Adoption of innovative energy services by the residential consumers: agent-based modelling approach

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Motivation

- Active role of consumers in the energy market

„Citizens are central to the successful uptake of low-carbon innovative solutions from smart meters in their homes to large-scale wind farms…"

Accelerating Clean Energy Innovation (EC, Brussels, 2016)

SOURCES
http://www.gocompare.com/gas-and-electricity/green-energy-tariffs/#UBFtct9a1DLKjklm.97
http://viget.opower.com/solutions/demand-response
http://www.smartek.life/smart-metering.php
http://www.connectedly.com/smart-appliances

Empirical evidence

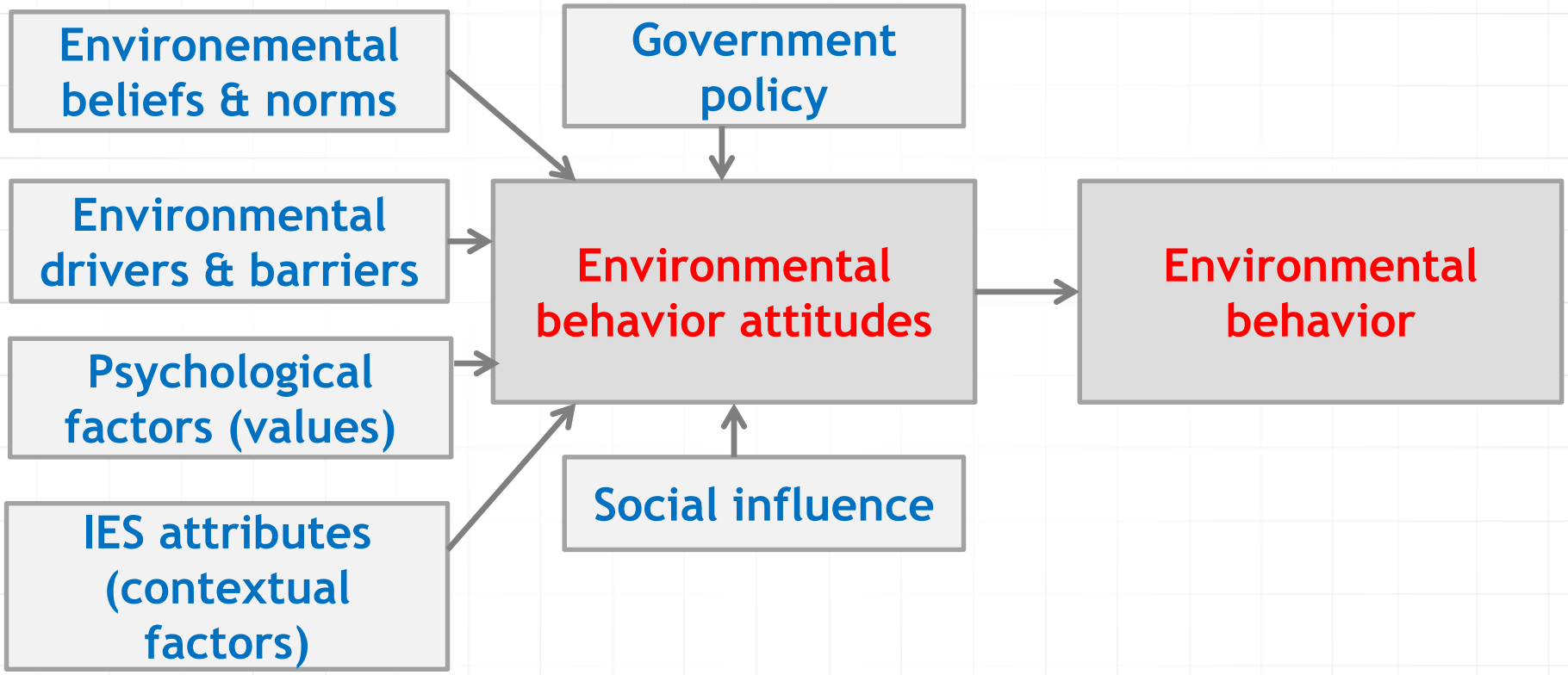
- Lack of engagement and interest in the energy sector (OFGEM, 2010; Hobman et al., 2014)
- Voluntarily subscription to green or dynamic tariffs is very rare.
  - in Australia in 2014 only c.a. 7% of the whole population subscribed to green electricity program (Hobman et al. 2014)
  - In the U.S. and in Europe average rates are estimated to be at or below 2% (Diaz&Tzvara, 2012)
- Intention-behavior gap
  - In Italy 70% of respondents are willing to increase energy saving and only 2% are currently reducing their use (Pongilione, 2011)

Reasons for slow diffusion

- Energy – invisible good
- Inelastic demand
- Confusion of choice
- Lack of advice
- Discomfort of usage
- Unstable opinions
- Free riding

