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Adoption of new energy technologies: impacts and incentives

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創新綠色發展 建設美麗城市
Innovation and Green Development – Solutions to Build Beautiful Cities

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Impacts in green city development

how to predict and evaluate them?

Going greener in cities has impacts in life quality – but cities must be have planned infrastructures to be able to allow smooth transitions – otherwise, we will be faced with the costs of repressed demand.

One important infrastructure is the energy (electricity supply) system/network/grid.

No green transition without more electricity

Investment is needed in anticipation to attend growing demand and changing patterns of consumption and self/distributed generation.

How to predict? How to assess the impacts of technology transitions?

When cities go green, the skies go blue

Innovation generates change that generates innovation

a matter of culture

The transformations we are witnessing and hopefully discussing...

- distributed renewables
- smart grids
- electric vehicles
- battery storage
- hydrogen...

result from innovation.

To socially accommodate these transformations, it is necessary to understand the phenomena and to be able to predict them - to promote appropriate regulatory and political decisions.

For good understanding: innovation is necessary also in the models themselves that look at innovation.

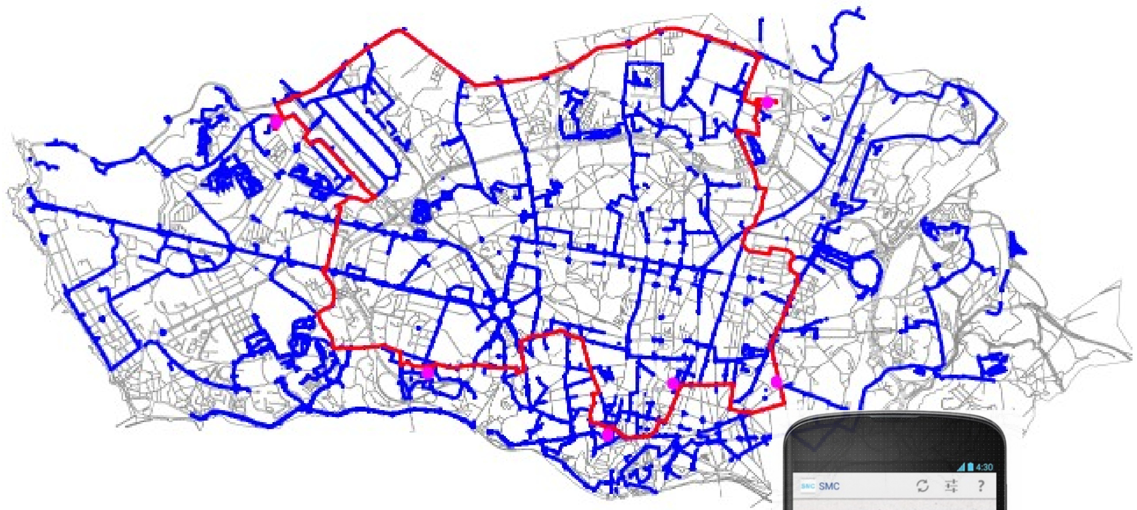
Culture of innovation

Establishing a culture of knowledge-based innovation calls upon more actors than the classic ones, including the media and cultural and political agents.

Cities fully infra-structured are a fertile field for innovation

Monitirong heart condition of drivers

Core fibre-optics city network of Porto



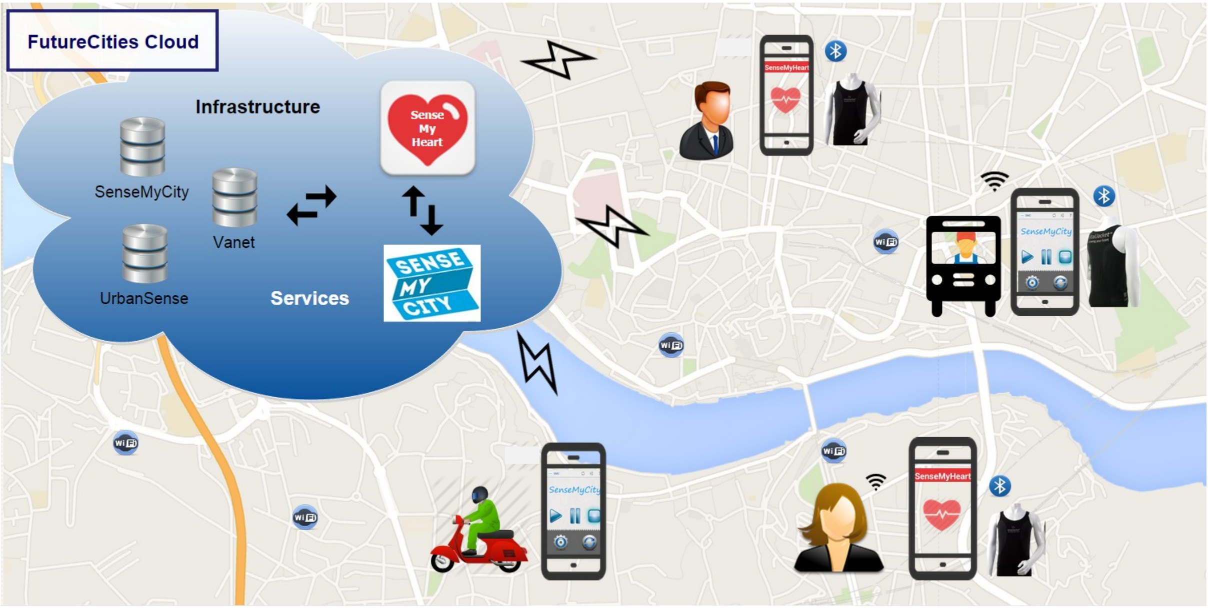
Communication and sensing nodes

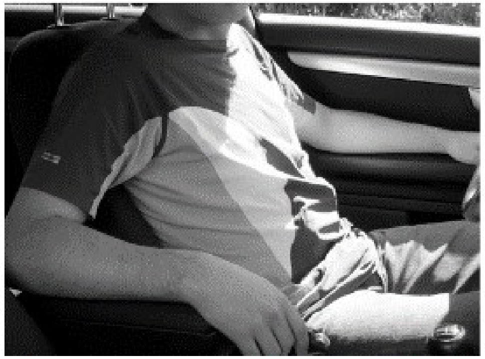
Apps allowing volunteer collection of data

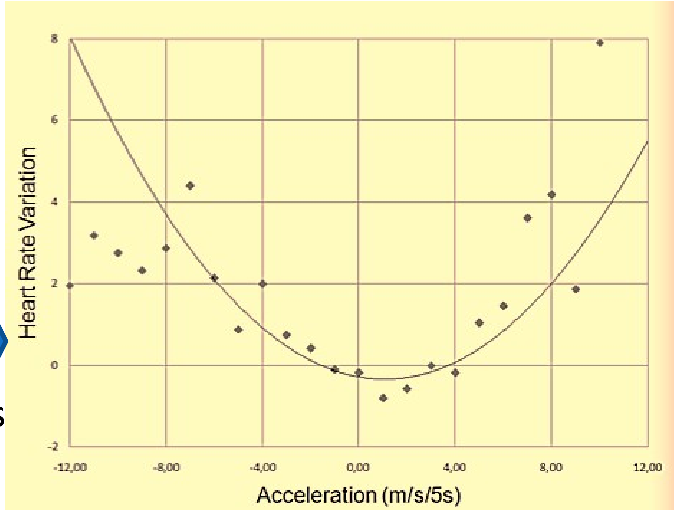
A pervasive technical infrastructure allows innovation to pop-up

