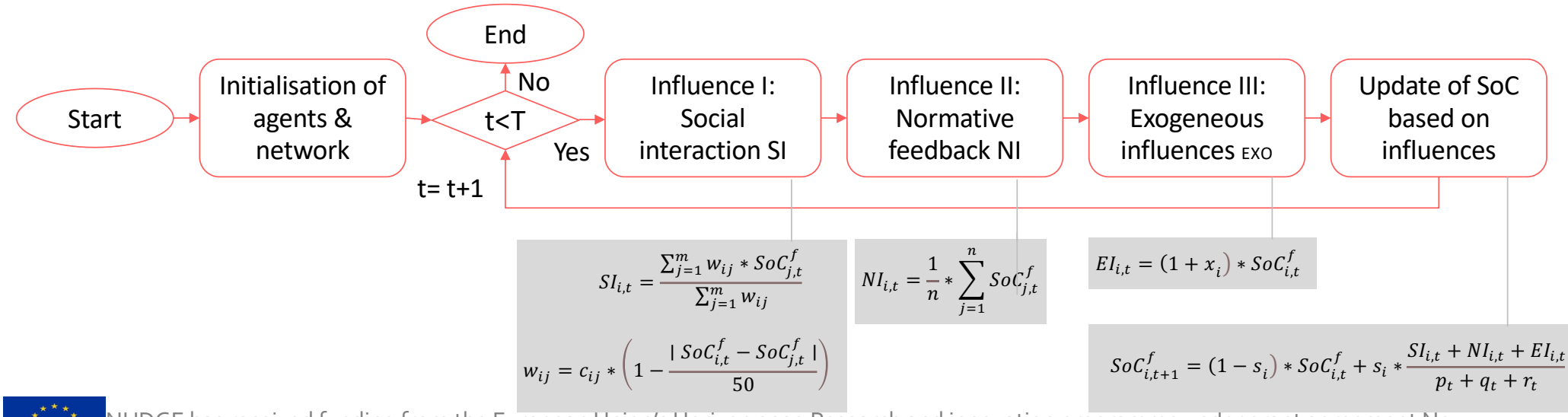
Next steps: Parameterization based on results of NUDGE field experiments and model coupling

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Setting up the agent-based model based on a social network

Nudging interventions based on social interaction extracted from the literature:

- **Social interaction (influence I)**: Distributed information on favorable and unfavorable behaviour of the own network (Zarei and Maghrebi 2020, Duggins 2014) - uncontrolled interventions, such as by information events
- **Normative feedback (influence II)**: Distributed information on favorable behaviour of the entire network (Friedkin 2001) – selective interventions, such as by smart home systems or energy management apps



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

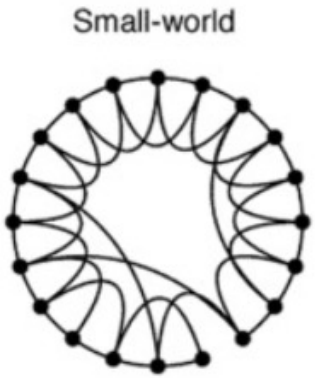
NUDGE

Nudging consumers towards energy efficiency through behavioural science

Experimental setup for testing the model

Scenario	Intervention / Influences
All (EXO + SI + NI)	All
EXO + SI	Social interaction + external influences
EXO	External influences
EXO + NI	Normative feedback + external influences

Parameter	Value
Number of agents	100
Number of simulation runs	100
Size of social contacts	12
Limit behaviour adjustment	18%
Simulation steps	52
Social network type	small-world