SOURCE: http://content.wisestep.com/students-make-wrong-career-choices/

Attributes of consumers' behavior



Source: Ajzen, 2005; Allcott, 2011; Gadenne et al., 2011; Hansla et al., 2008; Ozaki, 2011; Perlaviciute & Steg, 2014; Stern, 2000

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Challenges in research…

- How to examine the consumers' attitudes and behaviors towards IES?
  - Natural experiment, field study (Gans et al., 2013; Ozaki, 2011; Duetschke & Paetz, 2013)
  - Questionnaire surveys, interviews, focus groups (Nygren et al., 2015; Gerpott & Paukert, 2013)
  - Pilot program (Faruqui & Sergici, 2010; Erhard-Martinez et al., 2010; Siano,2014; Star et al., 2010)
  - Modelling and simulation (Zhang & Nutall, 2011; Kowalska-Pyzalska et al., 2014; Ringler et al., 2016; Moglia et al., 2017)

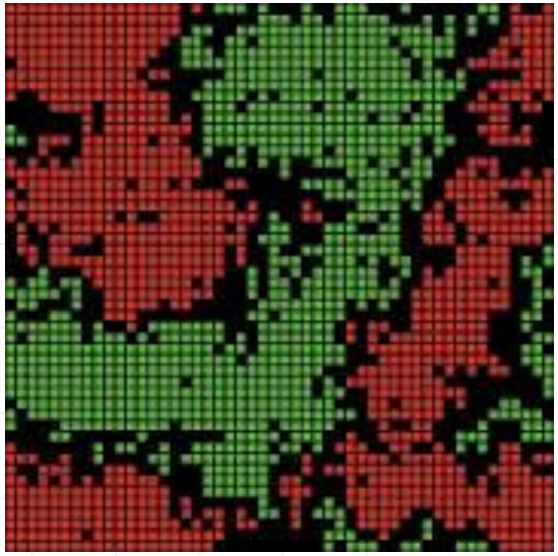
Advantages of modelling???

- Cost-effectiveness
- Investigation of various scenarios and possibility of sensitivity analysis
- Used as a testbed for analysing innovative concepts and paradigms
- Used before designing a proper social experiment

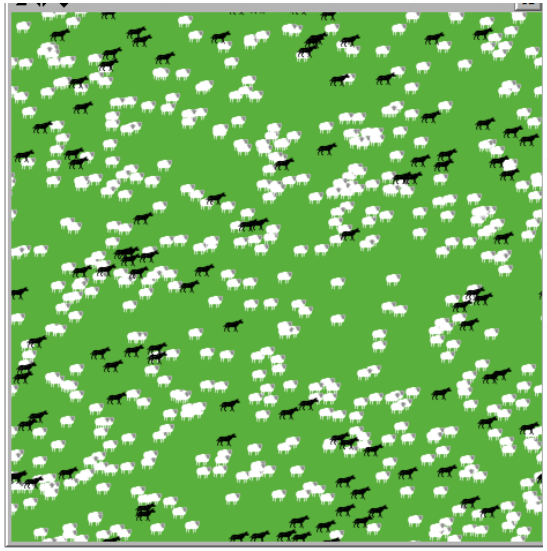
Source of graphics: https://www.bowelcanceraustralia.org/tests-investigations/advantages-disadvantages

Agent-based modelling (ABM)

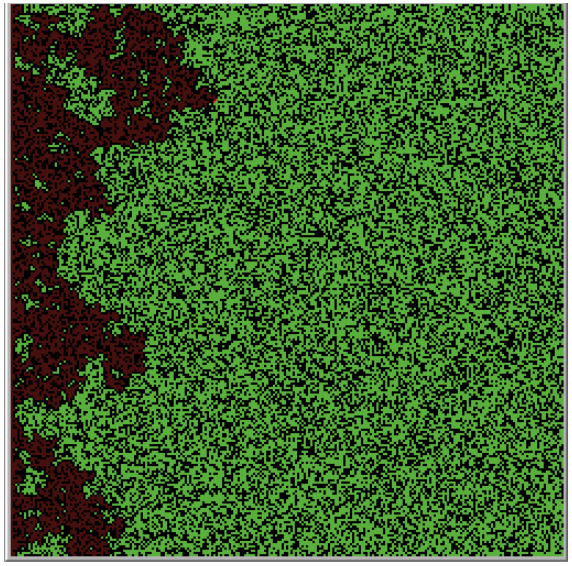
- Bottom-up approach from micro (agents, consumers) to macro behaviours (societies, populations)