Monitirong heart condition of drivers

Driver smart T-shirt collecting ECG and heart rate data







Heart rate changes with diferente accelerations

Driver stress maps allow many interventions

Bus driver stress data provide valuable indications on traffic organization

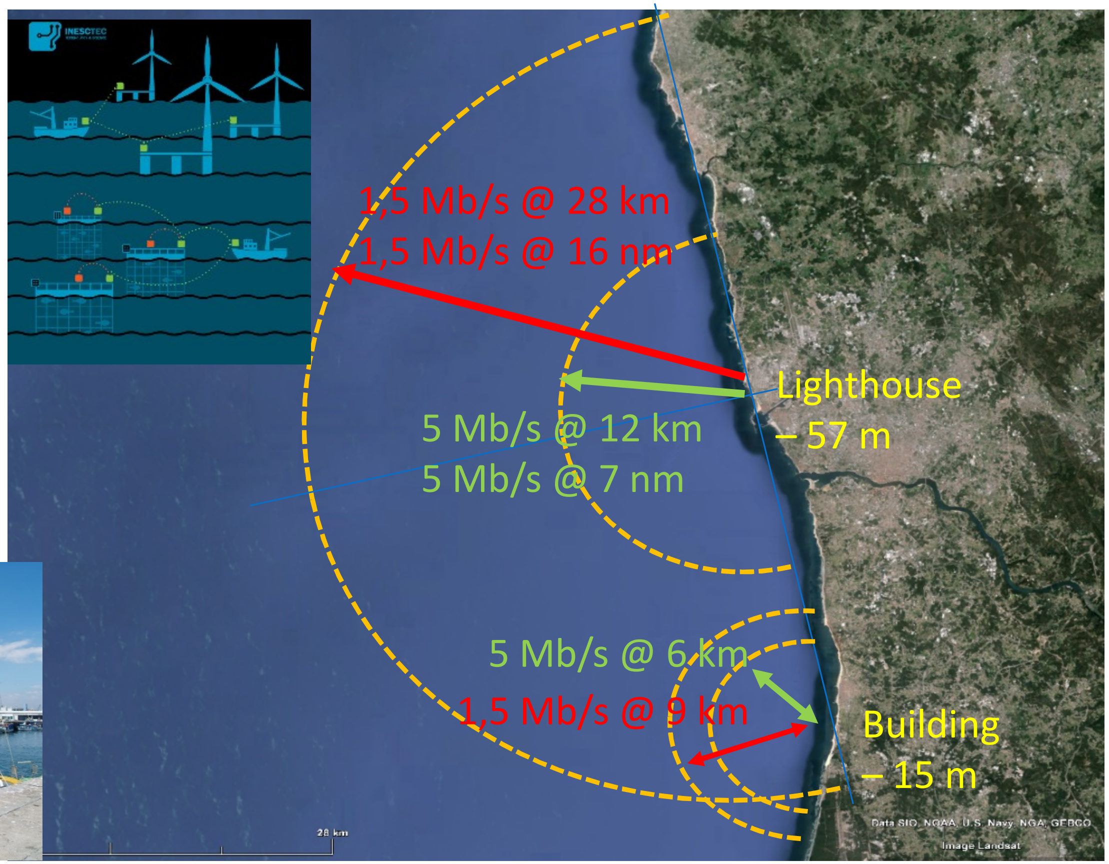
The city extended to the sea

Offering wi-fi connectivity to the fisheries communities and beyond

Broadband wifi access to vessels at sea.
Game changer: extremely limited costs, opposite to comercial sattelite alternatives for wifi.

- alternatives are narrow-band, expensive.
- land stations are connected to the city network

This induced new innovation to pop up, and new businesses – like virtual fish market, and navy uses.



Multi-sectorial antenna

Fishing ship wi-fi

Innovation incubates innovation

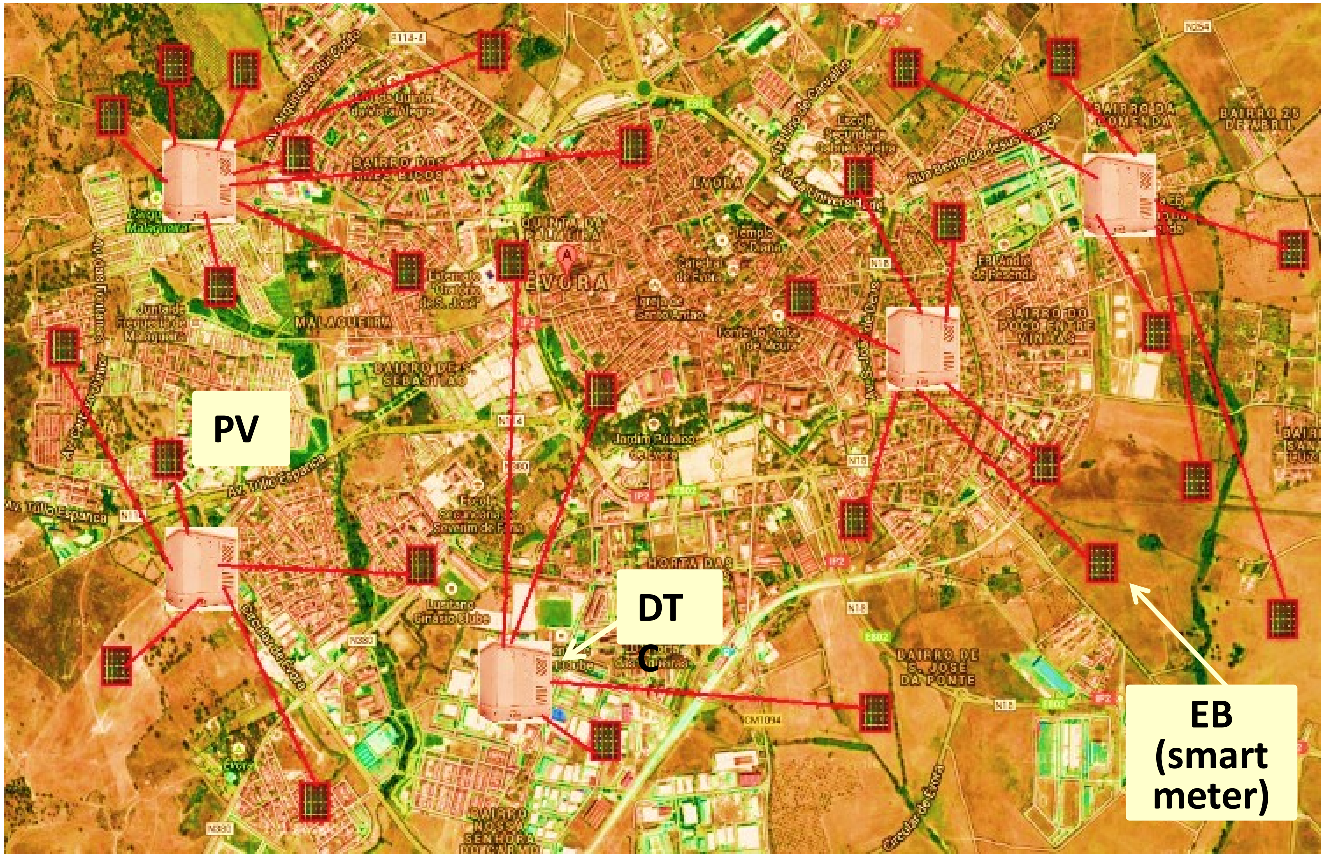
Can we take advantage of the territorial distribution of PV in cities?

