Digital City Exchange

Modelling electric vehicle demand in London using the DCE platform

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Systems-NET Webinar series
9 April 2014

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Digital City Exchange

- A “smart city” is a connected city: efficient use of resources through interaction and integration
- Requires better understanding of the complexity of cities and urban living
- This is not a new idea, but maybe it can now happen:
  - Networks everywhere
  - Large-scale modelling
  - Pervasive sensing
  - Internet of things
  - Cloud computing
  - Etc...
- Connecting physical and digital

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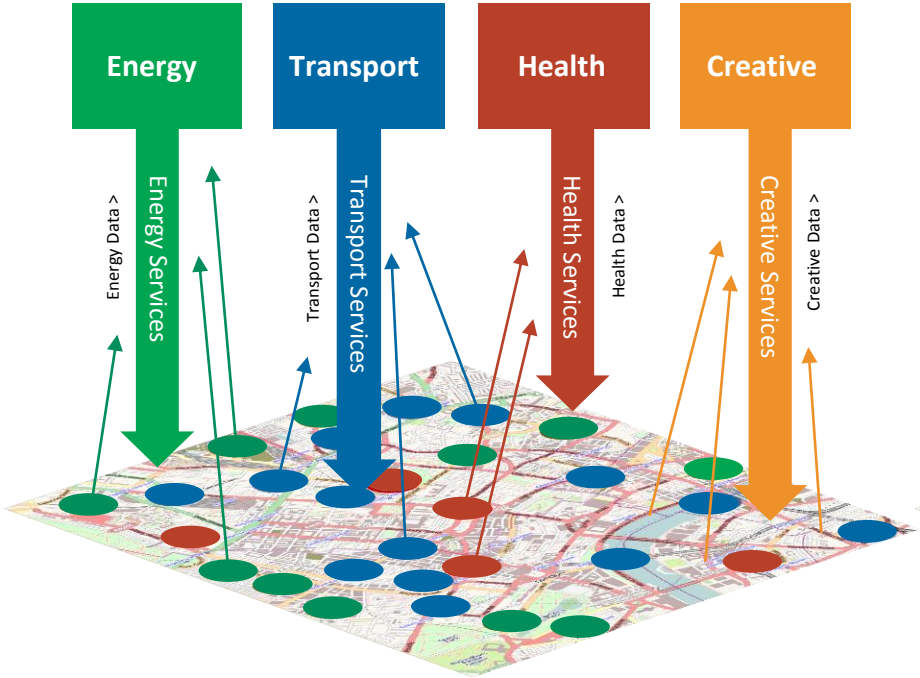
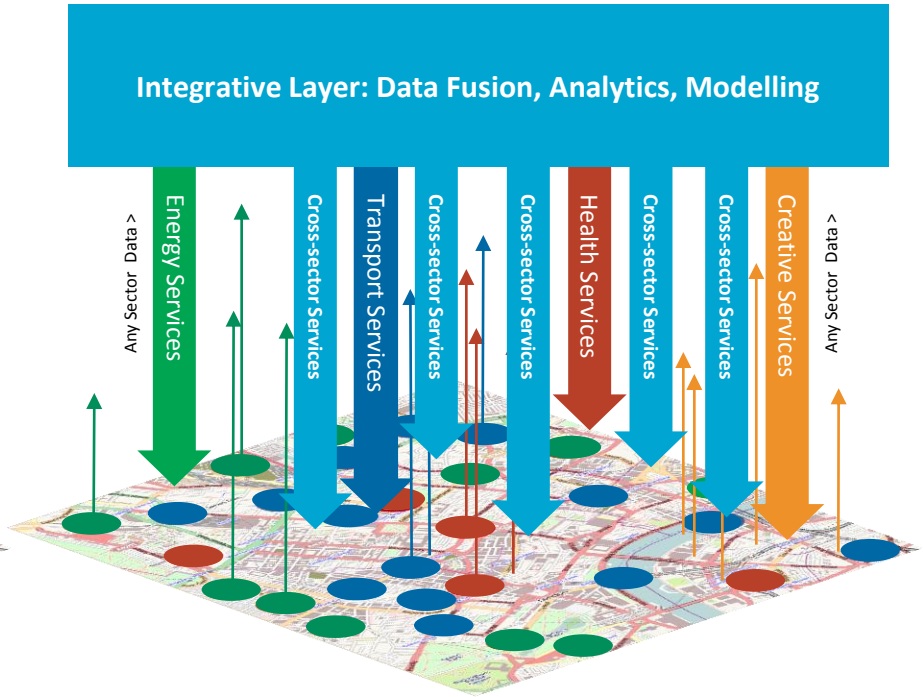
Conventional Data to Services Routes

