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The role of technology and communication in enabling behavioural change for cities of the future

Prof. Siobhán Clarke

School of Computer Science and Statistics

Today’s cities – problem!

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Cost of Congestion

In 2007, congestion induced economic losses in Dublin were valued at 4% of GDP

Ageing Population

In 2000, 6.9% of world’s population 65+
By 2050, 15.6% of world’s population 65+

Population Growth

180,000 people move to cities every day
By 2050, ~75% of population will live in cities

Ecological Footprint

- World uses 50% more resources than can be sustainably produced
- High-income countries average five times that of low-income ones

Municipal Waste

The average EU citizen generated 468 kg of municipal solid waste in 1995, which could rise to 558 kg per person by 2020.

Urban Sprawl

Countries with lowest population density have highest traffic CO_2 emissions
Urban sprawl has negative impact on cost of public services

Air Pollution Deaths

- Overall, world premature deaths will increase from ~150 to ~390 per ml from 2000 to 2030
- Europe/US project slight decreases – China at extreme end of increases (250-880)

We have to change the way we use city resources

Hoping, Asking not working

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THE IRISH TIMES 16th /17th November, 2013

State's €10m save energy advertising campaign failed to have any impact

CONOR POPE
Consumer Affairs Correspondent

The ads encouraged us to save money and energy by turning our heating down and wearing an extra warm woolly jumper.

But despite costing us €10.75 million over two years starting in 2006, the State-sponsored Power of One campaign appears to have had absolutely no effect on our behaviour, a new ESRI report has revealed.

The campaign was launched in a blaze of publicity by then minister for communications, marine and natural resources Noel Dempsey in 2006.

He assured the nation it wasn't just window dressing aimed at appeasing energy watchdogs in the European Commission and he expressed the hope that it would achieve a "sea change" in the behaviour of Irish consumers in relation to their use of energy. It didn't.

Swamped with ads

For the duration of the campaign, the airwaves were swamped with ads reminding us of all the financial and environmental benefits if we just switched off lights, turned televisions off at the source and did not leave mobile phone chargers plugged in.

However, the ESRI has now found that while the campaign "increased consumers' awareness of the potential savings" it did not "translate into persistent changes in behaviour".

The ESRI says in the first year of the campaign, fliers included with customers' gas bills made people more aware of possible savings, "no further effects were identified for the second year of the campaign".

World Business Sports

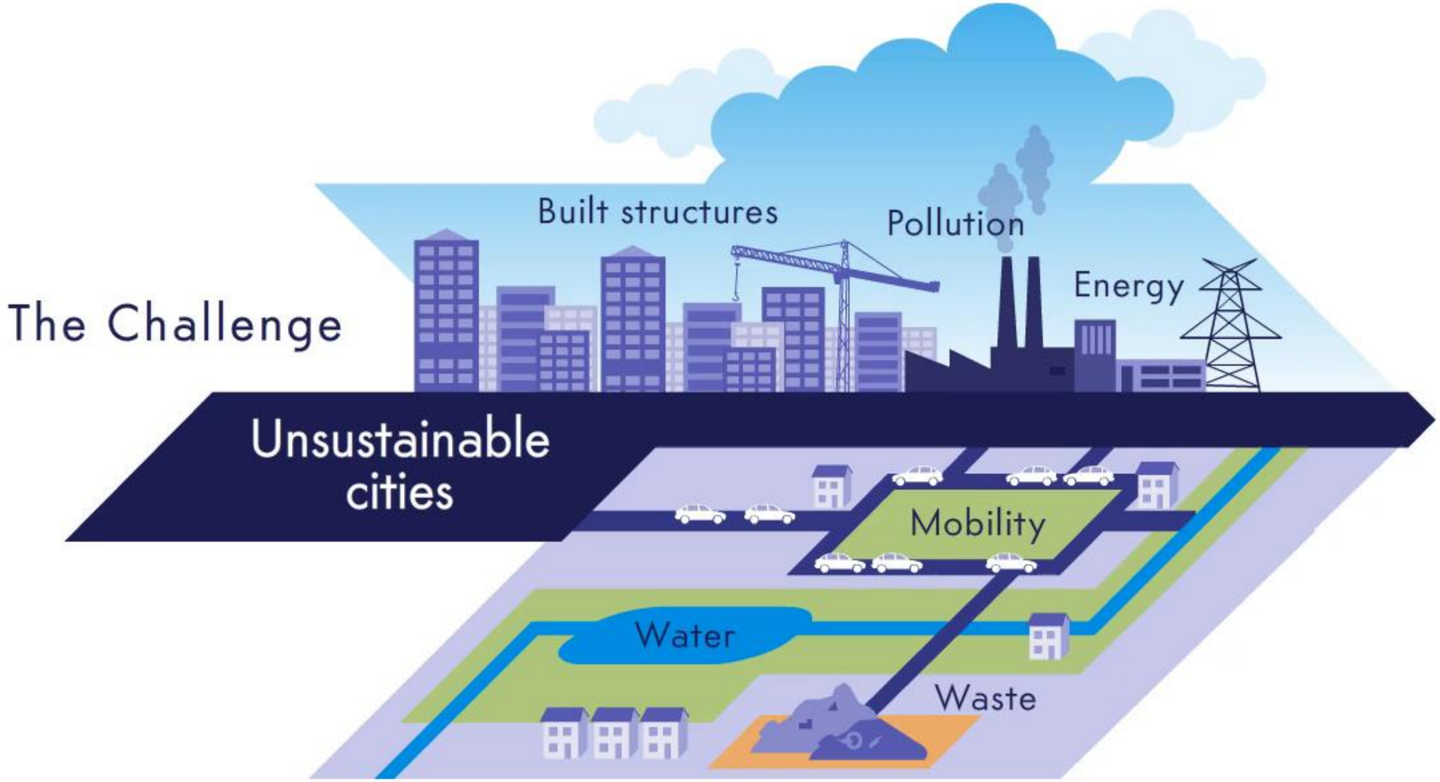
So, what should we do?

Autonomous behavioural change?