New solutions allow the PV injection prediction with high accuracy

- no satellite images
- no telescopes

-> only AI models mining the data coming up every 15 minutes!

DEEP - Digital Eye Enhanced Prediction for distributed PV generation – a solution improving the security of city infrastructures, originated by the diffusion of another innovation: smart meters.



INESC P&D BRASIL

This presentation is about diffusion of technology adoption

phenomena are dynamic and spatiotemporal

Diffusion of Innovations is a model originally proposed by Everett Rogers.

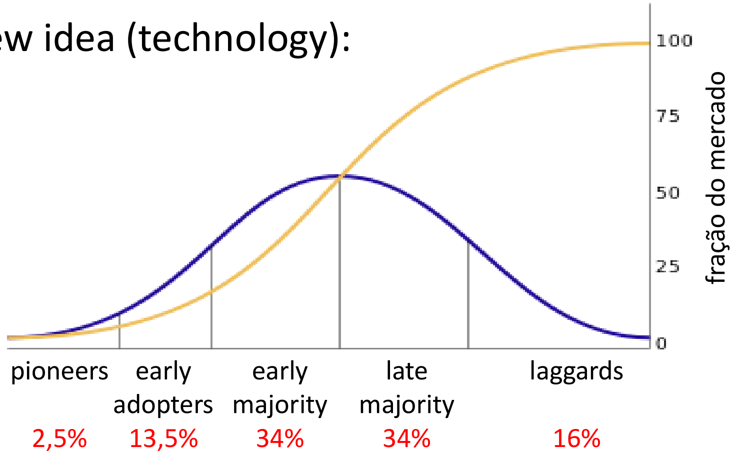
Four factors are said to influence the generalization of a new idea:

- innovation
- communication channels
- time
- the social system

Classically, five large social groups are defined among those who adopt a new idea (technology):

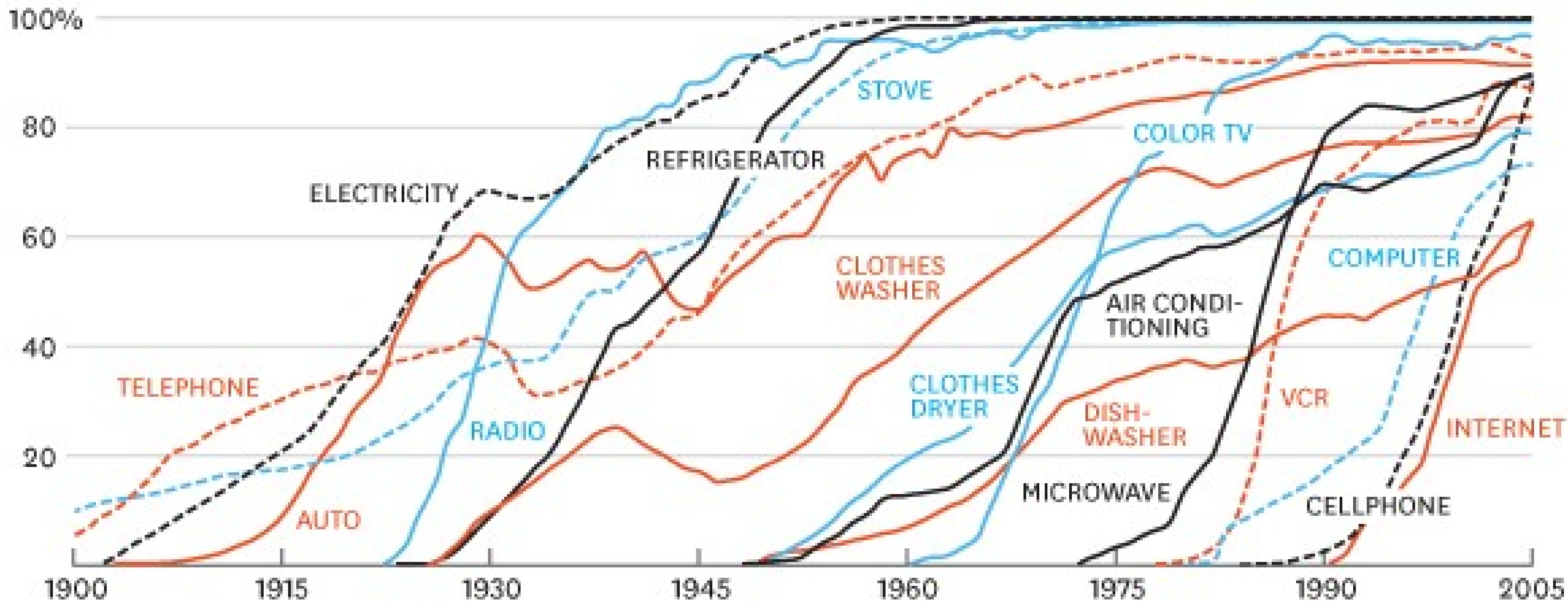
- innovators or pioneers
- early adopters
- the early majority
- the late majority
- laggards or resisters

Influencing the shape of this curve is a matter of policy.



Diffusion patterns for various technologies

different rhythms, same general law



Source: https://medium.com/@mcasey0827/speculative-bitcoin-adoption-price-theory-2eed48ecf7da

The prosumer paradigma, is it useful?