Agent initialization

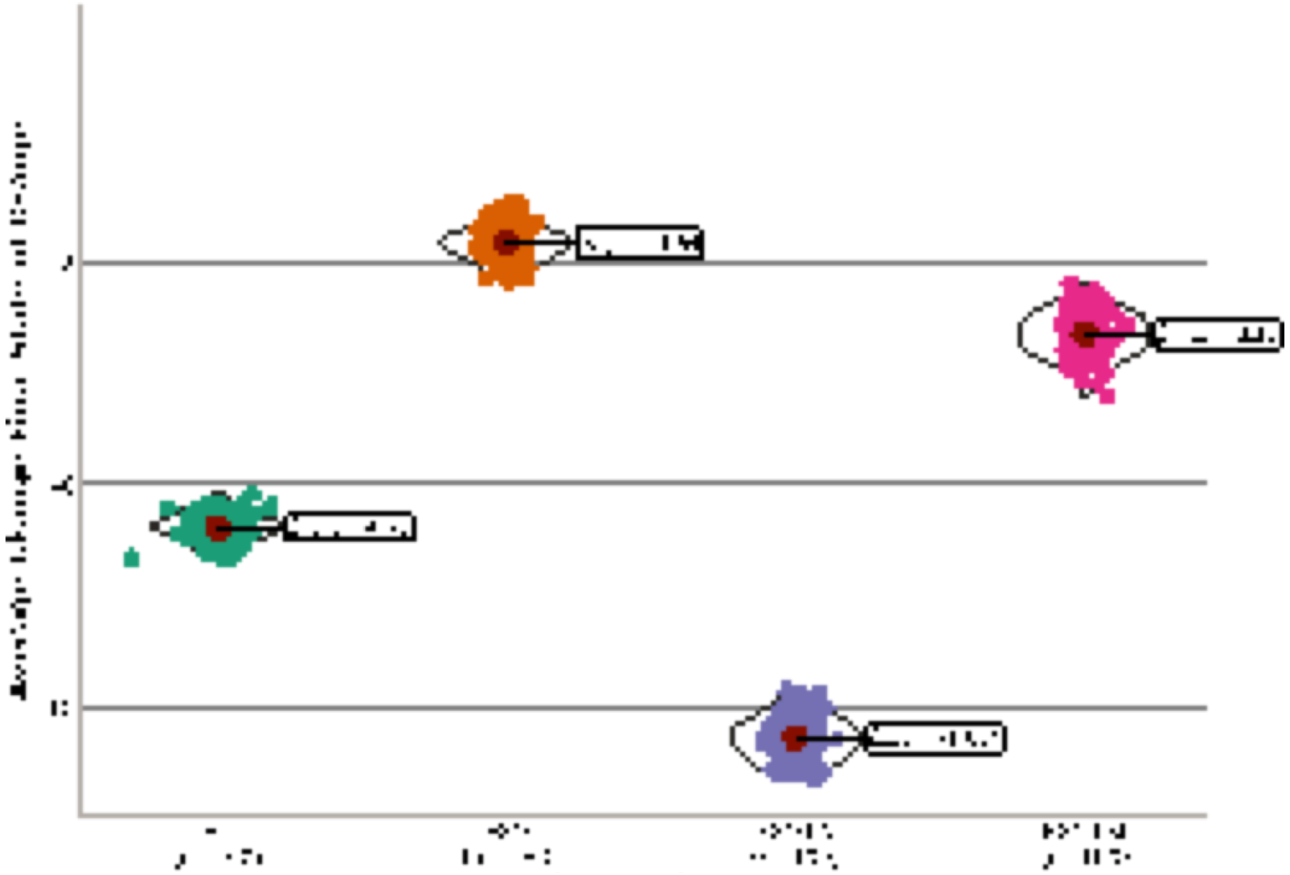
- EV battery capacity (75.7 kWh, 47.4 kWh, 26.3 kWh) (Gnann and Speth 2021)
- EV consumption (16-25 kWh/100 km)
- Distribution of initial SoC based on Quirós-Tortós et al. 2015
- Daily mobility demand of agents (= minimum technical SoC)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Nudging consumers
towards energy efficiency
through behavioural science

Experiment results: SoC reduction for all scenarios - strong influence of exposure to unfavorable behavior

- **EXO + N:** Strongest average SoC reduction (-10.54 %) compared to initialisation
- **All:** Medium reduction (-6.76%)
- **EXO + SI**: Lower reduction (-3.28 %)
- **EXO:** Also reduction due to high SoC at initialisation (-1.64%)
- All scenarios on average below the limit of behavioral adjustments (18 %)



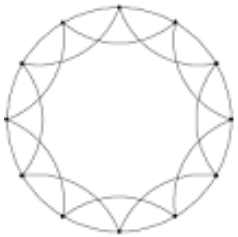
NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Nudging consumers
towards energy efficiency
through behavioural science

Sensitivity analysis: Limit of behaviour adjustment impacts the results strongly

Parameter	Value in the experiment	Value in the sensitivity analysis	Impact on scenario „all“
Size of social contacts	12	4 – 22	Decreasing SoC change with increasing number of contacts
Limit behaviour adjustment	18%	5 – 50 %	Strong impact: 15% results in highest available flexibility
Social network type	small-world	random, regular, scale-free	Minor impact: max. 0.3% smaller change for random network