The Segregation Model



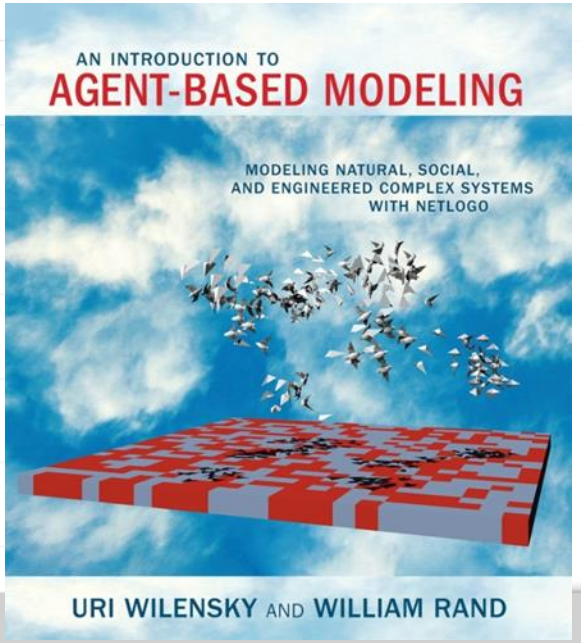
The Wolf/Sheep Predation Model



The Fire Model

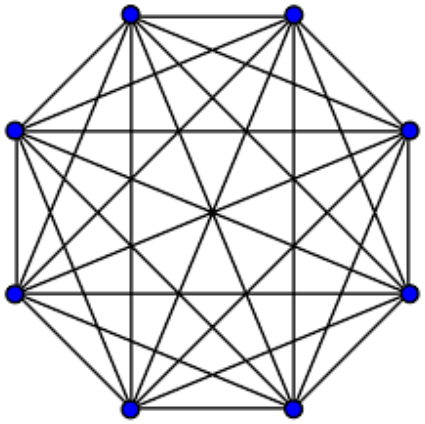
Agent-based modelling (ABM)

- ABM can capture irrational behaviour, complex social networks and global scale (Testafion, 2006; Kiesling et al. 2012)



ABM and diffusion of innovations

- ABM allows to:
  - simulate behaviour of individual consumers towards innovation
  - define how social influence, network topologies and external factors impact the diffusion time and schedule



ABM and diffusion of innovations in the energy market

- ABMs are used for modelling the diffusion of:
  - smart meters (Zhang&Nutall, 2011; Rixen&Weigand, 2014)
  - dynamic tariffs (Kowalska-Pyzalska et al., 2014)
  - storage devices (Zheng et al., 2014)
  - PV systems (Palmer et al. 2015)
  - novel biomass fuel (Guenther et al., 2011)
  - general eco-innovations (Byrka et al., 2016)

Before the model is built...

- Who are our agents?
- What attributes they have?
- What kind of behaviour they can perform?
- In what environment they act?
- What is the model framework (steps of the model)?
- What kind of results the model should provide?
- What are our prediction about the results?

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Model of green energy adoption

- Agents represent households making decisions to adopt green energy sources (RES)
- Each agent has two attributes:
  - ✓ Willingness to pay – WTP (R_i) that represents her appraisal of the RES
  - ✓ Adoption threshold $(R_{i_{min}})$ that depends on socio-economic variables
- The model shows the distribution of WTP towards green energy

A. Kowalska-Pyzalska (2017) Willingness to pay for green energy: An agent-based model in NetLogo platform, DOI: 10.1109/EEM.2017.7981943