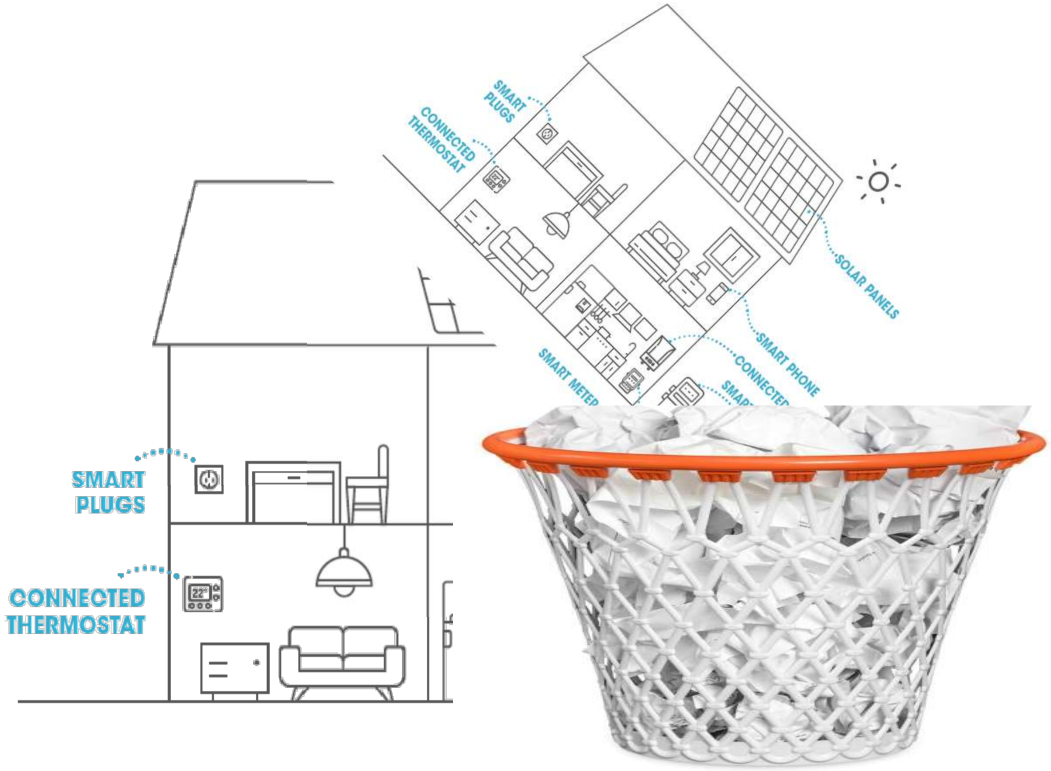
just theory…

The producer+consumer or *prosumer* paradigm assumes that all innovative technologies are simultaneously present in traditional consumption locations (e.g. households).

It is far from corresponding to a transformational reality.

It is not a paradigm that allows:

- Understanding and predicting the diffusion of distributed generation, electric vehicles, batteries, new technological processes of interaction with companies and regulators, etc.
- Identifying the risks associated with using coarse or primitive scale-out models
- Evaluating policy design and its impacts to explore the benefits of distributed resources



Source: IRENA (2019): Internet of things - innovation landscape brief

Understanding diffusion

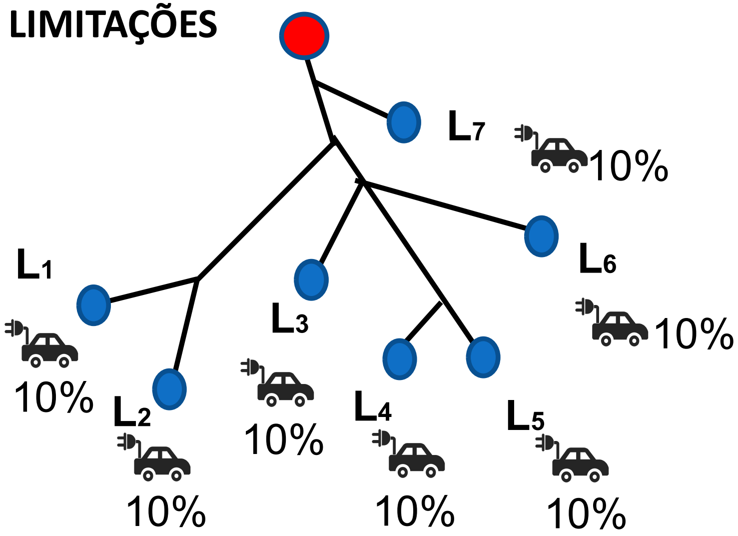
where are we today

Given future adoption scenarios for distributed renewables, where and when to expect their adoption?

Common modeling for the adoption of new processes/technologies, such as photovoltaics or electric vehicles, uses extrapolation methods: homogeneous growth rates associated with grid elements (e.g. MV/LV transformers)

leads to simplistic and crude assumptions about installed capacities or peak power values.

LIMITAÇÕES



Technological diffusion processes are separated from systemic impact studies.

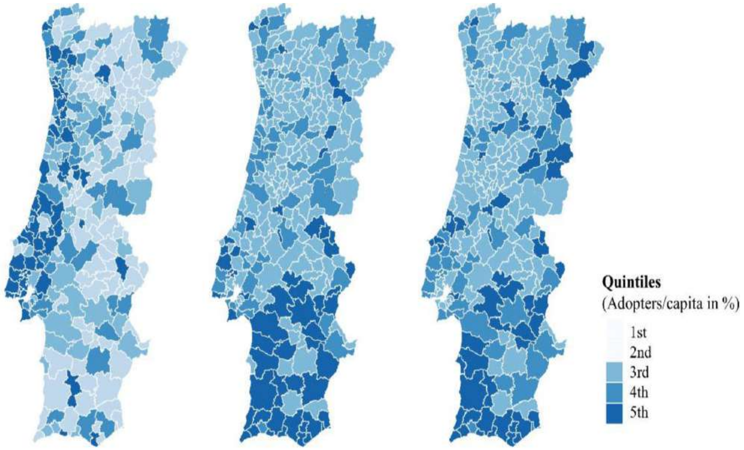
Dependencies between technical studies and social sciences with spatial expression are absent from consideration.

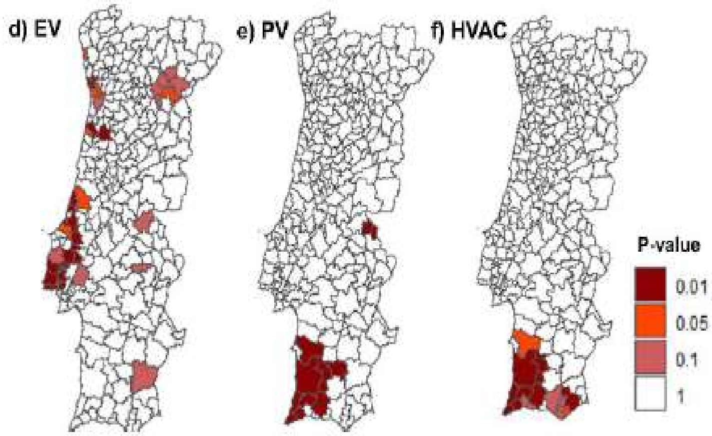
There is a globally poor representation of diffusion processes in the technical planning of electrical energy systems and in policy development.

Understanding Technology Adoption Patterns

study on Portugal using census data

Detailed analysis of households in Portugal – characterization of PV, EV and HVAC adopters and synergies in the combined use of distributed resources





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EPIA 2019: Progress in Artificial Intelligence pp 427-437 | Cite as

Explorative Spatial Data Mining for Energy Technology Adoption and Policy Design Analysis

SYNERGIES BETWEEN ELECTRIC VEHICLES AND DISTRIBUTED RENEWABLE GENERATION?