- Sector-specific data aggregation
- Single dimension, sector-specific services

Digital City Data to Services Routes

- Multi-sector Integrative Layer
- Multi-dimension, cross-sector services





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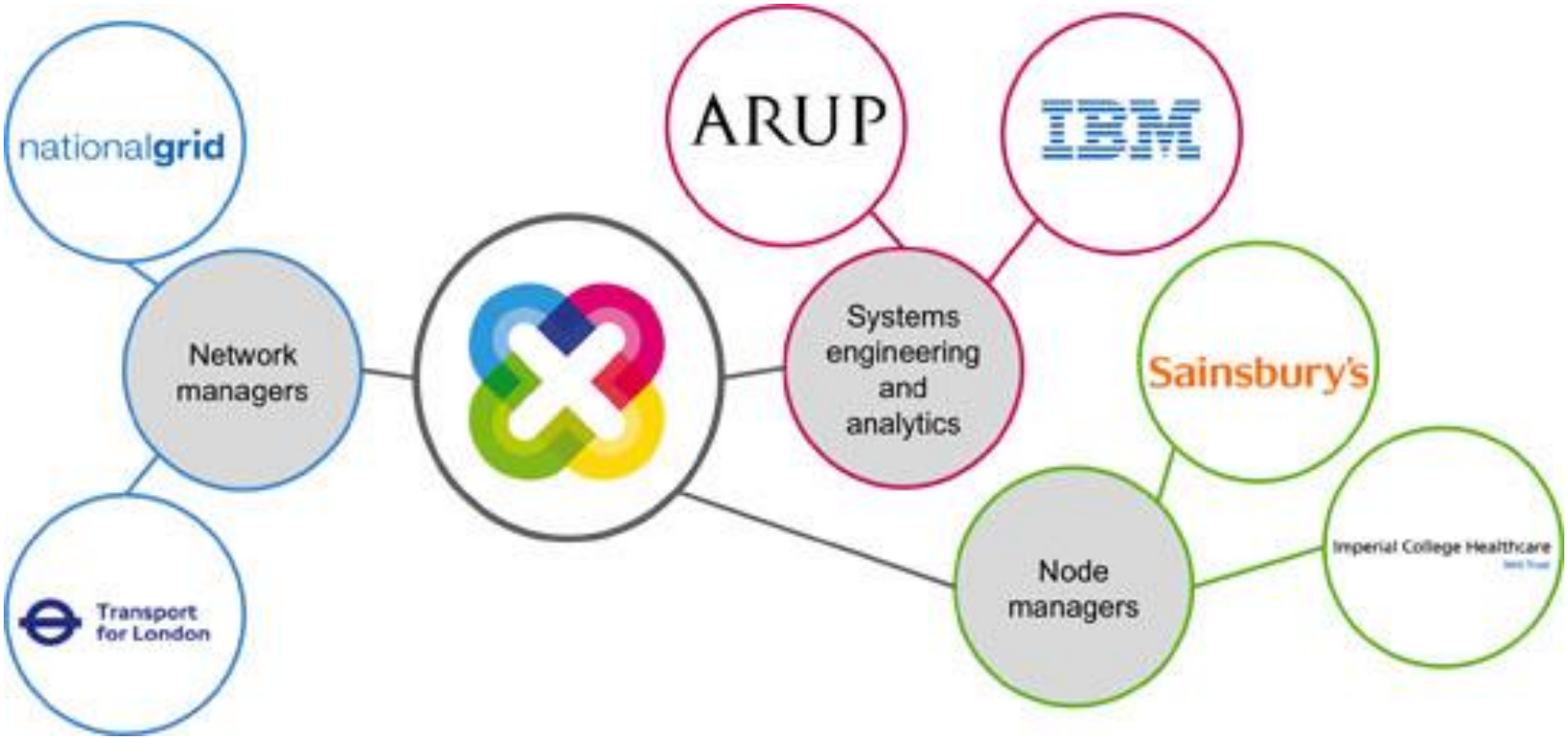

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Electric Vehicle Case

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- Determining optimal charging of electric vehicles (EVs) is key in developing an efficient and robust smart-grid
- Need to **understand** vehicle movements and **predict** demands to **analyse** impact on grid and **optimise** charging profiles
- Link energy and transport infrastructures – a unique opportunity to test DCE concept of addressing peaks in multiple infrastructures