All devices automated

Citizens only

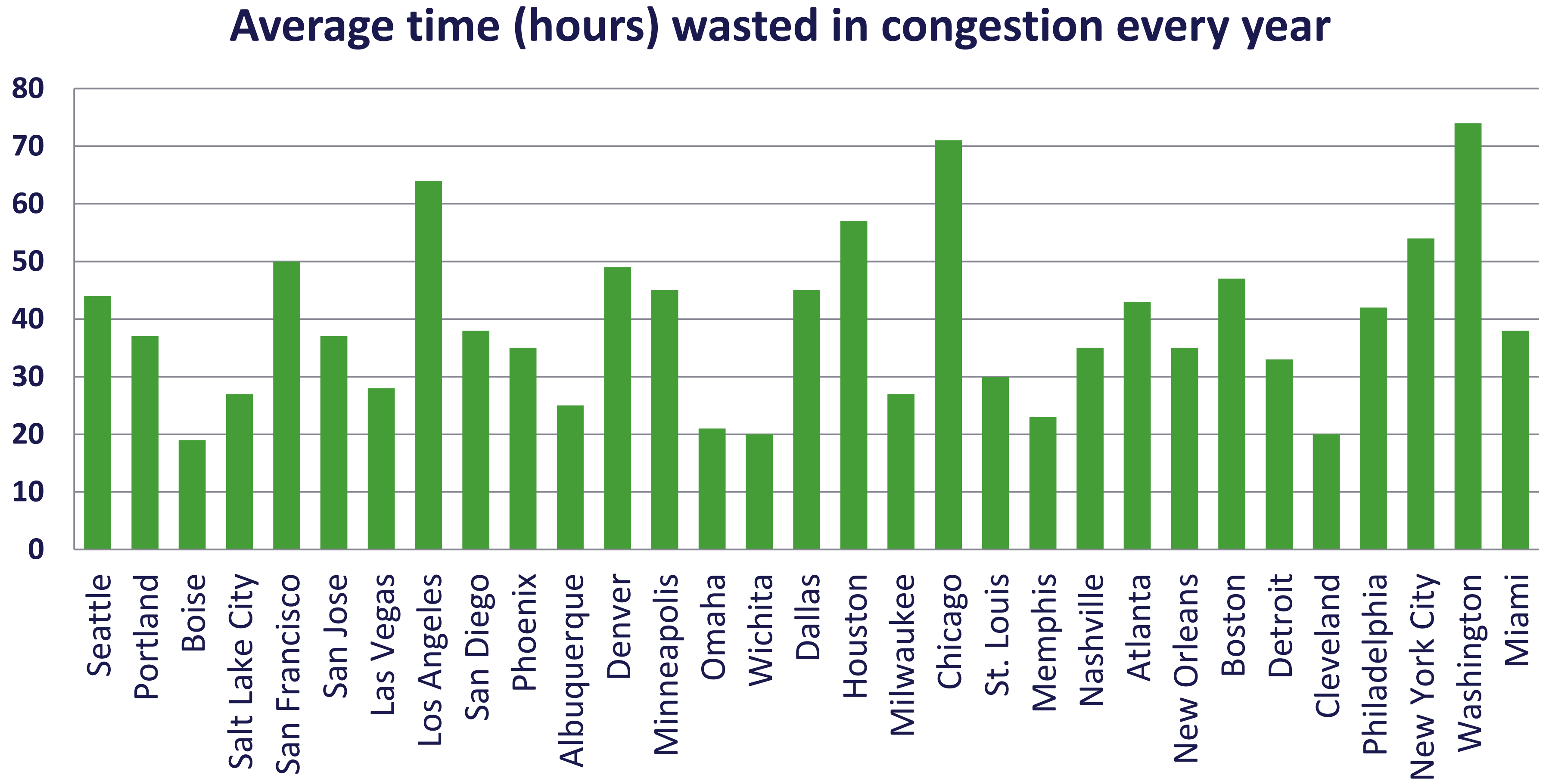
Mobility example



“Modern” Society

Source: Pandagon

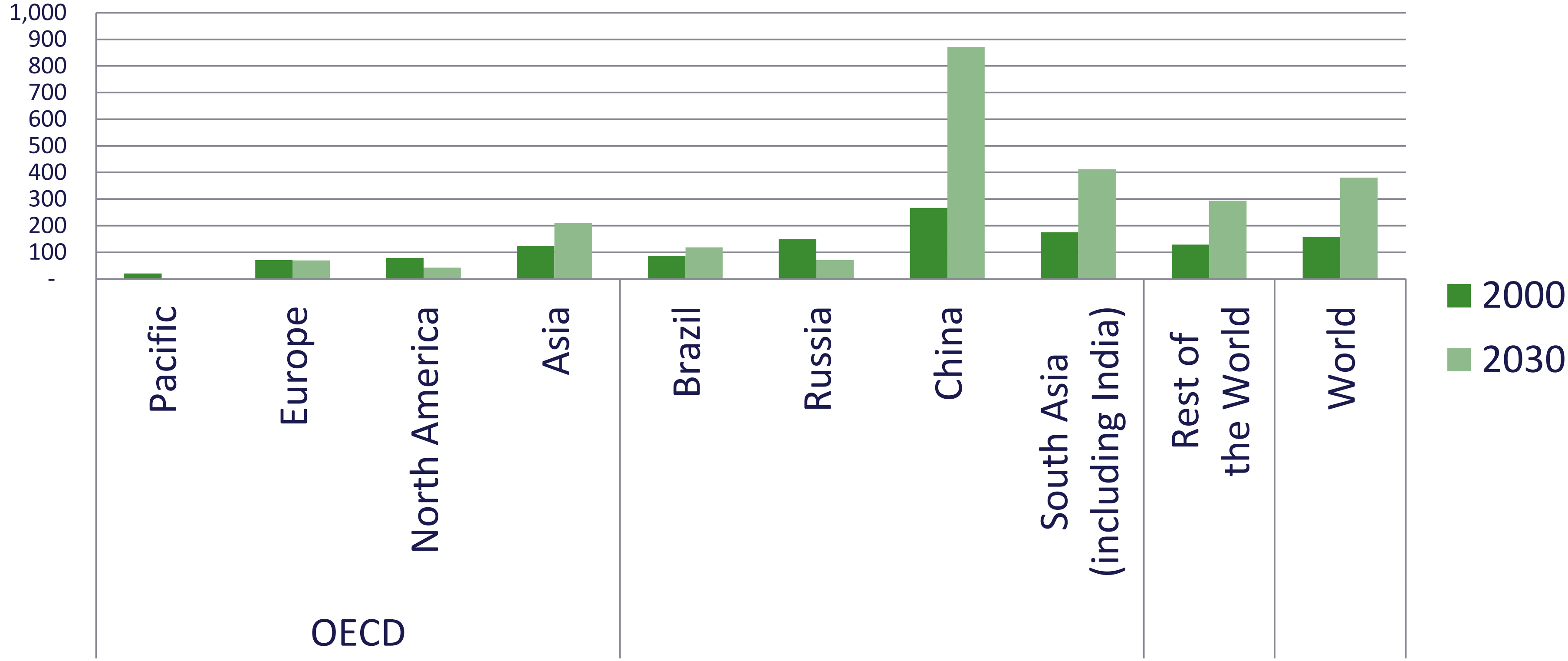
Economic Cost



Source: Texas Transportation Institute, Urban Mobility Report 2009

Environmental Cost

Premature deaths from PM10 air pollution for 2000 and 2030 (cases per million inhabitants)



Source: OECD, The OECD Environmental Outlook to 2030, *2008*

Human Cost

- Road Traffic Injuries
  - 90% of accidents are caused by human factors [1]
- Total traffic deaths
  - 1.2 - 1.3 million per year [2]