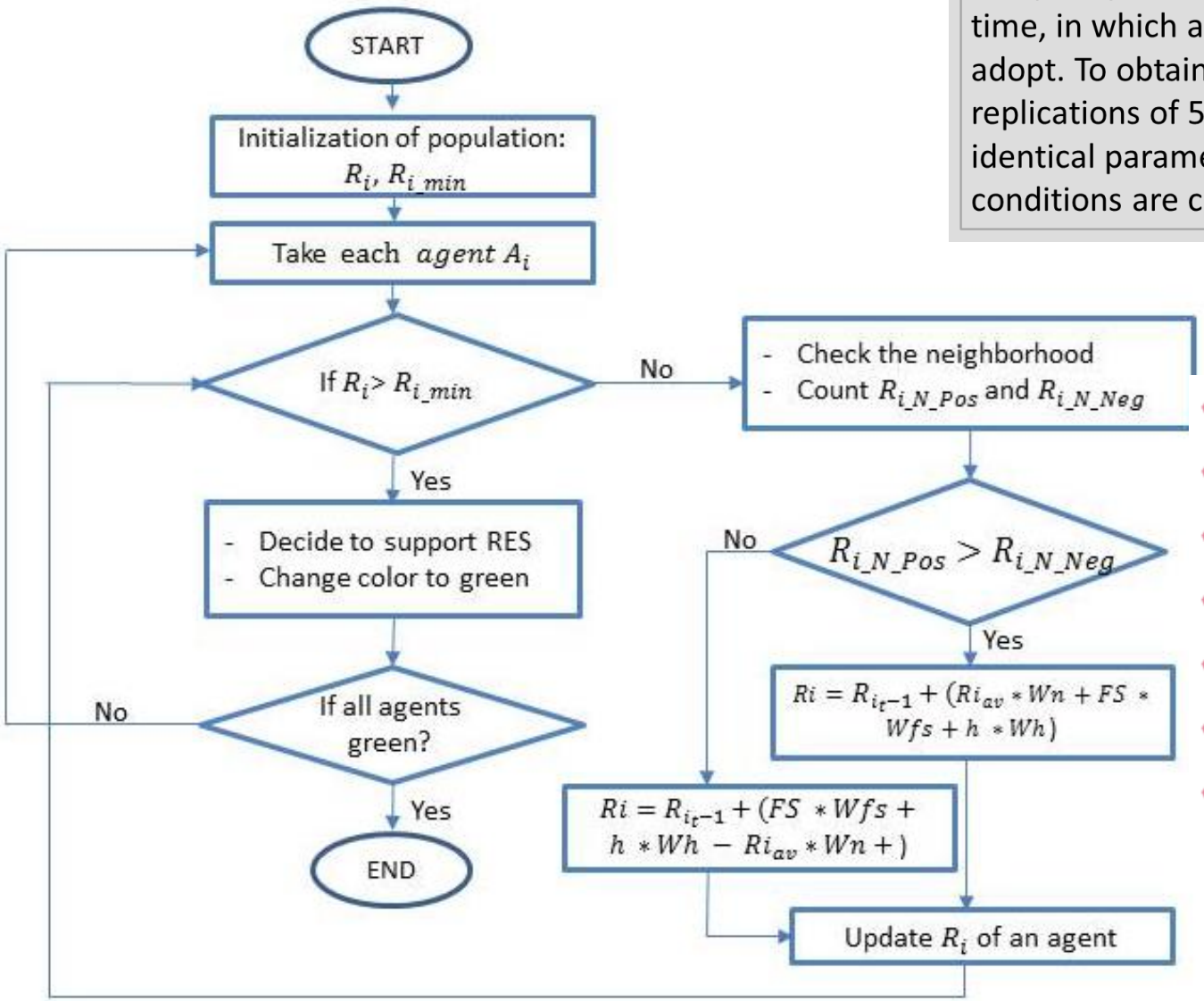
Agent's attributes

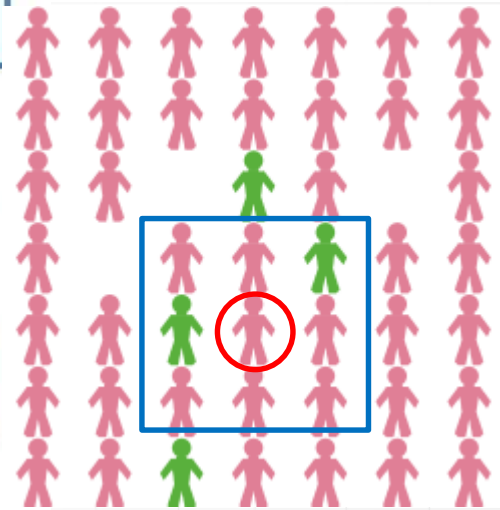
Consumer agent's attributes	Variable type	Initialization and allowable ranges
Reservation price, WTP (R_i)	Dynamic	- At the beginning of the simulation the initial distribution of R_i is assumed. - Afterwards, the R_i is a result of social influence and the impact of advertisement and financial support.
Adoption threshold (R_{i_min})	Static	- Each agent has a given adoption threshold, that represents his overall attitude towards IES, as well as it takes into account the difficulty of adoption (e.g. the need to change habits, or to pay a higher electricity bill)

- Initial R_i is c.a. 10% of the current electricity bill
- 30% of the population has R_i >0, $R_i \sim N(0.1, 0.05)$
- $R_{i_{min}} \sim N(0.5, 0.05)$