Fabian Heymann[1], Mário Lopes[2], Filipe Joel Soares[1], João M. Silva[1], Vladimiro Miranda[1], André Dias[2]*

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Understanding Technology Adoption Patterns

study on Portugal using census data

Characterization of the stability of the adoption of distributed resources at different levels of aggregation

- Inference about the drivers
- Ordering of the instability of the drivers at different levels of aggregation

Table 3 Top 15 rank similarity across technologies

	EV–PV	EV–HVAC	PV–HVAC
municipalities	0.40	0.53	0.27
boroughs	0.20	0.27	0.13
neighbourhoods	0.20	0.07	0.13

Table 4 Top 15 rank similarity across aggregation levels

	EV	PV	HVAC
Muni. to Bor.	0.60	0.33	0.27
Bor. to Neigh.	0.67	0.13	0.13

IET Renewable Power Generation

Research Article

Journals
The Institution of Engineering and Technology

ISSN 1752-1416
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www.ietdl.org

DER adopter analysis using spatial autocorrelation and information gain ratio under different census-data aggregation levels

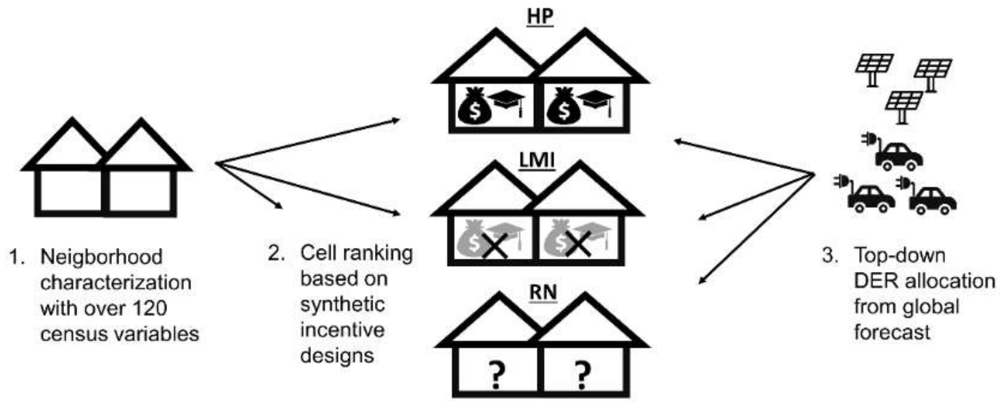
Fabian Heymann[1] ✉, Mário Lopes[2], Frederik vom Scheidt[3], João M. Silva[4], Pablo Duenas[5], Filipe J. Soares[6], Vladimiro Miranda[1]

The art of building diffusion forecasts

ETT – Energy Transition Technologies

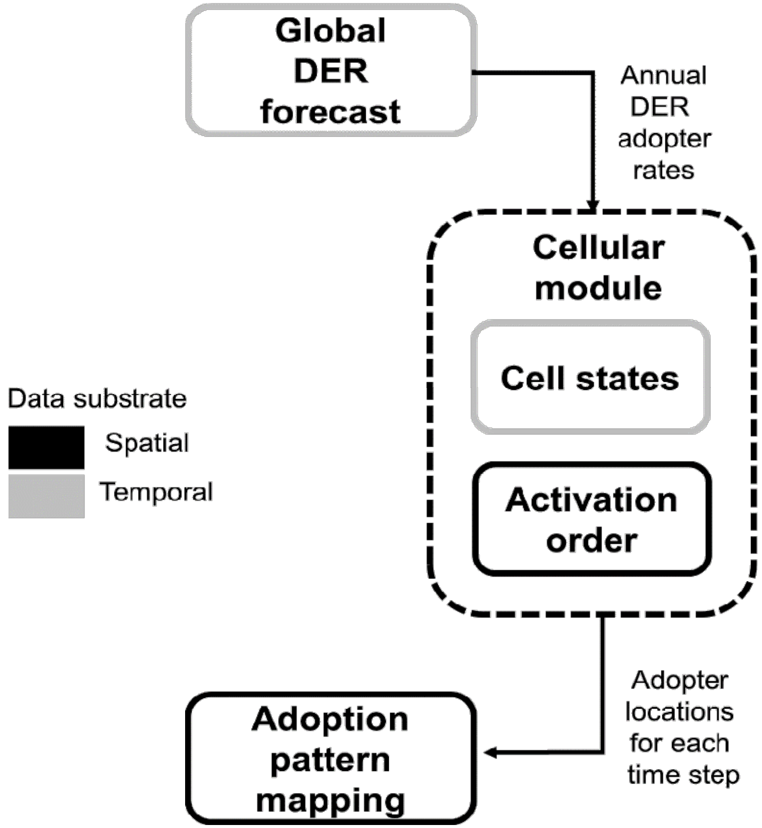
From a cell definition in the territory, it is possible to construct predictions by following a set of steps:

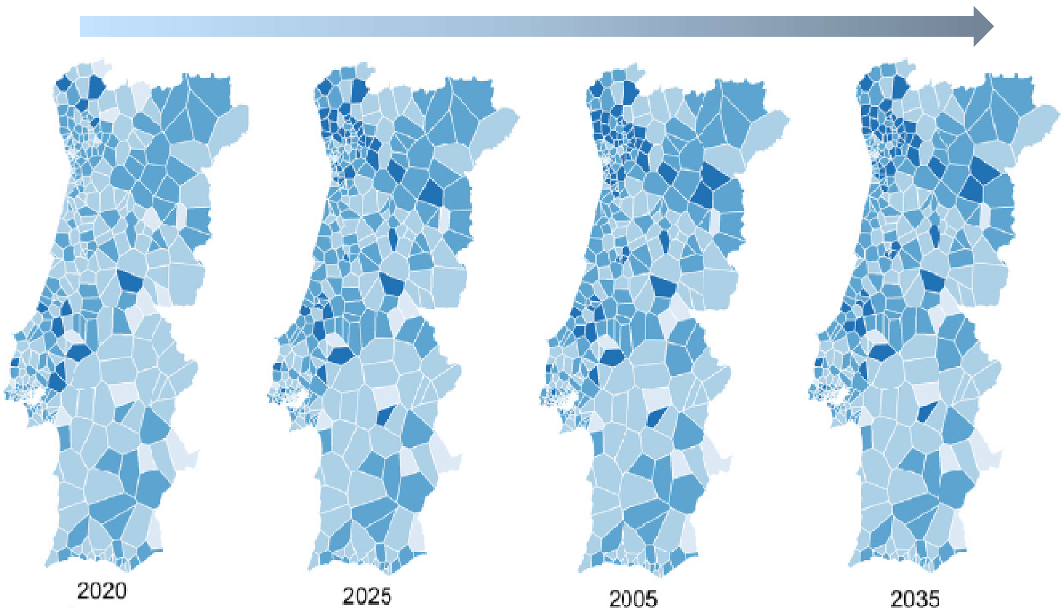
1. Progressive generation of scenarios with diffusion models
2. Cellular automata to emulate the progressive diffusion of Energy Transition Technologies (ETTs)
3. Association of the results of the propagation of ETT adoption to substation service areas
4. Observation of the evolution of factors and production of forecasts (time series in each aggregating cell) on loads/consumptions