[1] Bob Joop Goos , Chairman of the International Organisation for Road Accident Prevention, 2011
[2] Peden et al., WHO, *2002*

Smart Vehicles

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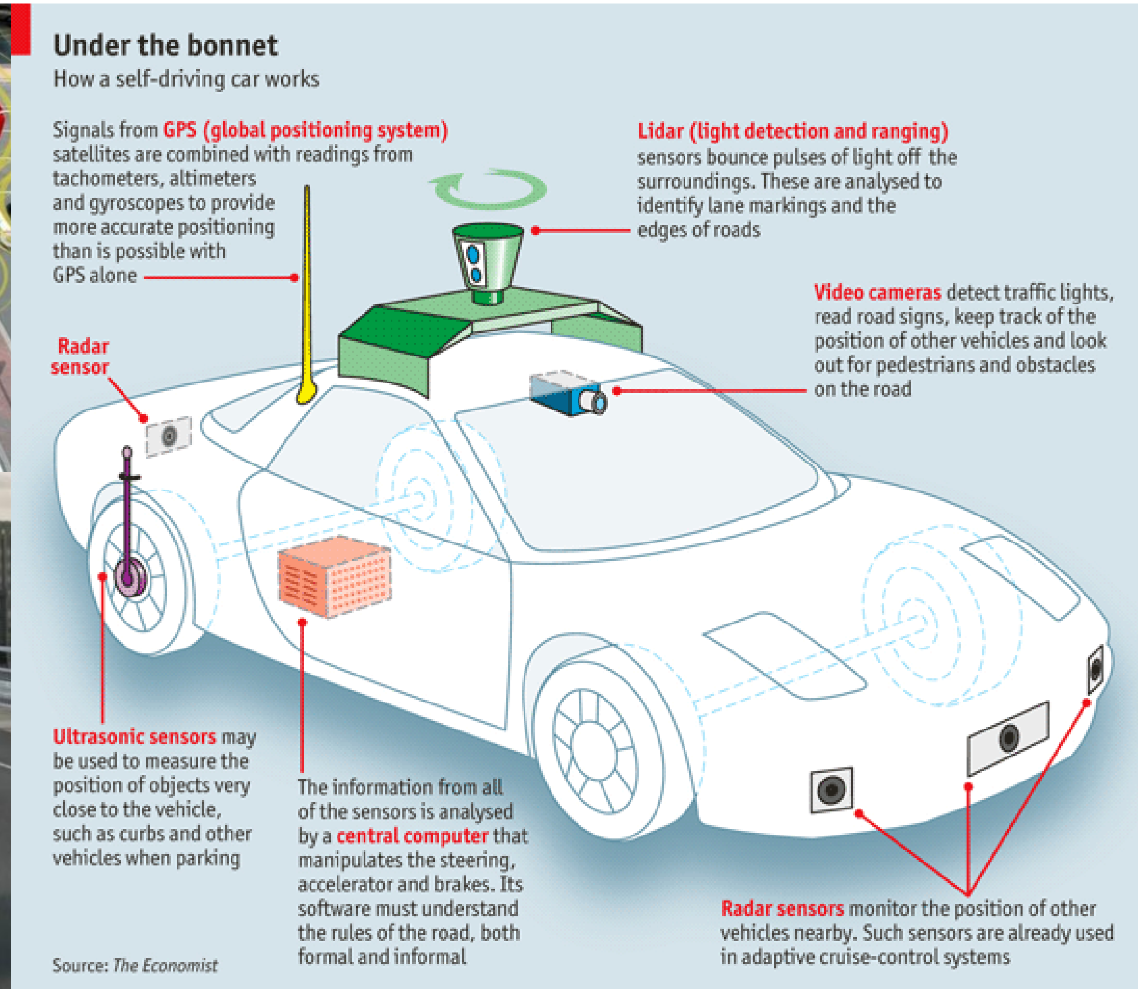

What if?

Source: Zurich insurance, used with permission

Cooperating Vehicles

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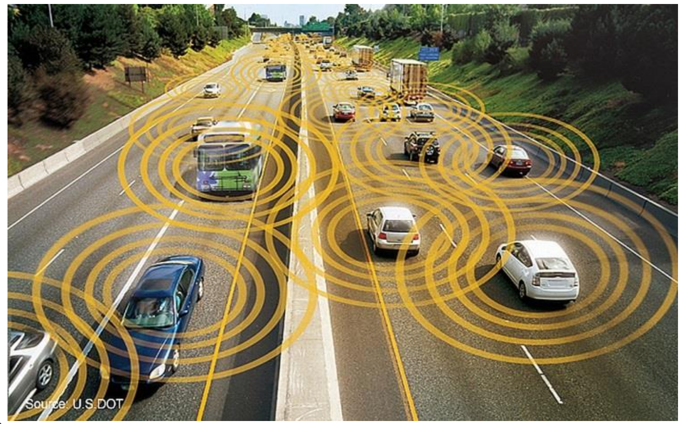


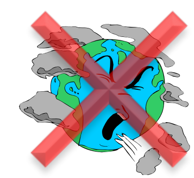
Less congestion

Saving time

Fewer crashes

Increased safety

Reduced pollution



Green transport

Why coordination?