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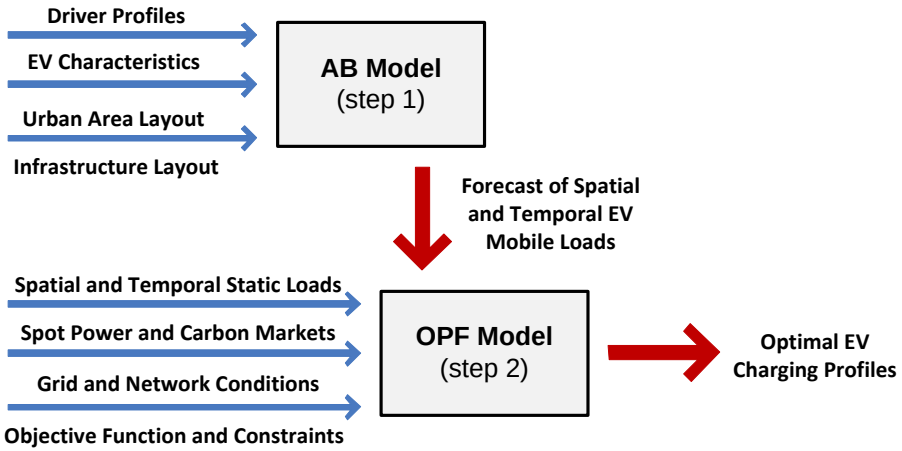
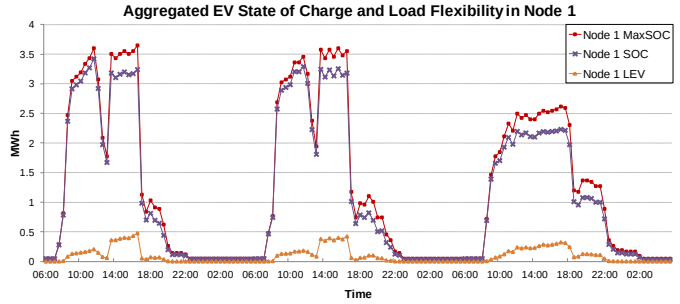
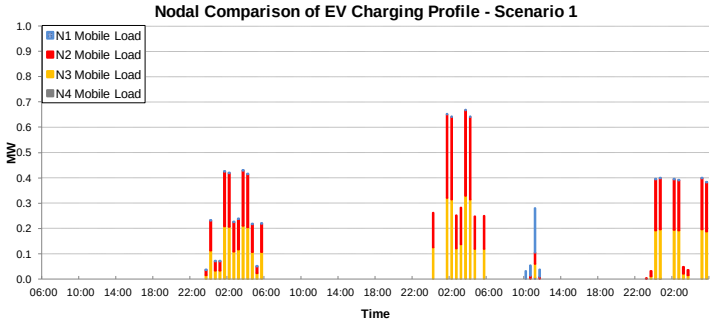
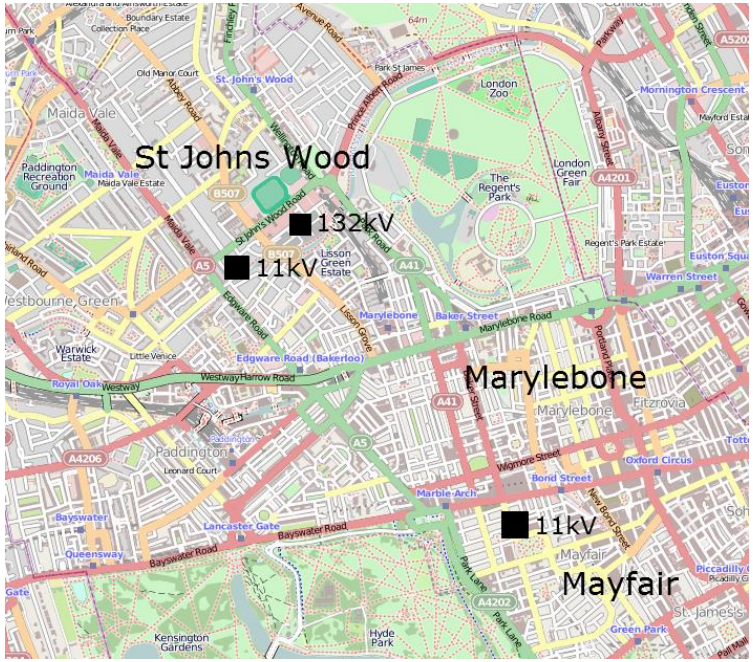
- **Phase 1**: started linking small agent-based model of EV to power flow optimiser [1]
- **Phase 2**: synthetic population of London to forecast EV movements (manually) [2]
- **Phase 3**: automate link between models [3][4]







- Two neighbourhoods in Central London with their own typical profile:
  - Residential with some retail
  - Commercial with some houses
- Predict mobile loads from EVs, fixed static loads



Metric	St. John's Wood	Marylebone/Mayfair
Number of cars	2,455	2,413
Domestic space	73%	33%
Retail space	20%	24%
Office space	7%	43%

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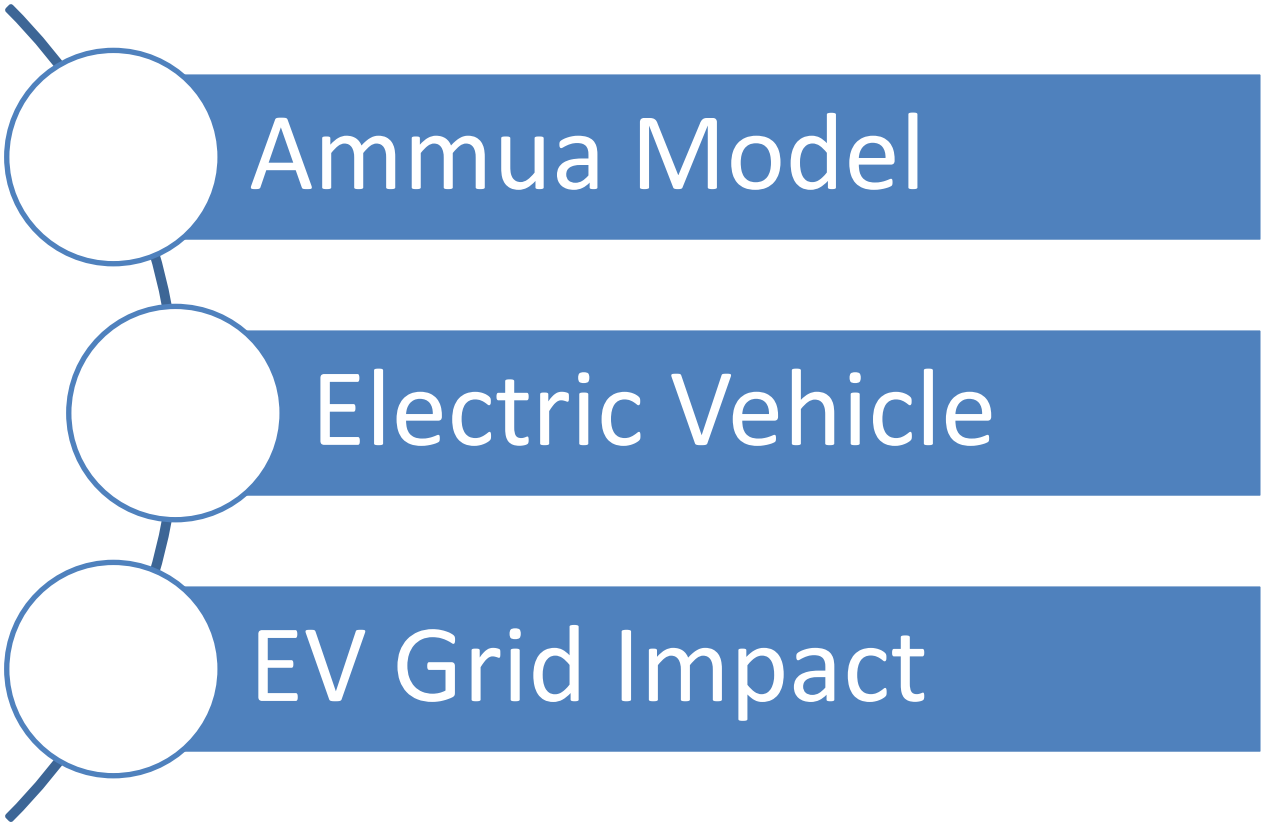