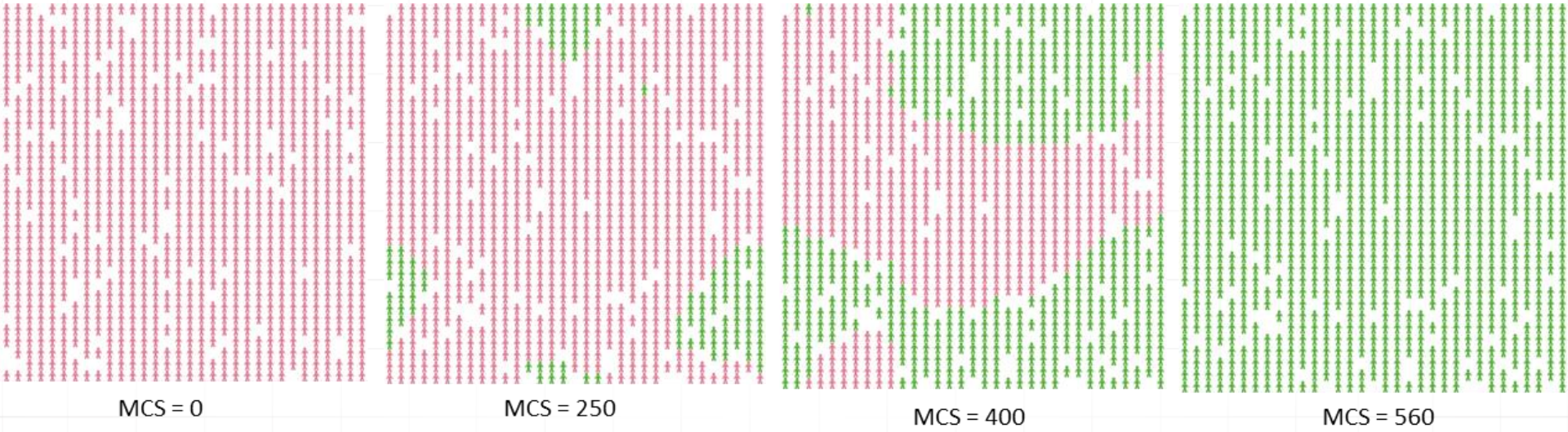
Model's framework

In each simulation there is a constant number of 1000 agents. Each simulation run (MCS) can be treated as a week time, in which a consumer decides to adopt. To obtain representative results, replications of 500 simulation runs with identical parameters and initial conditions are conducted.



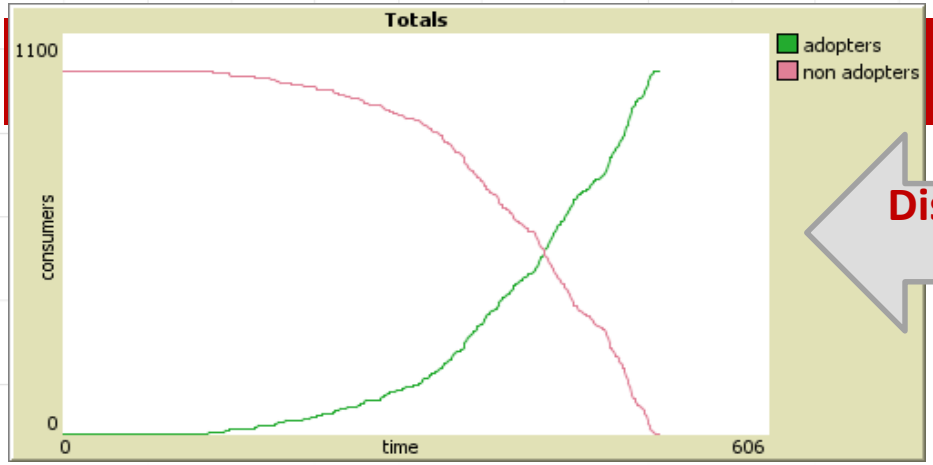


Results: a role of external forces

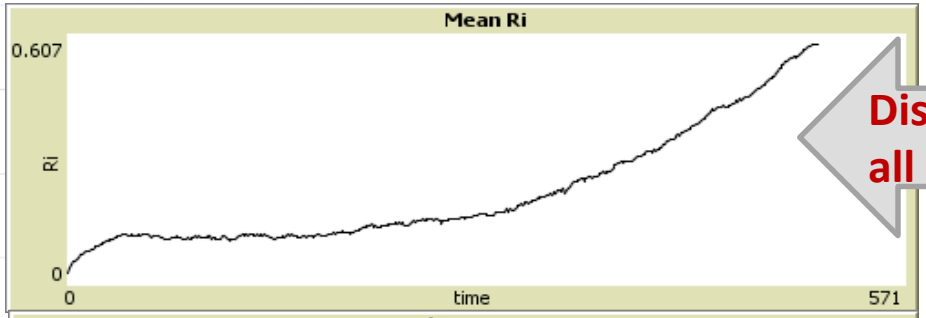


Snapshots show a time evolution of a system evolving from the initial state without adopted agents (all agents have $R_i < R_{i\_min}$ i.e. they are pink), for financial support FS = 0.01 and advertisement h = 0.