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- A solitary smart vehicle can only estimate the actions of other vehicles from noisy sensor data
- Coordination between smart vehicles can
  - Improve traffic safety through determinism
  - Improve traffic efficiency through planning and advance knowledge

However, **coordination is hard**

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Why is coordination hard?

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Smart vehicles operate in a challenging environment

- Noisy sensors and actuators
- Real-time constraints
- Unreliable communication
- Dynamic participants
- Interaction with human drivers
- Ever-changing surroundings
- Developing distributed algorithms is difficult and error-prone

Most important of all: **Driving is safety-critical**

Mixed traffic

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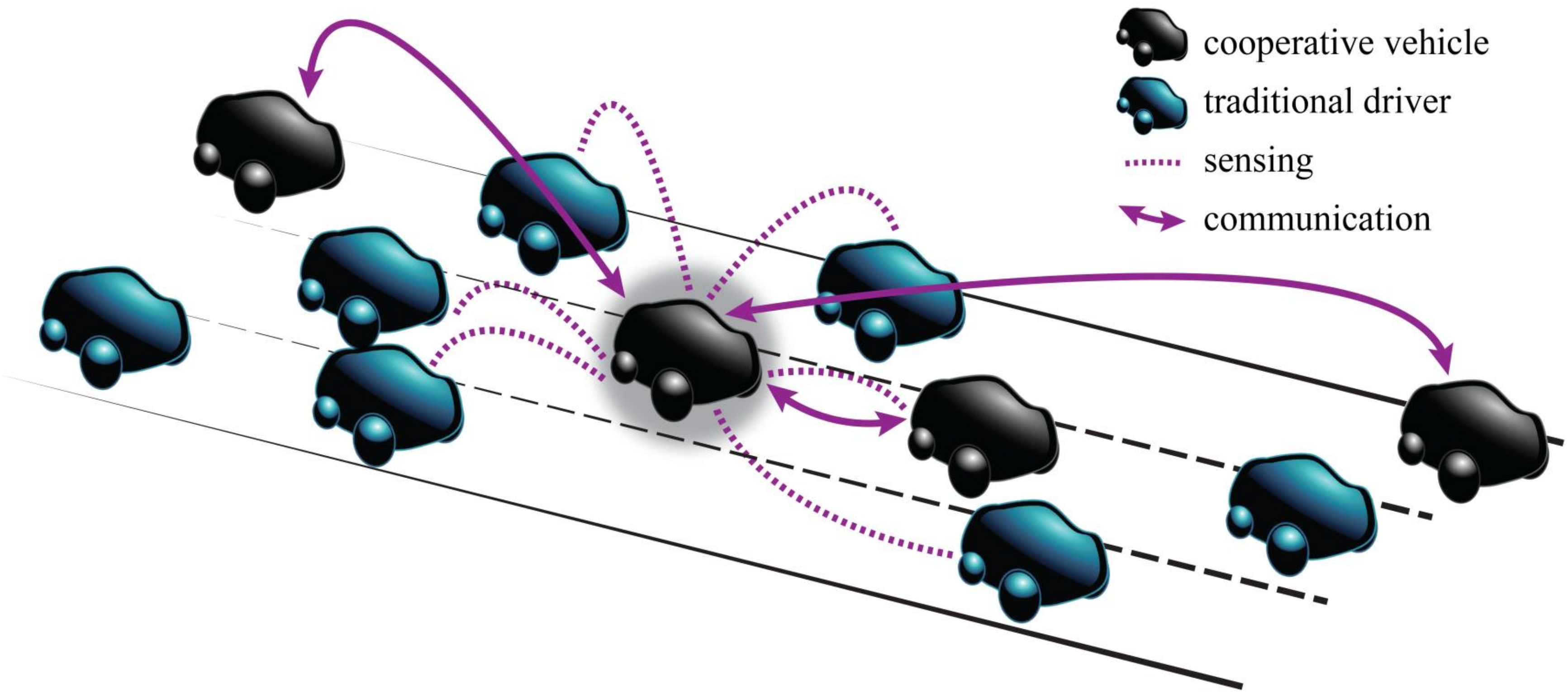
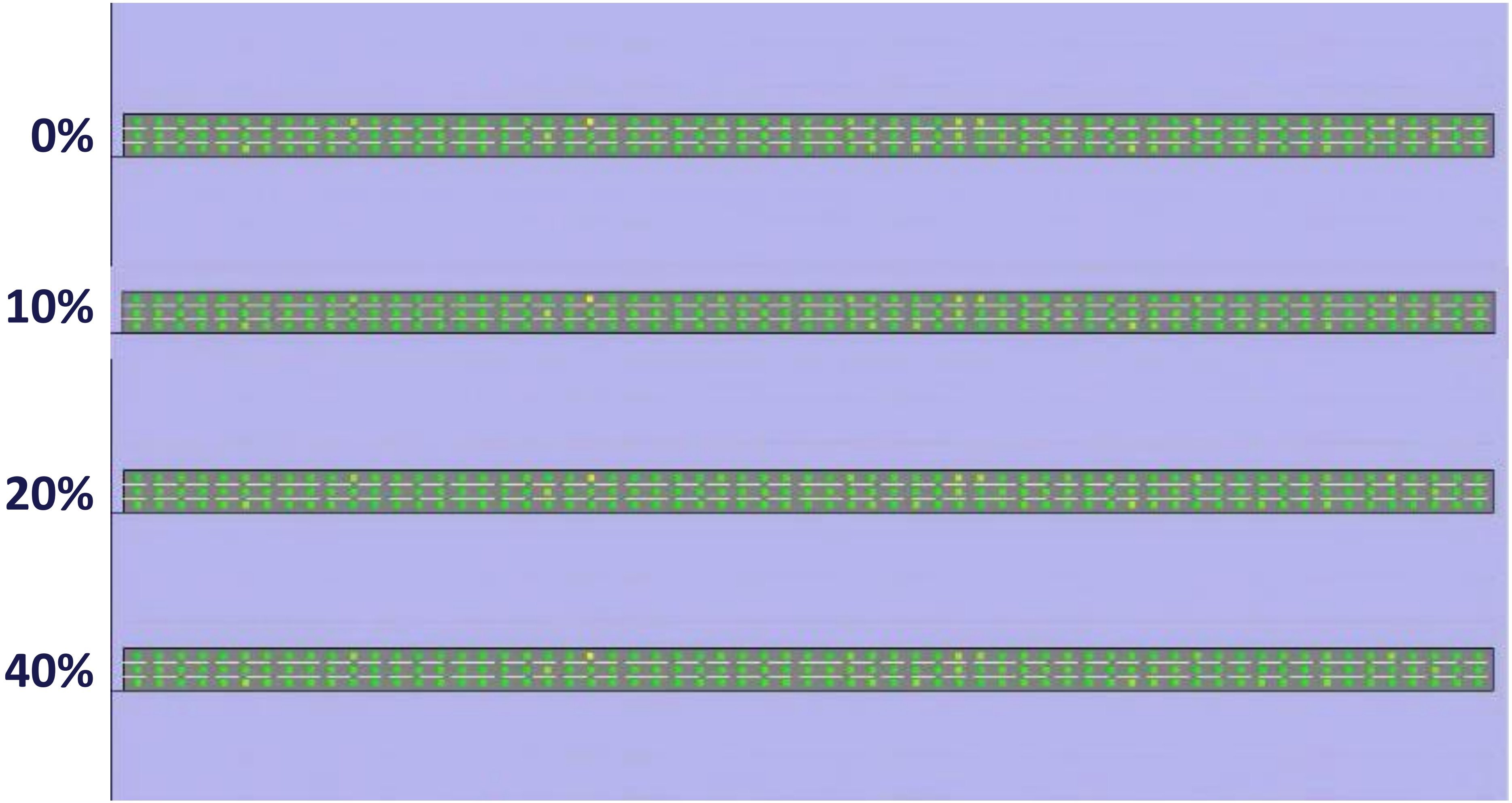