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1 – AMMUA

- **Agent based Micro simulation Model for Urban Activities (AMMUA)**
- Activity-based model simulating trips and activities in an urban environment
- Based on TASHA (Toronto, CA) and adopted and calibrated for London [5]

Inputs	Outputs
▪ Zonal configuration of London ▪ Land usage types per zone ▪ Distributions of travel habits	▪ Individual journeys from one zone to another. Includes departure and journey time.

2 – EV Model

- **Model to translate trips into EV battery status over time**
- Keeps track of people's position in the city (per zone) based on journeys from AMMUA
- For each journey the amount of energy consumed from the battery of the electric vehicle is calculated and the current state of charge (SOC) is stored

Inputs	Outputs
▪ Trips as generated by AMMUA ▪ Map of TfL zones and list of zones to study ▪ EV characteristics	▪ Snapshots at 30 minute intervals per zone with current SOC and max SOC, number of vehicles ▪ Total amount of energy to charge over a 24 hour period

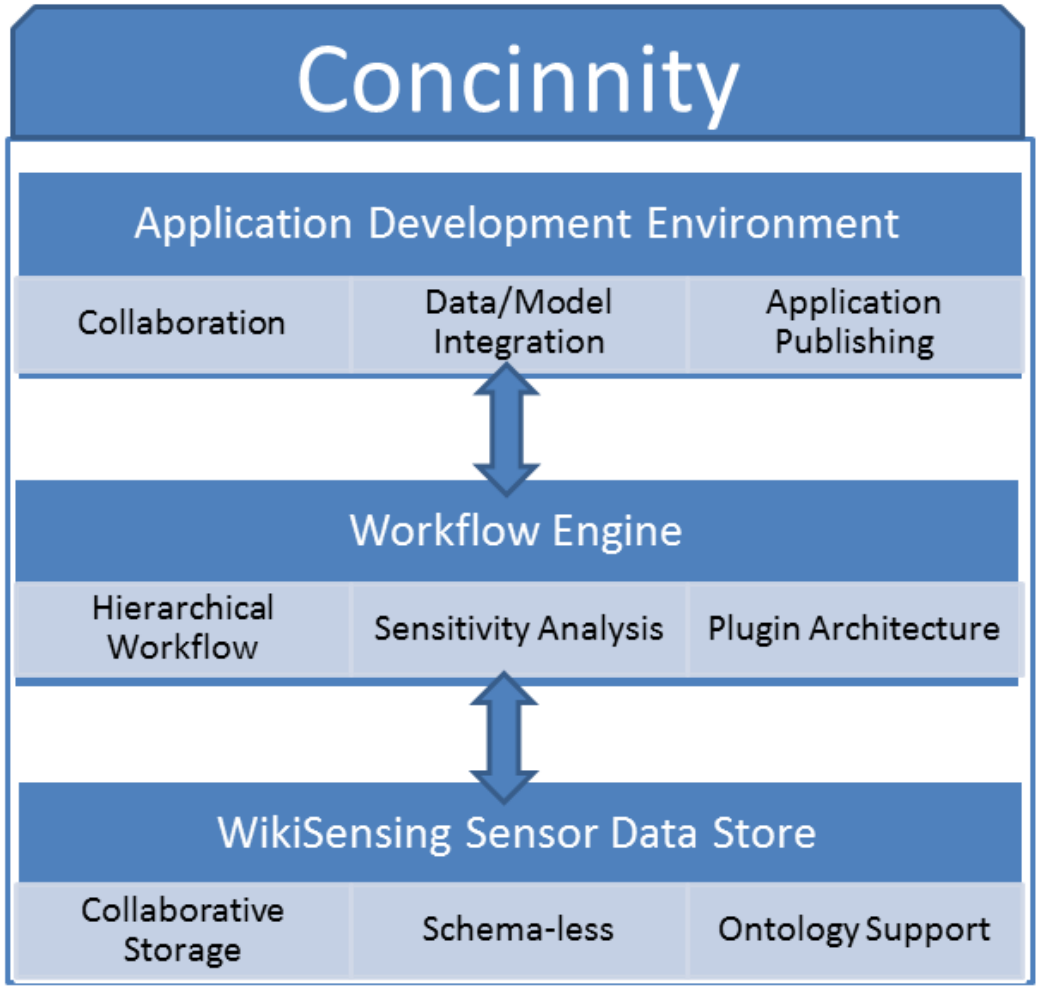
3 – Grid Impact Model

- **Time-coordinated power flow optimiser minimising energy or emission costs incurred from charging EVs.**