Regular



Scale-free

Random

NUDGE has received funding from the European Union’s Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

Summary

Results

- Creation of agent-based model based on social network, in which agents adapt their final SoC depending on their social interaction
- Normative feedback (=selective information of only favorable behavior of entire network) results in strongest reduction of SoC (=highest provision of flexibility)

Discussion and next steps

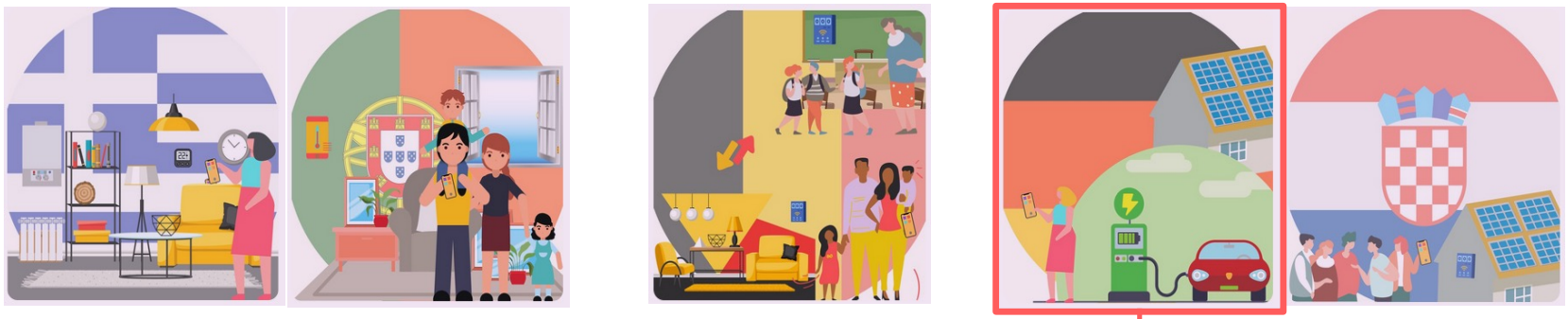
- Exposure to unfavorable behavior (boomerang effect) and limit of behavior adjustments influences the results strongly
- Parameterization (esp. w.r.t. adjustment limit and heterogenity of agents) and validation based on results of NUDGE field experiments
- Medium-term step: Model coupling with cost-minimisation model

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers
towards energy efficiency
through behavioural science

H2020 project NUDGE: 5 pilots testing the impact of nudging interventions on energy-saving behavior of households



Decreasing electricity consumption

Decreasing heating consump.

Increasing self-consumption

Charging app HERMINE

Webportal
for monitoring

For more information, visit our website:

https://www.nudgeproject.eu/

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Intervening me Softly - Modeling Nudging Interventions to Change Electric Vehicle User Preferences (6-161-22)

Thank you for your attention!

Jonas Burkhardt[1], Dr. Matthias Kühnbach[1], Sabine Pelka[1, 2]
(sabine.pelka@isi.fraunhofer.de)
[1]Fraunhofer Institute for Systems & Innovation Research ISI, [2] Delft University of Technology