Unreliable communication
Noisy sensors
Different driving behaviours

Safety critical!

Cooperative Car Following



Cooperative Lane Changing

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0%

20%

Conclusions *(mobility)*

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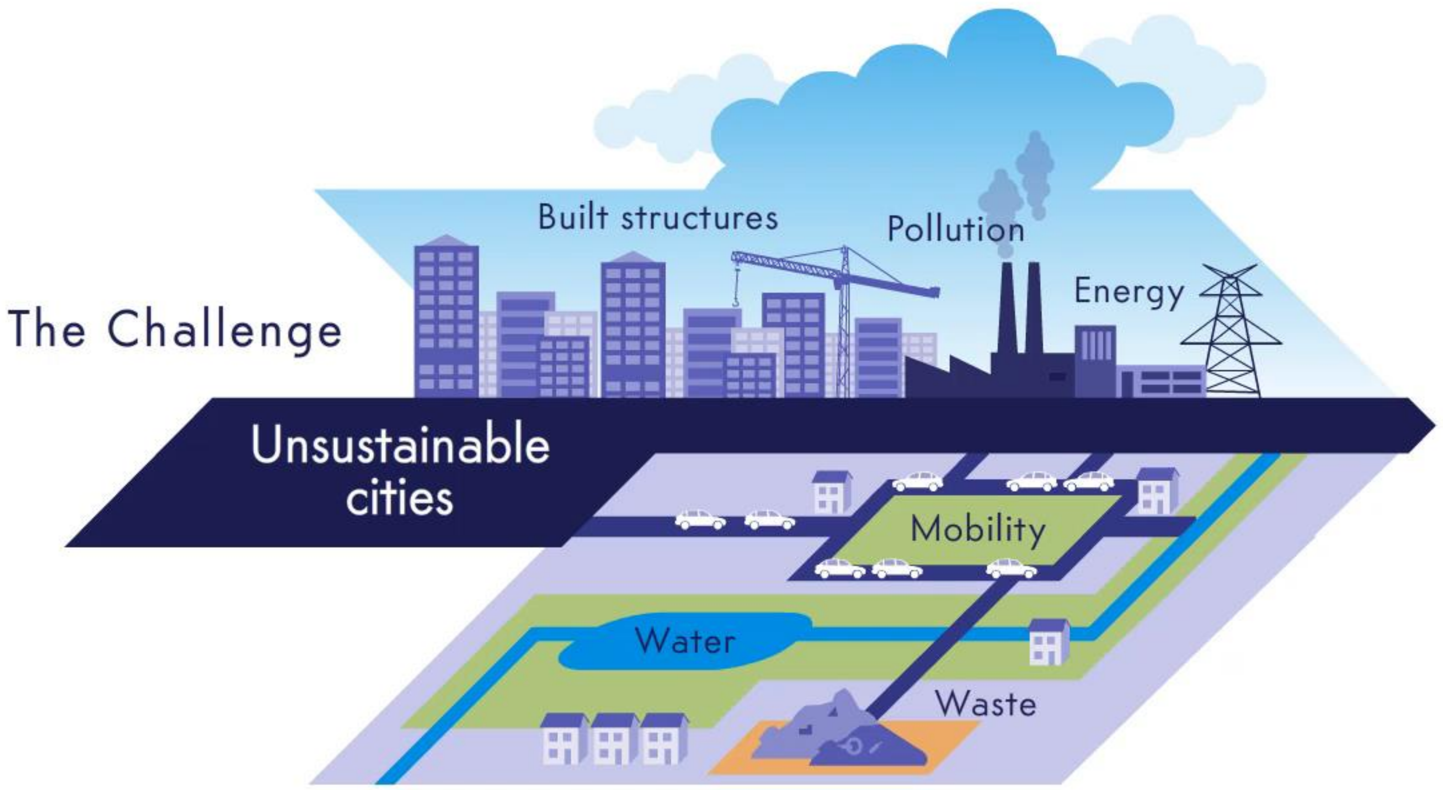
- Transport and congestion have a very high impact on quality of life, which is increasing with urbanisation
- New technologies can be exploited to mitigate this, by providing personalised information & feedback
- Eventually also by allowing vehicles to collaborate and use roads better