Predictions on the adoption of distributed resources

how to build a model





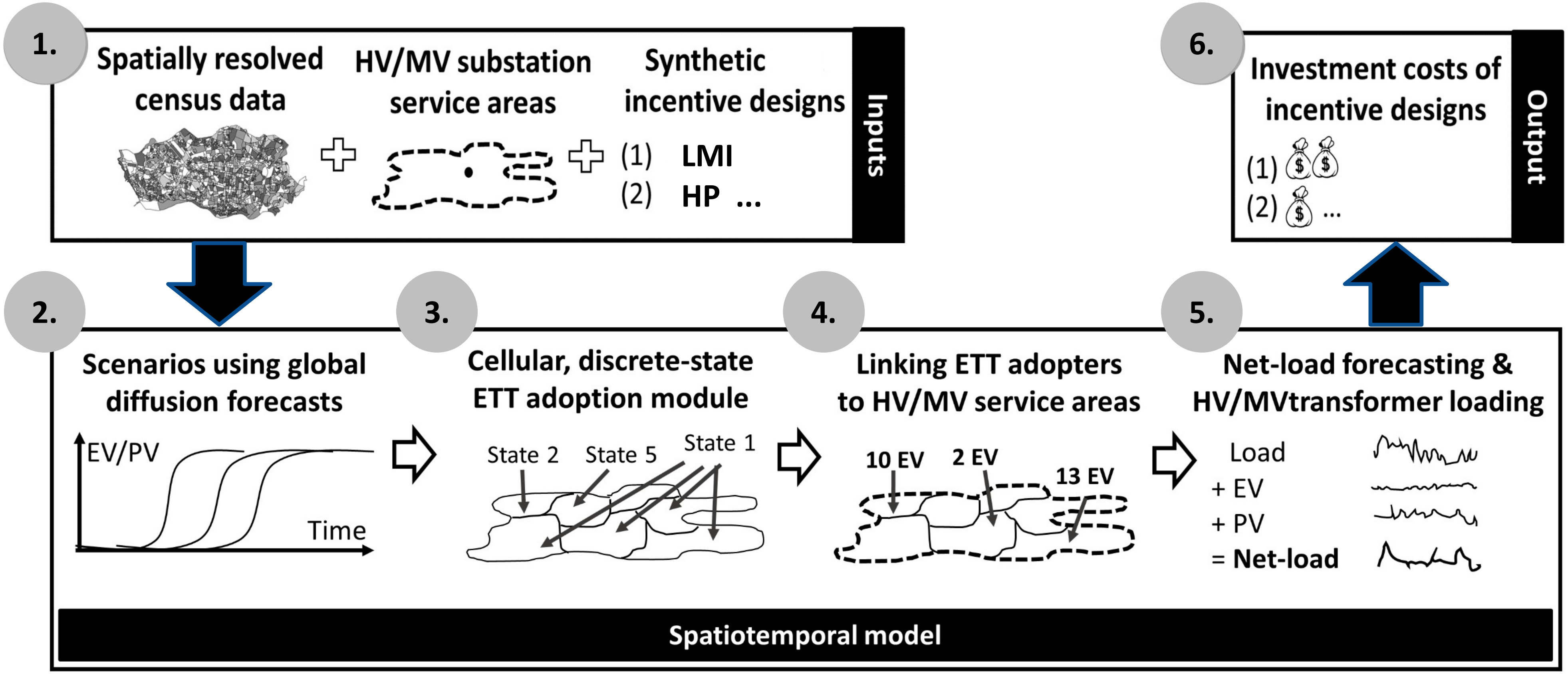
Page 1 of 8 IEEE PES Transactions on Sustainable Energy

Forecasting Energy Technology Diffusion in Space and Time: Model design, Parameter choice and Calibration

F. Heymann; F. vom Scheidt; F. J. Soares; P. Duenas; V. Miranda

The art of building diffusion forecasts

the model and process



Verifying the effects of technological diffusion

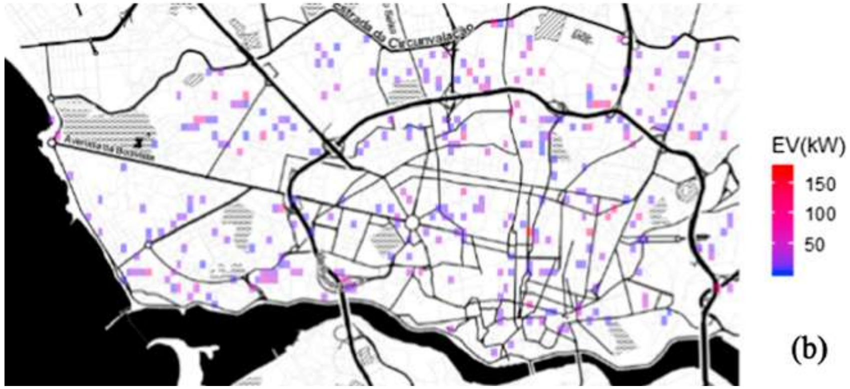
in our beautiful cities

The choice of a specific distributed resource allocation model (e.g. EVs) has strong implications for demand estimation and the consequent production of planning decisions on city infrastructures.

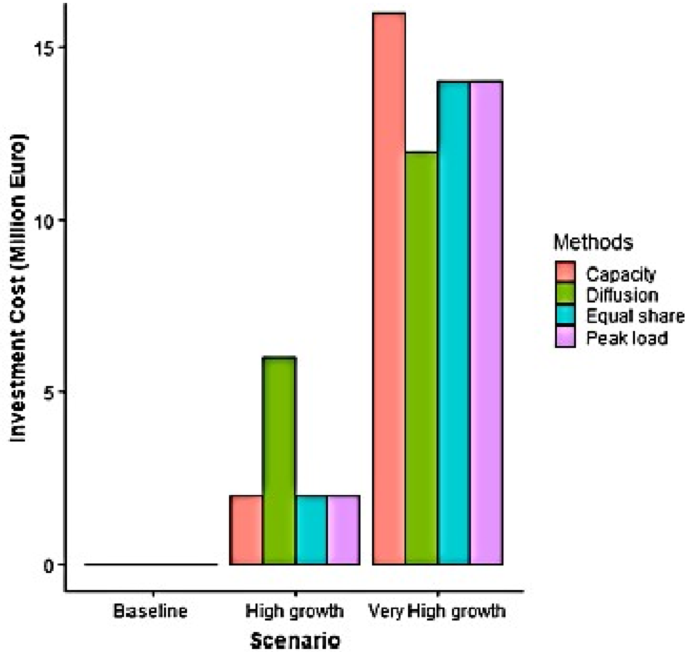
ELSEVIER
Contents lists available at ScienceDirect
Electrical Power and Energy Systems
journal homepage: www.elsevier.com/locate/ijepes

Distribution network planning considering technology diffusion dynamics and spatial net-load behavior

Fabian Heymann[a], João Silva[a], Vladimiro Miranda[a], Joel Melo[b], Filipe Joel Soares[c], Antonio Padilha-Feltrin[d]