ECEEE Conference, 6-10/06/2022

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

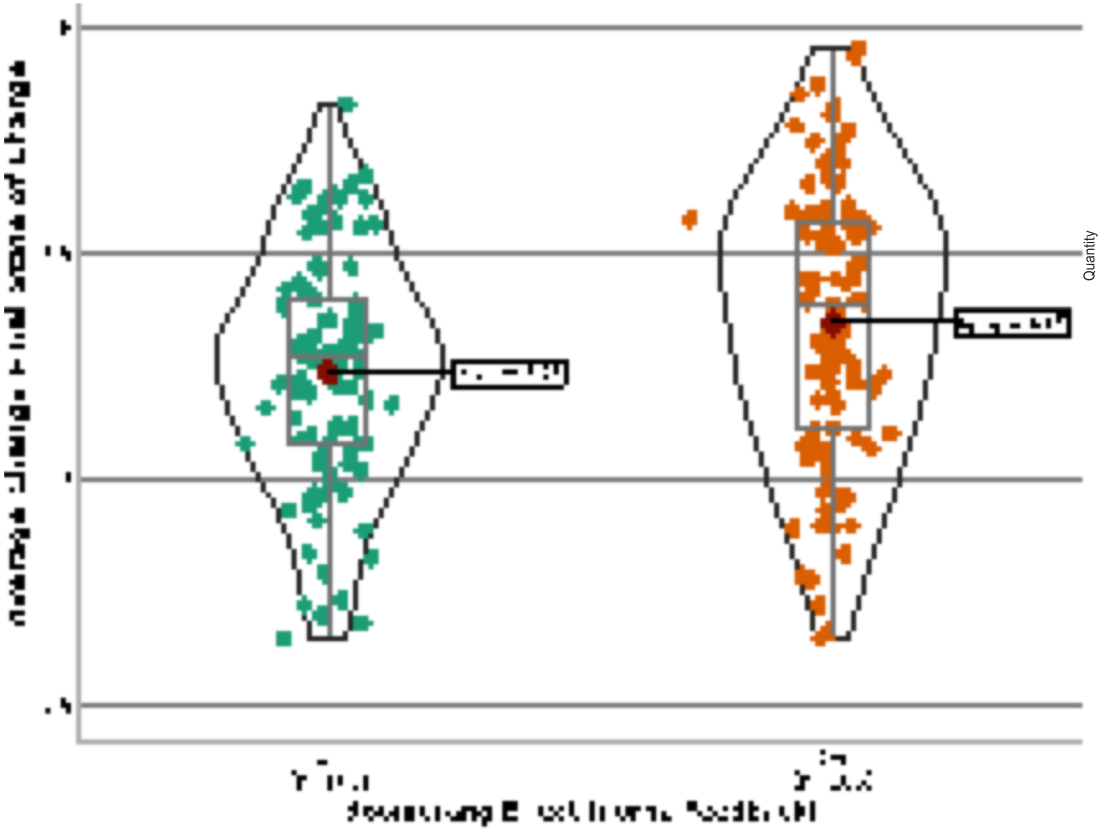
NUDGE

Nudging consumers towards energy efficiency through behavioural science

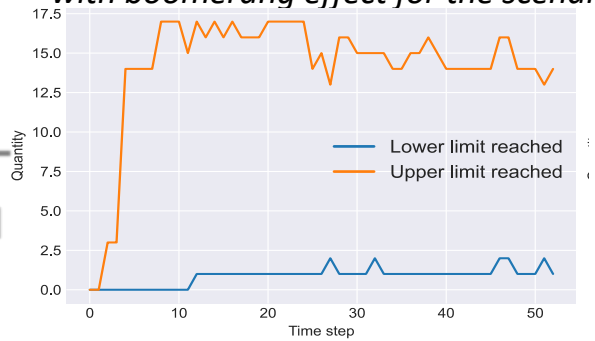
NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Nudging consumers
towards energy efficiency
through behavioural science

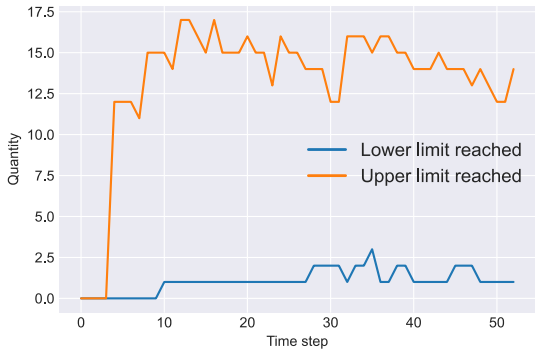
Impact of the Boomerang Effect (considering unfavorable behavior for normative feedback)



Agents at the limit of behaviour change for a model run with boomerang effect for the scenario "All".