Inputs	Outputs
▪ EV battery status over time and space ▪ Static energy loads, retail and office floor space, number of cars owned* ▪ Grid conditions, including carbon and electricity spot prices ▪ Objective function and constraints	▪ Optimised load profiles per substation ▪ Costs (£) ▪ Emissions CO_2

*(Open data from Office for National Statistics)

DCE platform


Concinnity
Application Development Environment
Collaboration
Data/Model Integration
Application Publishing
Workflow Engine
Hierarchical Workflow
Sensitivity Analysis
Plugin Architecture
WikiSensing Sensor Data Store
Collaborative Storage
Schema-less
Ontology Support

See [6]

Digital City Exchange

Concinnity - AppEditor | GridFS | Help

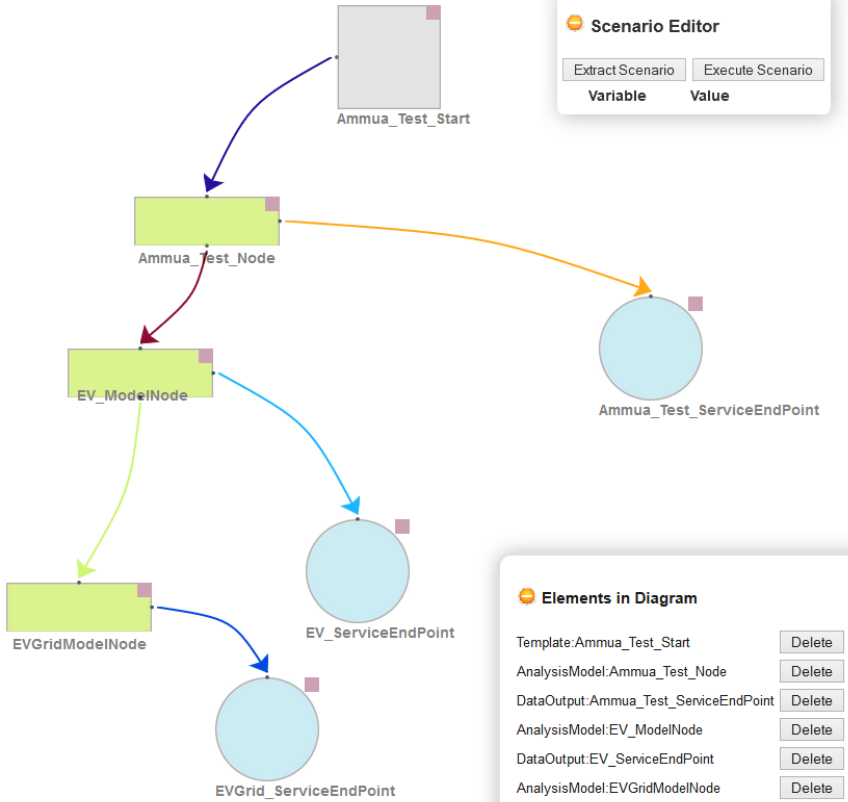
Available Elements

- Element Templates
  - AmmuaNode
  - EVGridModelNode
  - EV_ModelNode
  - SimNode
  - GeneratorNode
  - ExcelNode
  - ExcelQueryNode
  - GISQueryNode
  - CSVNode
  - MapEndPoint
  - StreamStatistics
  - WikiSensingWriterNode
  - ServiceEndPoint
  - WikiSensingNode
- Available Elements
  - ServiceEndPoint
  - StreamStatistics
  - WikiSensing
  - Root
  - Ammua_Test_Start
  - Ammua_Test_ServiceEndPoint
  - Ammua_Test_Node
  - WikiSensingParam
  - EV_ModelNode
  - EV_ServiceEndPoint
  - EVGridModelNode
  - EVGrid_ServiceEndPoint
- Available Workflows
  - SampleWorkflow_Test
  - Ammua_Test
  - Sample_Scneario_Test
  - Ammua_EV_Test
  - Ammua_EV_Test_tree
  - EV_Study_Full

Commands

Workflow Results

Map



Scenario Editor

Extract Scenario | Execute Scenario

Variable | Value

Node Editor

Clear Tree | Load Node by ID | Save | Save As... | Delete

ID = 124015f2-919f-47c2-b861-
Name = Ammua_Test_Node
Owner = DAvid
IsPublic = ☑

Node
- TemplateID = -1
- InstanceID = -1
- Name = Ammua_Test_Node
- Description = A New Node
- InstanceNameExpr = TemplateName
- InstanceName = Not Evaluated
- IsVariableMapping = false
- IsVariableMappingExpression = false
- GeneratedVariableMappingName = N/A
- VariableMappingNameExpression = N/A
- FilledbyParentQuery = false
- DataSetUniqueKey = expr
- AcceptsDataSet = true
- Hidden
- Hidden
- ExecutionLinks
- ShouldExecute = true
- Variables
- Outputs
- DataLayers
- Hidden
- Hidden
- RunName = Ammua_Test
- atimes2001
- fin_actc
- fin_coor
- fin_flow2001

Elements in Diagram

Template:Ammua_Test_Start	Delete
AnalysisModel:Ammua_Test_Node	Delete
DataOutput:Ammua_Test_ServiceEndPoint	Delete
AnalysisModel:EV_ModelNode	Delete
DataOutput:EV_ServiceEndPoint	Delete
AnalysisModel:EVGridModelNode	Delete
DataOutput:EVGrid_ServiceEndPoint	Delete