Study for the city of Porto, Portugal



Impacts of policies

study for the city of Porto until 2030

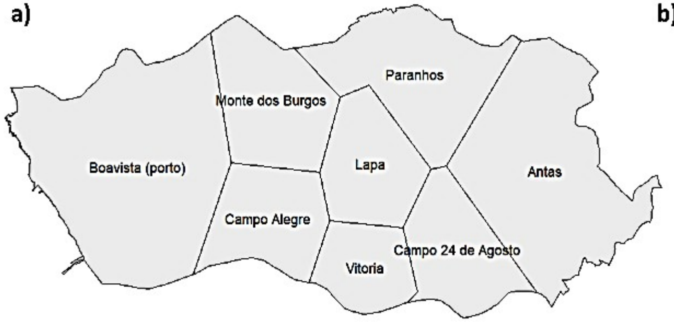
HV/MV transformer service areas and adoption of incentives for photovoltaic and electric vehicles. Three scenarios: Baseline (current extrapolated rate), Growth (supported by incentives) and Explosion (above expectations)

Blue:
incentives aimed at the upper-middle class

Red:
incentives aimed at the lower-middle class

The variations identified with technological diffusion models impact investment decisions in the city infrastructure of electricity supply network – which must be planned and be ready in advance!

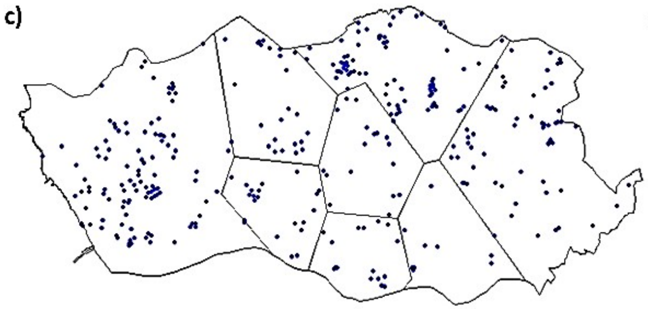
a)



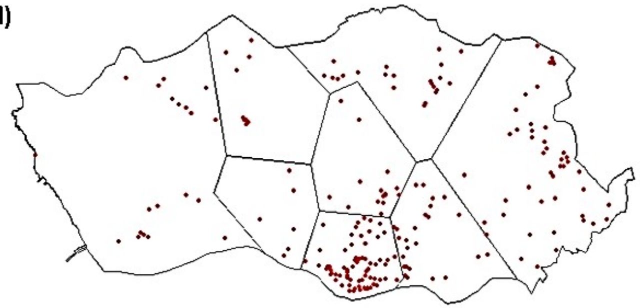
b)

Substation	Inst. Capacity (MW)	Peak-load (2015)	Peak-load 2030 (Baseline)	Peak-load 2030 (High growth)
Antas	85	40	40	50
Boavista (porto)	84	44	44	55
Campo 24 de Agosto	56	30	30	38
Campo Alegre	84	39	45	52
Lapa	59	22	22	28
Monte dos Burgos	56	39	39	49
Paranhos	56	31	31	39
Vitoria	59	25	29	34

c)

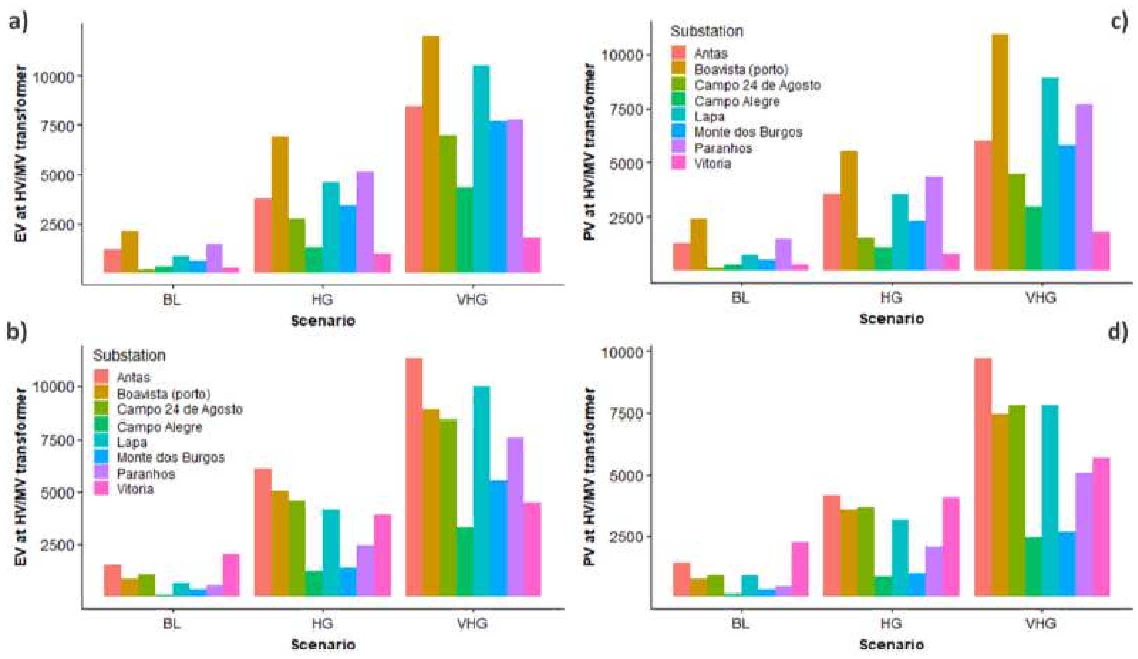


d)



Impacts of policies

case study of Porto: investment at risk



Estimated residential EV adopters (no. households) and PV (kW) connected to each HV/MV transformer for HP-favouring incentive schemes (a, c) and for EV/PV incentive schemes favouring LMI groups (b, d)

Investment at risk (million Euros)		Baseline	High Growth	Very High Growth
EV	Slow	0.0	0.0	2.5
	Fast	0.0	5.0	0.0
PV	Normal	0.0	0.0	0.0
	Upper	0.0	0.0	7.5

High investment risks for 2030 in case of changing policy designs, due to missing upgraded equipment in HV/MV service areas with high diffusion and transformer expansions in areas of low needs.

Investment-at-risk between 5.0 and 7.5 million Euros in high adoption scenarios (high and very high growth) for Porto.

Policy design

How to turn potential adopters into prosumers?