Energy example



Demand Side Management

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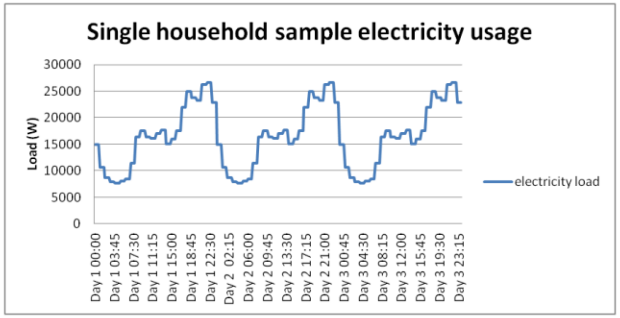
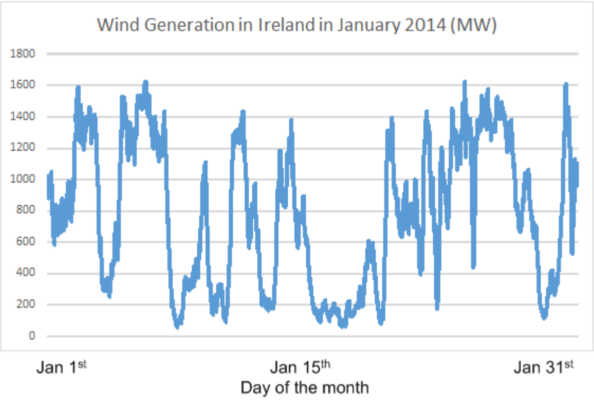
- Energy usage not distributed evenly during the day – morning peak, large evening peak, valley during the night
- Renewable energy generation not evenly distributed and intermittent – depends on weather
- Demand side management (DSM): modification of consumers' electricity consumption with respect to their expected consumption
    - peak clipping, valley filling, load shifting …
- Based on prediction:
    - influence consumers to **reschedule/defer loads** that are not essential during the peaks and run them during low demand periods instead
    - or **use wind-generated energy just-in-time** to avoid using storage or curtailing generation





Some challenges…

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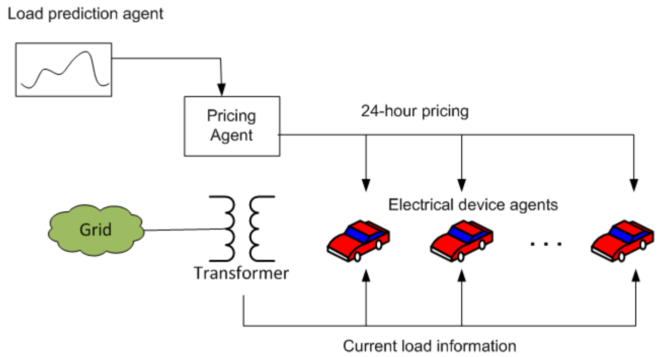
- Not feasible for householders to constantly monitor environment for best decision-making
  - Lives to be led!
- Different devices exhibit different constraints in how they are used
  - Variable output (e.g., electric radiator) vs fixed output (e.g., electric kettle)
  - Temporally variable (e.g., EV) vs fixed time (e.g., lighting)
  - Constrained by other device (e.g., washer/dryer)

Multi-Policy Optimization

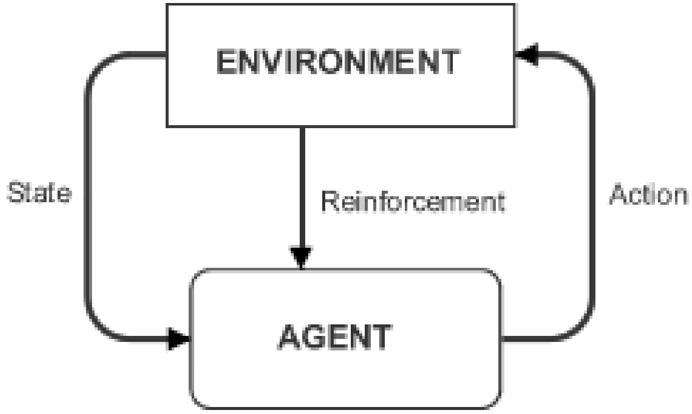
- Challenges:
  - Heterogeneous system policies
    - Different regional scope, temporal scope, priority
  - Heterogeneous agents
    - Implementing different policies, different capabilities
  - Potential dependencies between agents and policies
    - Shared operating environment

Energy Demand-Side Management



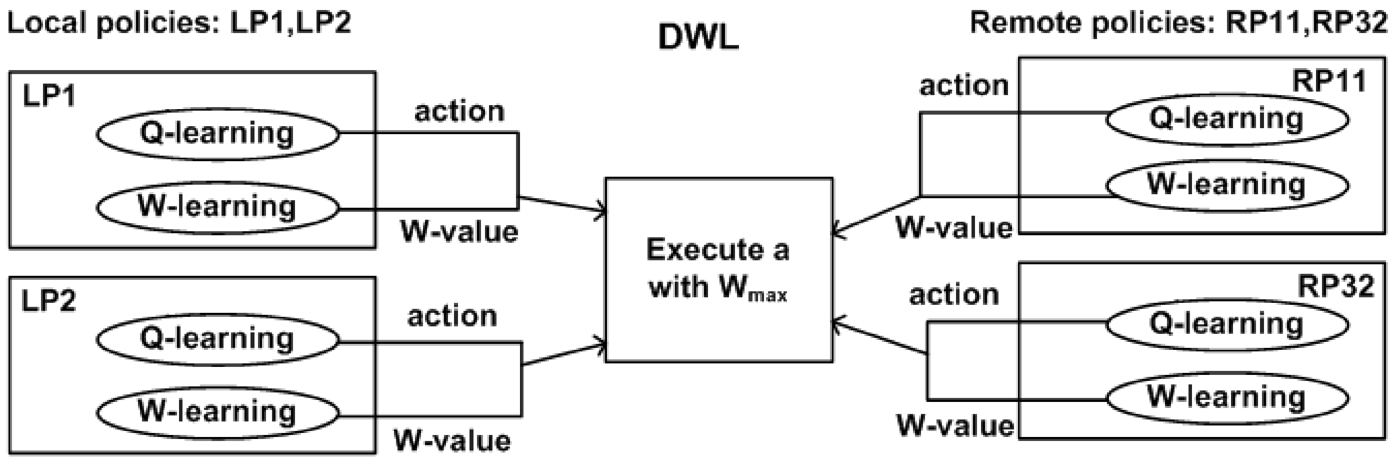
Optimization Using Reinforcement Learning