Workflow Editor

Clear Canvas | Save | Save As... | Delete

ID = 47260bf8-c43c-4926-9f58-
Name = EV_Study_Full
Owner = David
IsPublic = ☑

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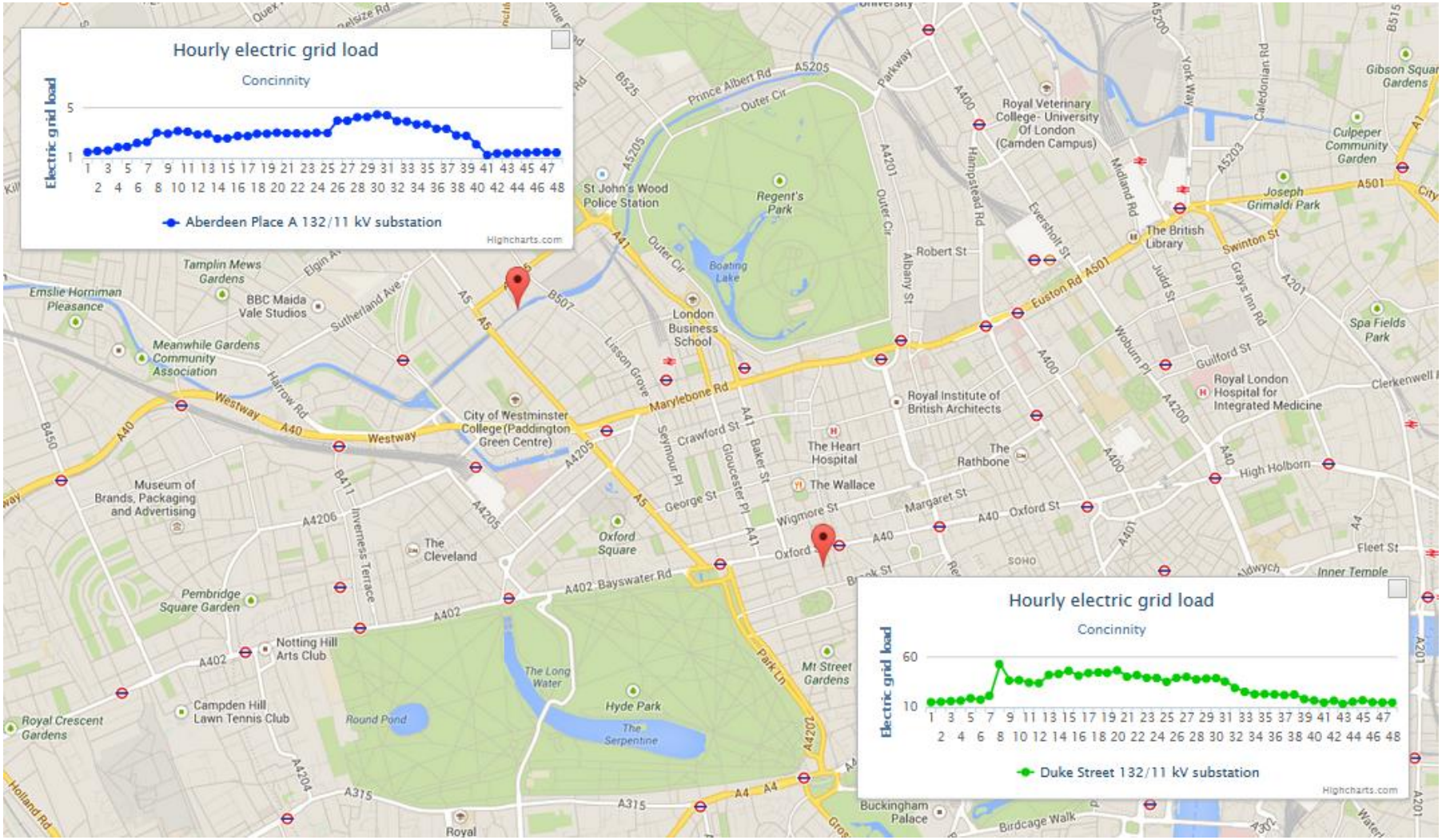
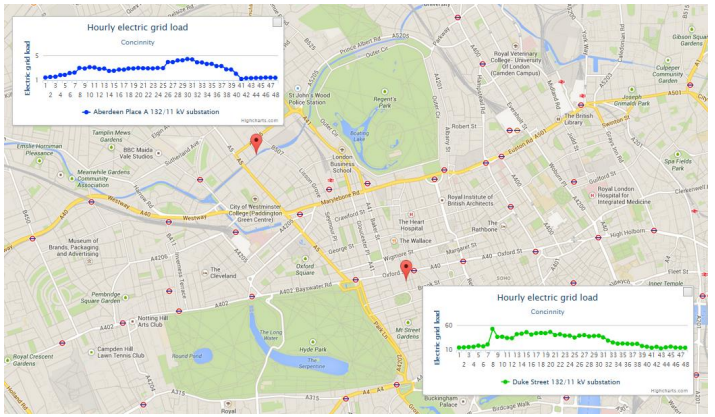