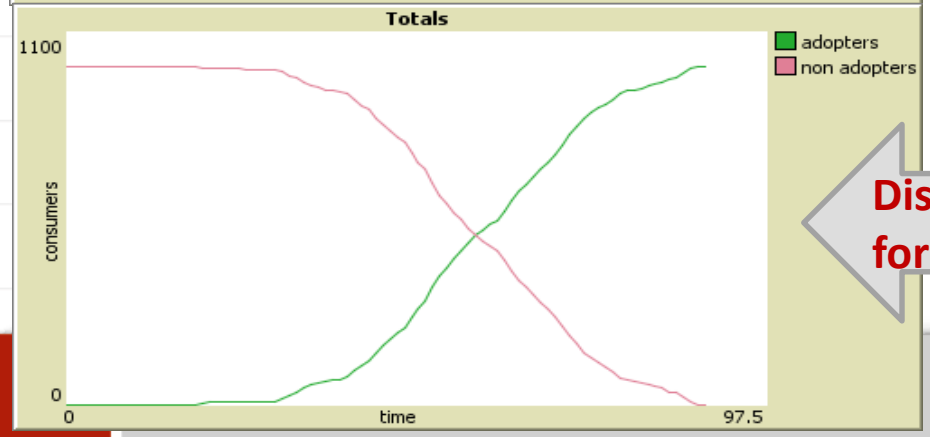
Results: financial support & advertisment



Distribution of adopters and non-adopters for *FS* = 0.01, *h*=0 in c.a. 600 MCS



Distribution of mean reservation price R_i of all the agents during the simulation