- Use Reinforcement Learning (RL) for learning agent behaviours
  - Model-free
  - Takes into account long-term effects of agent's actions
- Learn suitable actions through interaction with environment:
  - Receive feedback (reward, reinforcement) from the environment
  - Learn quality of particular actions in particular environment states
  - Stationary environment
- Q-learning
  - Q-value, Q (s,a)
  - Single-agent single-policy model-free RL technique



Collaboration Using Distributed W-Learning

- W-learning
  - Learn dependencies between local policies
- Distributed W-Learning (DWL)
  - Learn dependencies between neighbouring agents
- Each agent learns how its actions affect its immediate neighbours
  - Implemented as Remote Policies



I. Dusparic, V. Cahill. Autonomic Multi-Policy Optimisation in Pervasive Systems: Overview and Evaluation" In ACM Transactions on Autonomous and Adaptive Systems, Vol. 7 Issue 1 2012

Energy Demand Side Management

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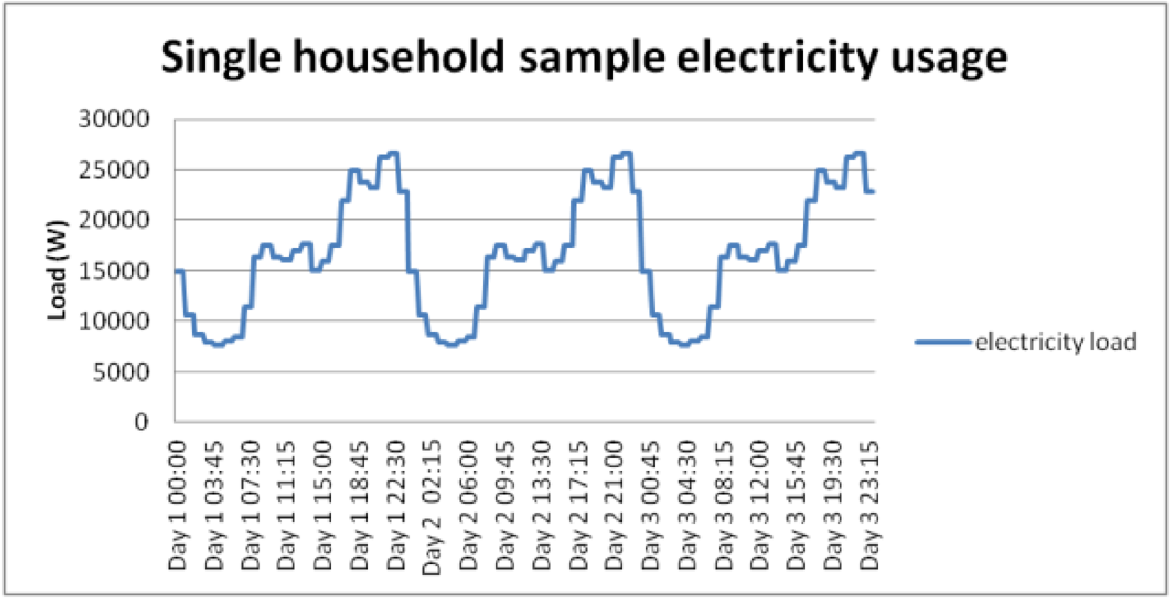
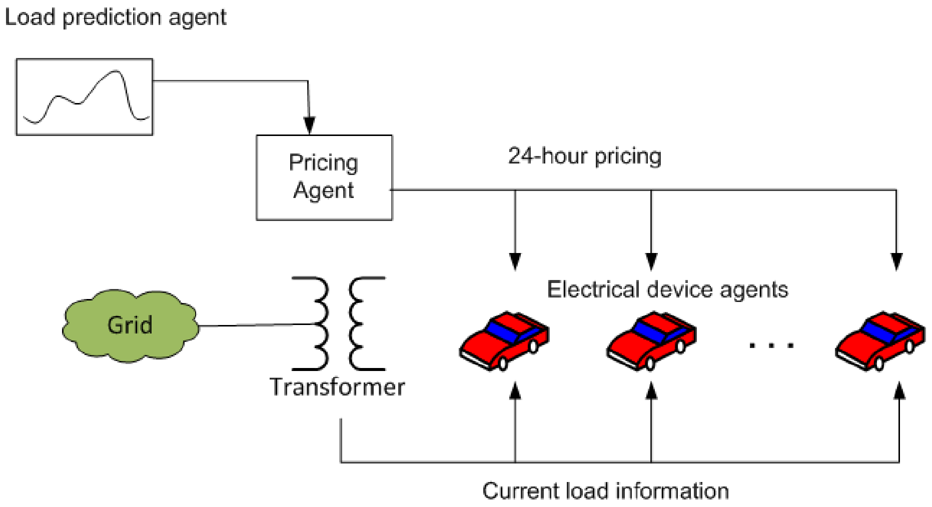