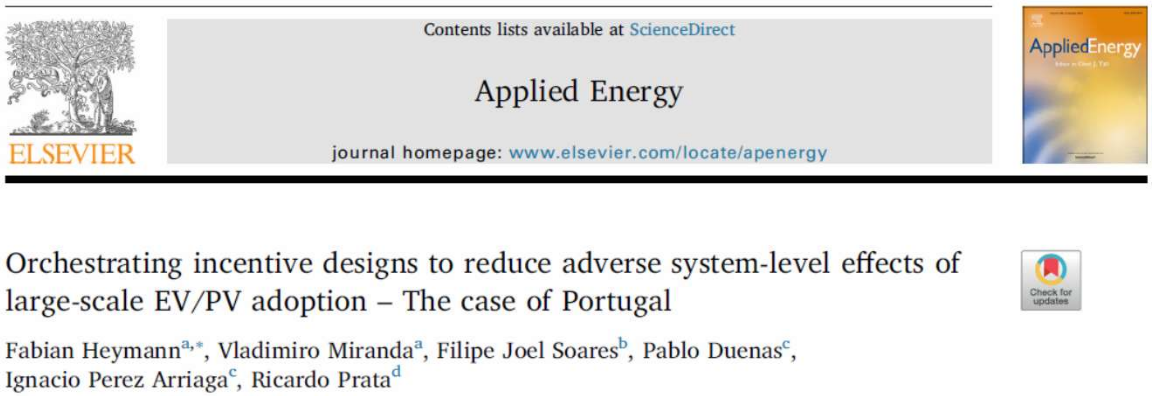
General disaggregation models for nationwide diffusion scenarios...

- spatial resolution: < 0,1 km^2
- time resolution: < 1 month

... allowing later aggregation to the appropriate levels

For policy design, it is assumed that the decision maker intends to

- minimize system costs — evaluated by difference to a baseline scenario withot adoptions
- minimize social asymmetries — assessed by an indicator of economic inequality (Theil T-Index)


Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Orchestrating incentive designs to reduce adverse system-level effects of large-scale EV/PV adoption – The case of Portugal

Fabian Heymann[a,*], Vladimiro Miranda[a], Filipe Joel Soares[b], Pablo Duenas[c], Ignacio Perez Arriaga[c], Ricardo Prata[d]

Study on the Portuguese case

Some preliminary information

Data from the last census in Portugal (INE 2011): 17,000 spatial cells, each associated with 120 socio-demographic criteria (e.g. family status, level of education, age of subjects, % of employment, type of residence, etc.)

Association, within a GIS (geographic information system), of data with energy service areas.

Cases studied:

- Diffusion of electric vehicles (EV)
  - 30% fast charging and 60% slow charging assumed, typical 24 kWh batteries
- Diffusion of residential photovoltaic (PV)
  - Panels of 200 W and 1,5 m^2 assumed, usable coverage area of 30%, usual performances and per capita coverage area of 13 m^2

Two fundamental estimates derived:

- Global technology adoption forecast for each year
- Total technology adoption potential for each cell (linked to the census grid).

Study on the Portuguese case

Comparison of incentive policies

LMI (Low or Medium Income) – Incentives targeting low- and middle-income population groups
HP (High Performance) – Incentives targeting persons with high access to educational or financial resources
RN (Randomized) – Incentives without specific target, causing random adoption (for benchmarking)

These schemes translate into different weights regulating the diffusion processes

Incentive combination schemes (IDC)

IDC	EV	PV
1	HP	HP
2	LMI	HP
3	RN	HP
4	HP	LMI
5	LMI	LMI
6	RN	LMI
7	HP	RN
8	LMI	RN
9	RN	RN

The impacts of different combinations of incentives for electric mobility (EV) and distributed photovoltaic (PV) were studied.

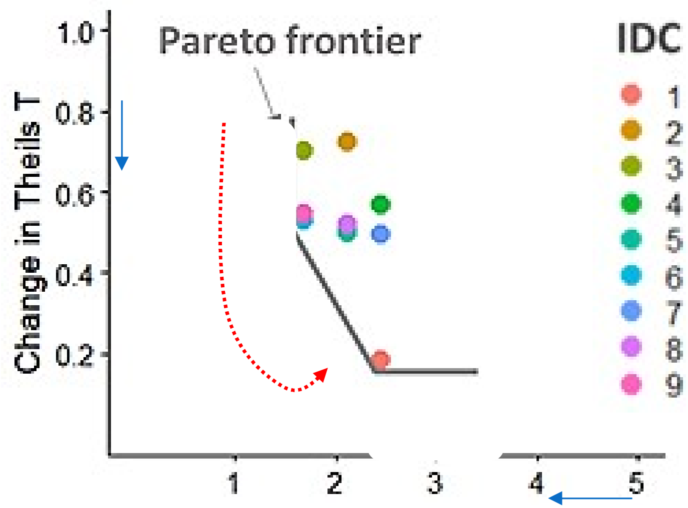
Typical residential load profiles projected in MV and real EV charging and PV generation profiles, in hourly steps, were used.

The base scenario was the 2015 situation and the typical curves adopted were those recommended by the electricity regulator.

Exemple of results

a limited sample

Condensing the simulations, for the various combinations of incentive policies, into an attribute plan of [surplus cost x variation of social asymmetries], compared to a base case without adoption of transition technologies, the Incentive Schemes that are dominant are identified.



Overcost tp base scenario [in 2030]

In the case of Portugal analyzed, sensitivity studies and data permutations were carried out (to ensure the robustness of the conclusions), and the dominant Scheme that consistently emerges is the IDC 1

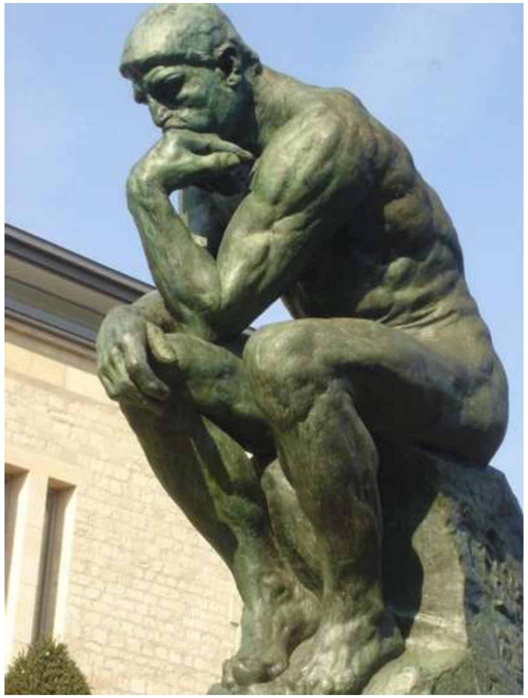
- i.e., contradicting certain sensitivities, it corresponds to directing incentives to the social classes most endowed with resources

IDC 2 and IDC 4 schemes are those that systematically lead to situations of greater overcost and larger social asymmetries

- These are the hybrid schemes of HP and LMI

Impacts in city development from technology diffusion

a possible summary of the main lines of reasoning



New technology adoptions are not distributed homogeneously in space, just as social groups are not distributed homogeneously in social systems.

there are always "early adopters", a mix of crazy people and people with more resources who can take advantage of purchase/usage incentives

These adoption phenomena translate into spatial clustering, which has an effect on investment plans in electrical networks and systems (and other city infrastructures).

The nature of subsidies has a major impact on spatiotemporal dispersion.

For example, reverse subsidies, addressing low-medium income families instead of high-income families – e.g. new approaches in the US, California – may result in completely different geographic dispersions

New approaches, based on diffusion models, cellular automata, artificial intelligence, can help regulators/political agents to predict future effects/impacts on the electricity system – in planning, structuring, operation

They allow us to assess the structural impacts of different incentive schemes, and to what extent different policy objectives are achieved – **and how cities are impacted by such policies**.