Distribution of adopters and non-adopters for *FS* = 0, *h*=0.07 in c.a. 100 MCS

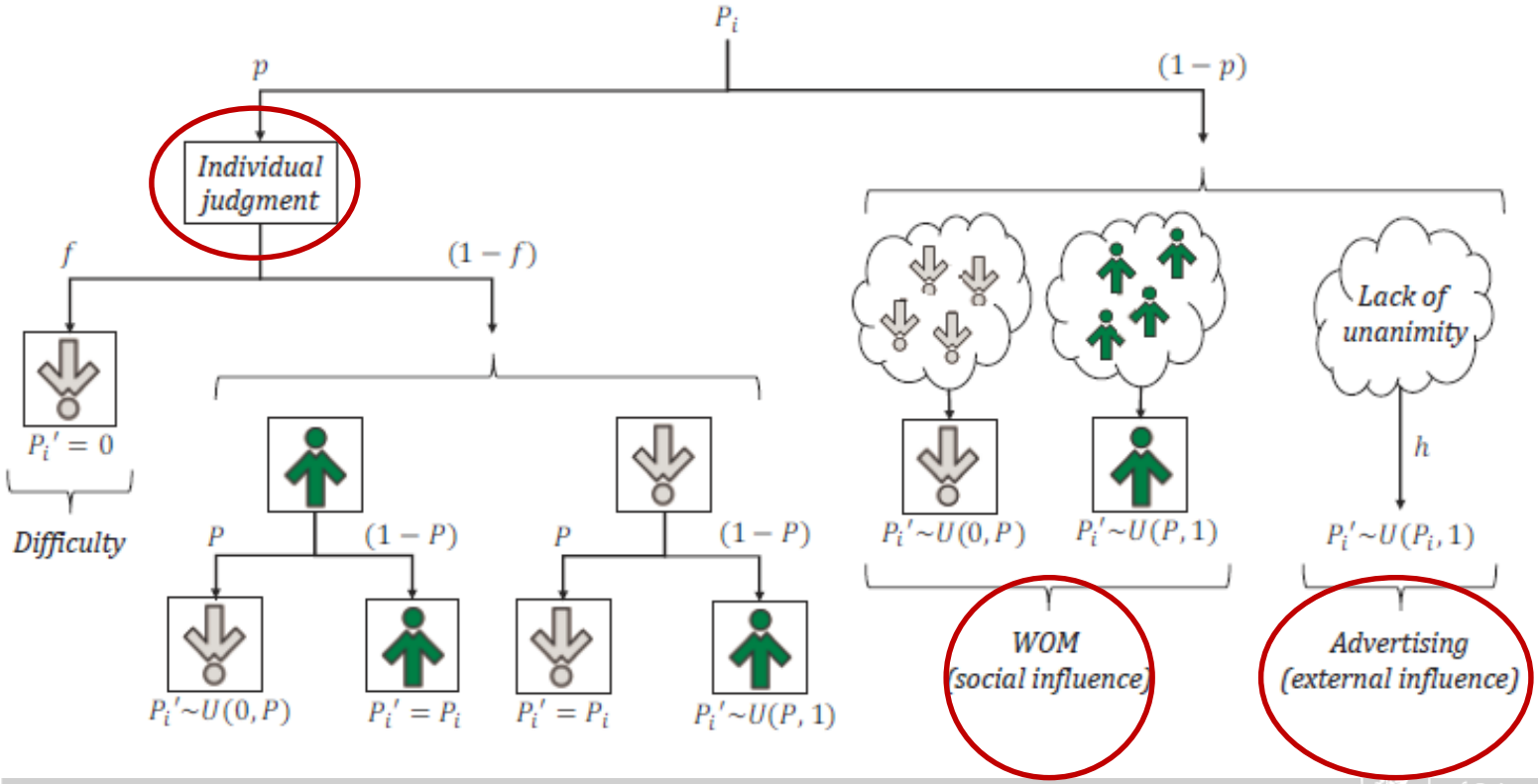
Results

- To encourage consumers to support the development of RES:
  - adoption threshold must be lowered
  - financial support (including stable legal regulations) or / and promotion of RES is necessary to create a critical mass of consumers, interested and engaged in supporting RES

Model of SM platforms' adoption

Agents represent households who potentially may start using SM platforms or other enabling technologies

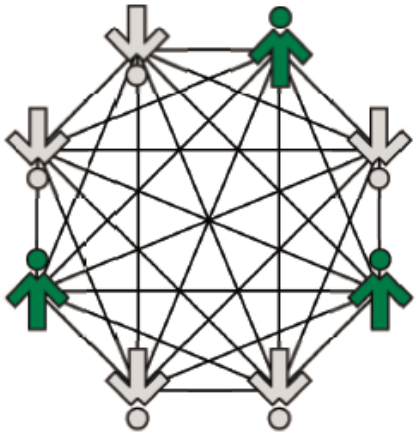
We observe the evolution of the reservation price (WTP) and the demand curve

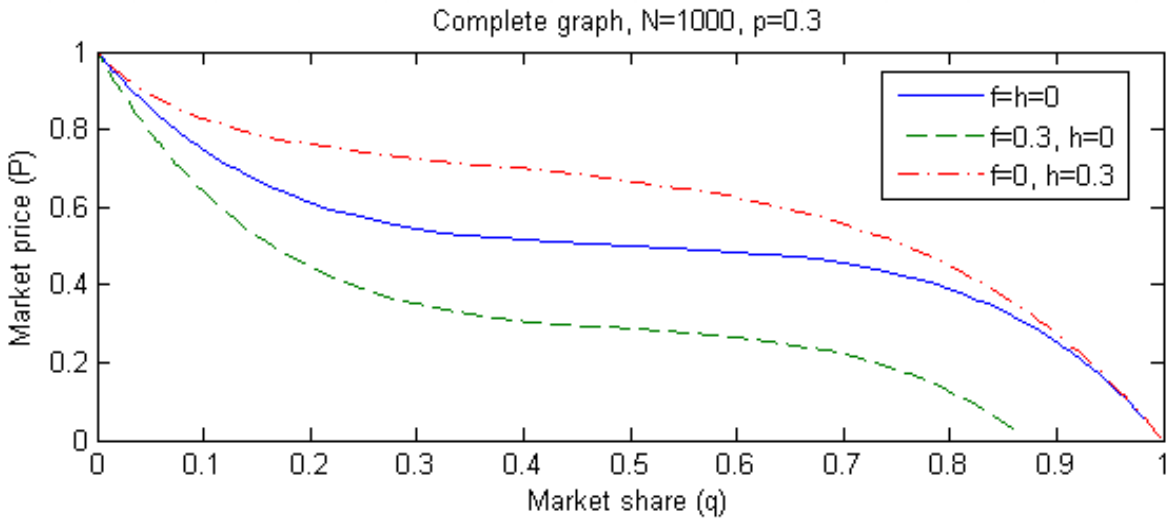


Results: impact of individual judgment and advertisment

The results are calculated analytically by the method called mean-field analysis for complete graphs