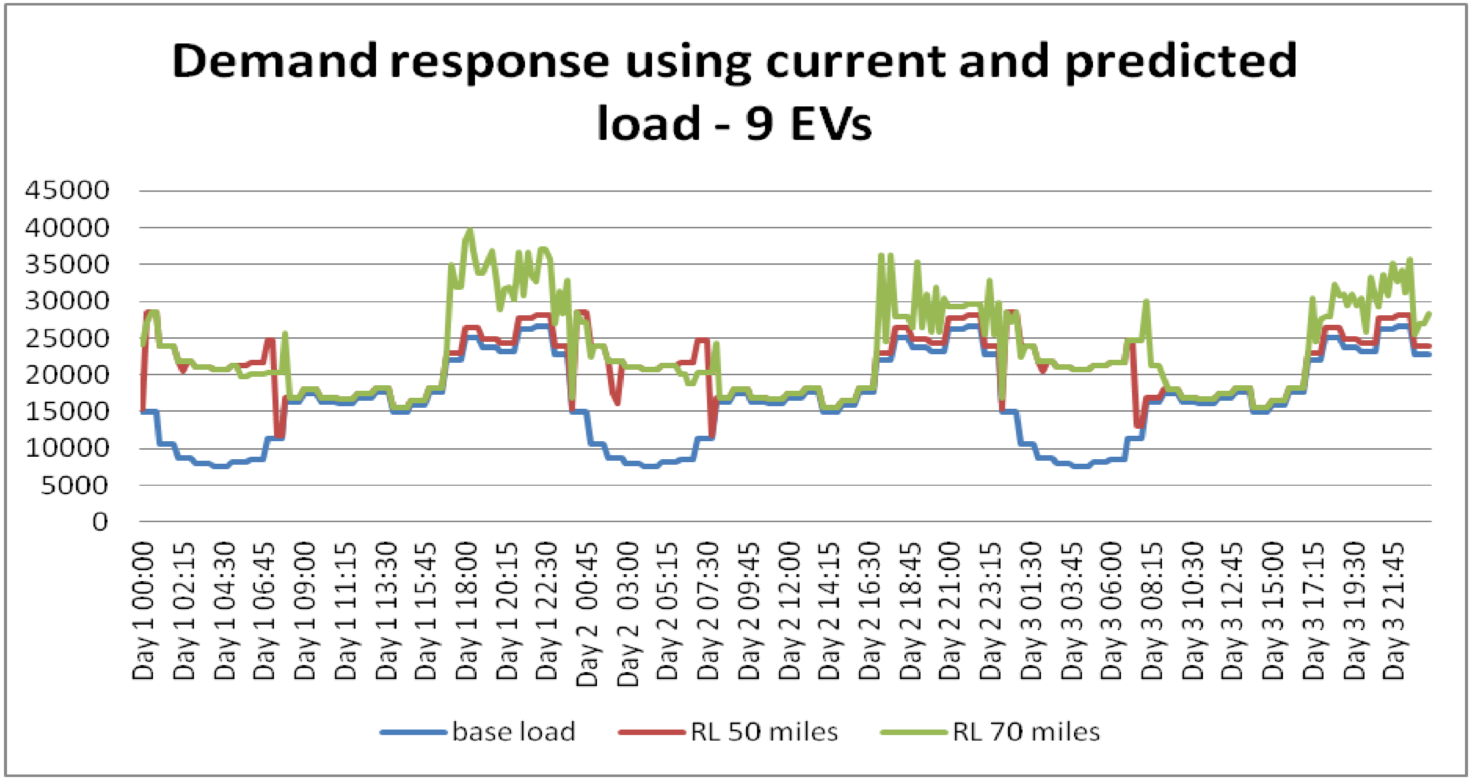
- influence consumers to defer loads that are not essential during the peaks and run them during low demand periods instead
- or use renewable energy just-in-time to avoid using expensive and inefficient storage or wasting energy by having to curtail its production

Adaptive multi-agent residential demand side management based on load forecasting

- Implement the grid as a multi-agent system - each EV is controlled by an RL-agent which implements 3 policies:
  - Policy 1: achieve at least the minimum required battery charge
  - Policy 2: charge at the minimum possible price/during the lowest load
  - Policy 3: keep under set transformer limits/renewable energy limits
- Agents given
  - Current load/ current price only
  - Predicted load/ predicted price too
  - Current levels of wind



Adaptive Multi-agent residential demand side management based on load forecasting



A. Marinescu, I. Dusparic, S. Clarke. "Prediction-Based Multi-Agent Reinforcement Learning in Inherently Non-Stationary Environments" accepted, ACM Transactions on Autonomous and Adaptive Systems,, 2017

Technology part of the story: Myriad of Urban Sensors

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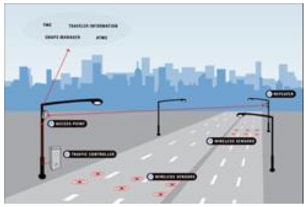

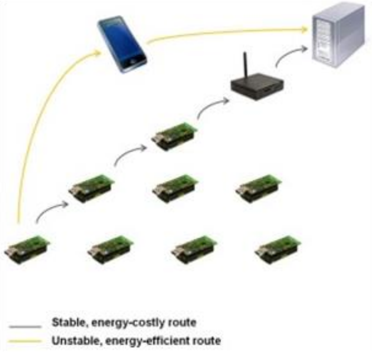

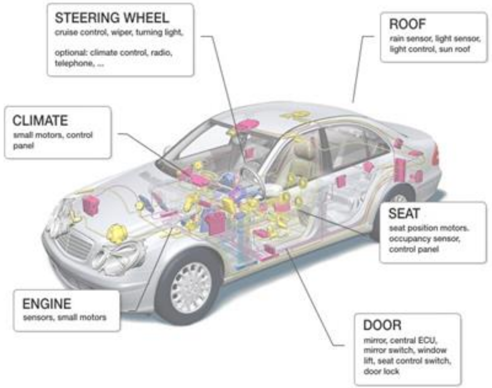

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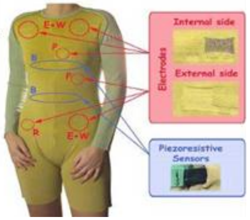

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Thank you.

Prof. Siobhán Clarke

Director, Future Cities. The Trinity Centre for Smart and Sustainable Cities

Trinity College Dublin

Siobhan.Clarke@scss.tcd.ie

www.tcd.ie/FutureCities/