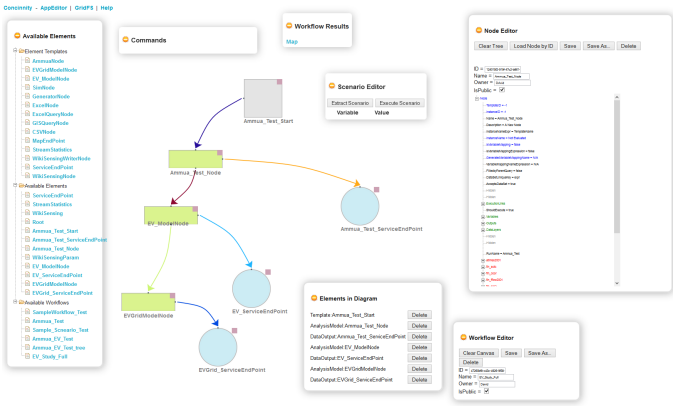
Capability	Benefits
Automation	No manual data transformation / increased accuracy by removing potential for human error / Consistency of data between models / repeatability / quick results
Collaboration	Easy access to models developed by others / collaboration / Reuse existing models in further case studies
Publication	Use of workflows, data and models by other researchers / repeatability of results / publishing of workflows with API's / Historic results storage
Scenario analysis	**Sensitivity analysis of parameters** **Policy / demographic scenarios**

Next steps

- Expanding Electric Vehicle case study shown in Concinnity Platform demo
- Idea: explore urban phenomenon at city scale looking at impact of large developments e.g. Stratford
- Two stages:
  1. Update parameters of existing models for new area
  2. Introduce additional models, incl. EV uptake, mode choice, etc



- What can we learn from this?
  - How to use the platform for larger scale studies
  - Insights city wide impact EVs
- New capabilities:
  - Expanding power flow and EV models by opening up 11kV nodes
  - Sensitivity analysis
  - Interface with data (ONS, energy prices)
  - Testing platform larger scale
  - Feedback loops (e.g. impact of energy prices on usage of Evs)
- Challenges:
  - Data on layout distribution network



[1] Acha, S. and K.H. van Dam (2013) "Modelling Electric Vehicle Mobility in Energy Service Networks" in Modelling Distributed Energy Resources in Energy Service Networks, IET Press, ISBN: 978-1-84919-559-1
[2] Acha, S., K.H. van Dam and N. Shah (2013) "Spatial and Temporal Electric Vehicle Demand Forecasting in Central London" in proceedings of CIRED2013, 10-13 June, Stockholm
[3] David Birch, Orestis Tsinalis , Koen H. van Dam , Chun-Hsiang Lee, Dilshan Silva, Chao Wu, Moustafa Ghanem, Yike Guo (2013) Concinnity: A Digital City Exchange Platform, proceedings of DE2013: Open Digital, 4-6 November, Salford, UK
[4] Koen H. van Dam, Salvador Acha, Aruna Sivakumar, John Polak and Nilay Shah (2012) Smart cities through data, models and services -- a model exchange platform, DE2012: Digital Futures, October 23rd - 25th 2012, Aberdeen, UK
[5] Sivakumar, A., Vine, S. L. and Polak, J.W. (2010) An activity-based travel demand model for London. In Proceedings of the European Transport Conference, Glasgow, UK, October 2010.
[6] Chun-Hsiang Lee, David Birch, Chao Wu, Dilshan Silva, Orestis Tsinalis, Yang Li, Shulin Yan, Moustafa Ghanem, and Yike Guo (2013) Building a Generic Platform for Big Sensor Data Applications. 2013 IEEE International Conference on Big Data