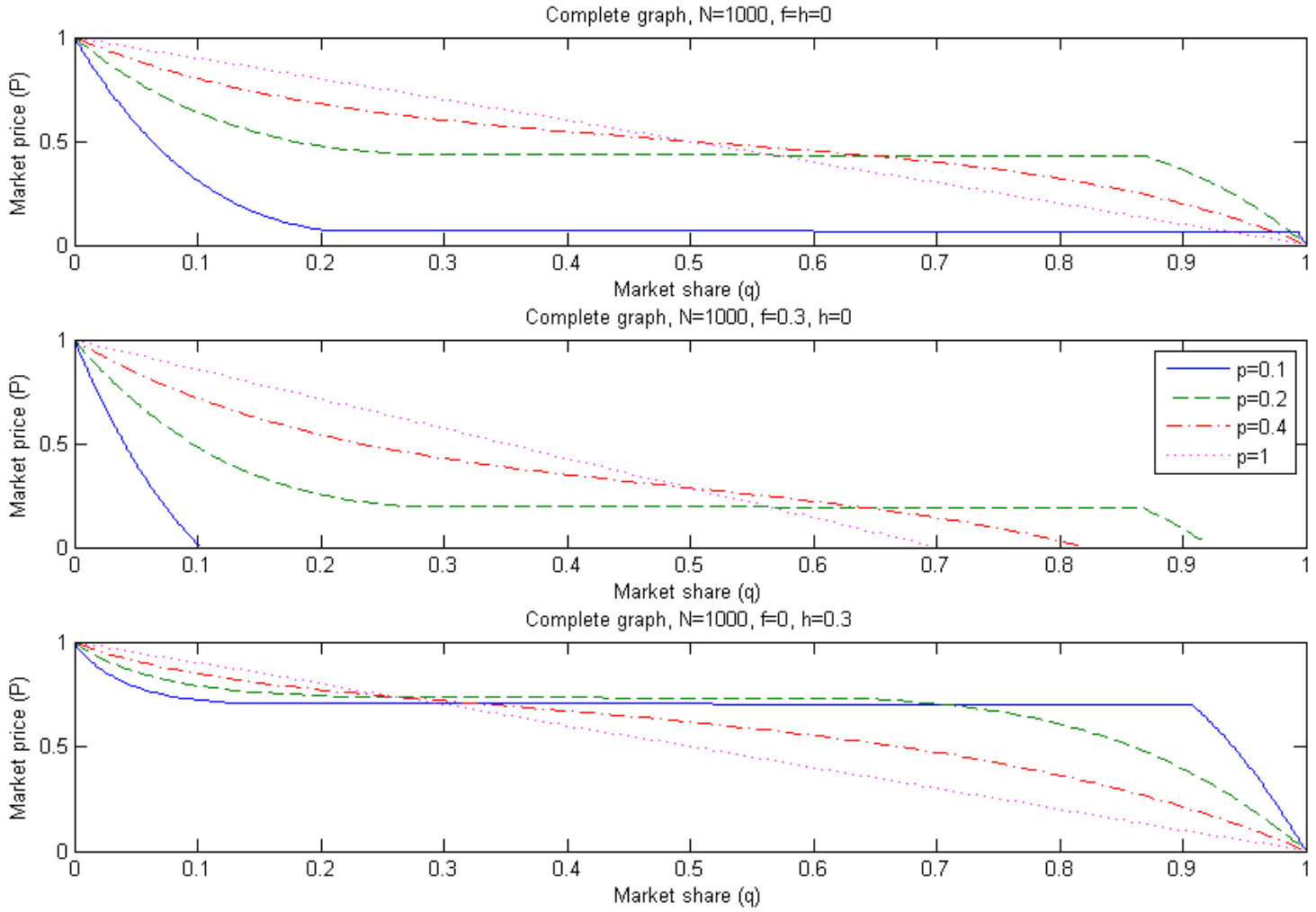
- WTP is influenced by: individual judgement (*f*) and advertisement (*h*).





- **A. Kowalska-Pyzalska (2016) An analysis of factors enhancing adoption of smart metering platforms: an agent-based modeling approach, DOI: 10.1109/EEM.2016.7521246**
- **A. Kowalska-Pyzalska, et al. (2016) *Linking consumer opinions with reservation prices in an agent-based model of innovation diffusion,* Acta Physica Polonica A, 10.12693/APhysPolA.129.1055**

Results: impact of social influence



Results

- WOM may change the impact of individual judgement and advertising.
- The effect depends strongly on the market prices of the SM technologies.
  - If the prices are high, WOM reduce positive impact of advertising and strengthens the impact of adoption difficulty.
  - For low market prices the effect of WOM acts in opposite directions by weakening the effect of adoption difficulty and strengthening the effect of advertising.

Results

- Suppliers of SM platforms and enabling technology should:
  - Be aware of impact of social influence and difficulty on the adoption
  - Propose appropriate marketing strategies to decrease the perceived difficulty and to raise awareness and interest.

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Final conclusions

A successful diffusion is conditioned by a significant change in consumers' attitude and behaviour towards IES.

Customers must be convinced that adopting to IES offer more benefits than costs also not only on societal but also on personal level.

Agent-based modelling can be a good tool for examining social influence, advertisement and education on the diffusion of IES.

Final conclusions

How to achieve a critical mass of customers necessary to boost the diffusion of IES?

INCREASE AWARENESS & UNDERSTANDING:
- design a proper feedback system
- display information in a an easy and clear way to reduce confusion

LIMIT DISTRUST AND FEAR OF CHANGE:
- reduce perceived difficulty of adoption by: emphasizing all potential benefits on societal and personal levels
- provide consumers with information about data protection arrangements

PROVOKE POSITIVE WORD-OF-MOUTH:
- convince satisfied customers to share this information with others
- advertise in traditional and social media
- create strong social norms

Thank you for your attention!

Questions?

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