and without boomerang effect

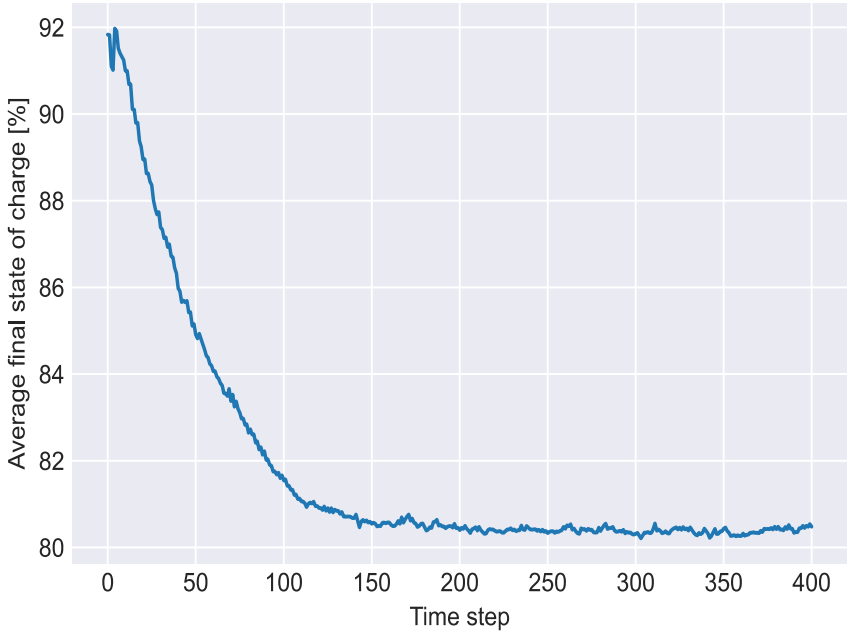


NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

NUDGE

Nudging consumers towards energy efficiency through behavioural science

Long-term development of average SoC of all agents (left) & number of agents at the limit of behaviour change (right)



NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Nudging consumers
towards energy efficiency
through behavioural science

Attribut	Abkür-zung	Beschreibung	Typ	Ausprägung
Agent ID	ID	Identifikator	int	-
Batterie-größe	BS	Kapazität des Elektroautos	float	3 Kategorien (Groß/Mittel/Klein)
Endlade-stand	SoC^f	Ladestand der Batterie nach Lade-vorgang	float	prozentual
Mobilitäts-bedarf	MN	Mobilitätsbedarf des Agenten	float	in km/d
Sensibilität	s	Empfindlichkeit des Agenten ggü. externen Einflüssen	float	zwischen 0 und 1
Verbrauch	C	Verbrauch des Elektroautos	float	gleichverteilt (16-25kWh/100km)

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.

Nudging consumers
towards energy efficiency
through behavioural science

Verhaltensänderung:

$$SoC_{i,t+1}^{f} = (1 - s_i) * SoC_{i,t}^{f} + s_i * \frac{SI_{i,t} + NI_{i,t} + EI_{i,t}}{p_t + q_t + r_t}$$

Einflüsse:

$$SI_{i,t} = \frac{\sum_{j=1}^{m} w_{ij} * SoC_{j,t}^{f}}{\sum_{j=1}^{m} w_{ij}}$$

$$w_{ij} = c_{ij} * \left(1 - \frac{| SoC_{i,t}^{f} - SoC_{j,t}^{f} |}{50}\right)$$

$$NI_{i,t} = \frac{1}{n} * \sum_{j=1}^{n} SoC_{j,t}^{f}$$

$$EI_{i,t} = (1 + x_i) * SoC_{i,t}^{f}$$

Nebenbedingung:

$$SoC_i^f \geq \frac{MN_i * {C_i}/{100}}{BS_i} * 100 + 10$$

Parameter		
BS_i	[kWh]	Kapazität des Elektroautos von Agent *i*
C_i	[kWh/100km]	Verbrauch des Elektroautos von Agent *i*
c_{ij}	[-]	Anzahl identischer sozialer Kontakte von Agent *i* und *j*
$EI_{i,t}$	[%]	Exogener Einfluss auf Agent *i* zum Zeitpunkt *t*
m	[-]	Größe soziales Netzwerk
MN_i	[km/d]	Täglicher Mobilitätsbedarf von Agent *i*
n	[-]	Gesamtzahl Agenten
$NI_{i,t}$	[%]	Einfluss von normativem Feedback auf Agent *i* zum Zeitpunkt *t*
p_t	[-]	Binärvariable, Vorhandsein sozialer Interaktion zum Zeitpunkt *t*
q_t	[-]	Binärvariable, Vorhandsein normatives Feedback zum Zeitpunkt *t*
r_t	[-]	Binärvariable, Vorhandsein exogener Einfluss zum Zeitpunkt *t*
s_i	[-]	Sensibilität von Agent *i*
$SI_{i,t}$	[%]	Einfluss sozialer Interaktion auf Agent *i* zum Zeitpunkt *t*
$SoC_{i,t}^{f}$	[%]	Endladestand von Agent *i* zum Zeitpunkt *t*
w_{ij}	[-]	Gewichtungsfaktor der Stärke der Beziehung zwischen den Agenten *i* und *j*
x_i	[-]	Zufallszahl zwischen -0,1 und +0,1

NUDGE has received funding from the European Union's Horizon 2020 Research and innovation programme under grant agreement No 957012.