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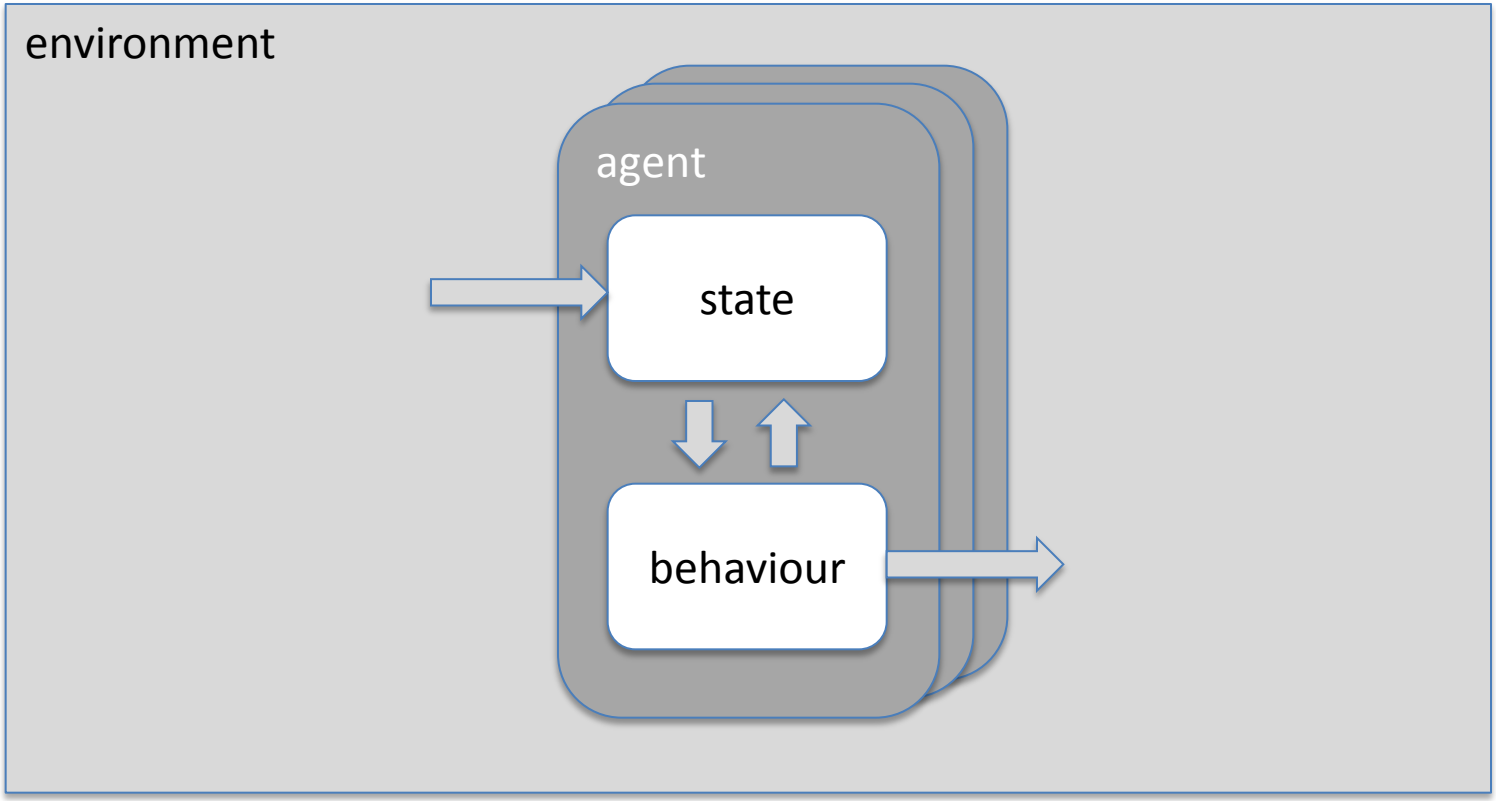
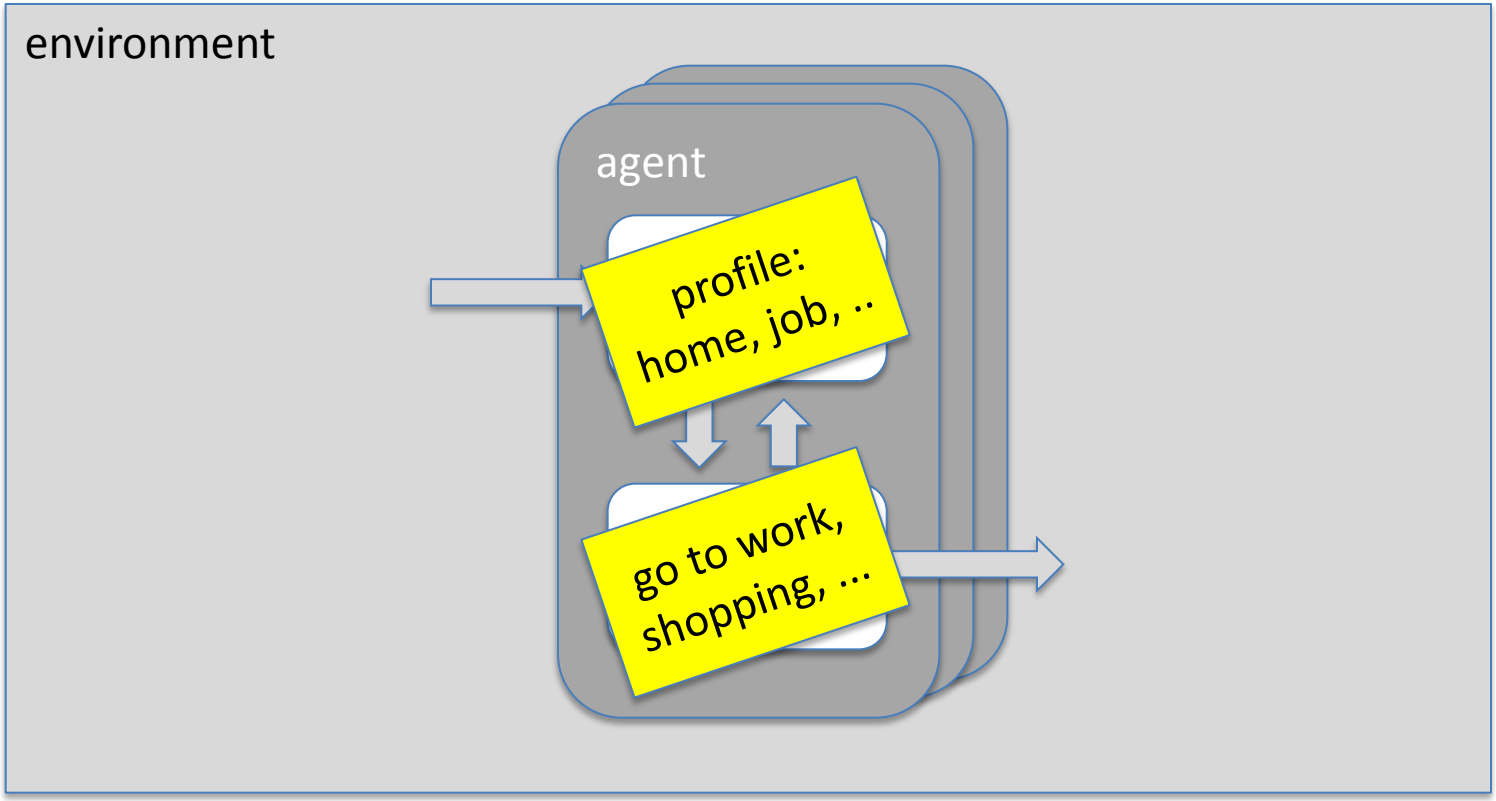
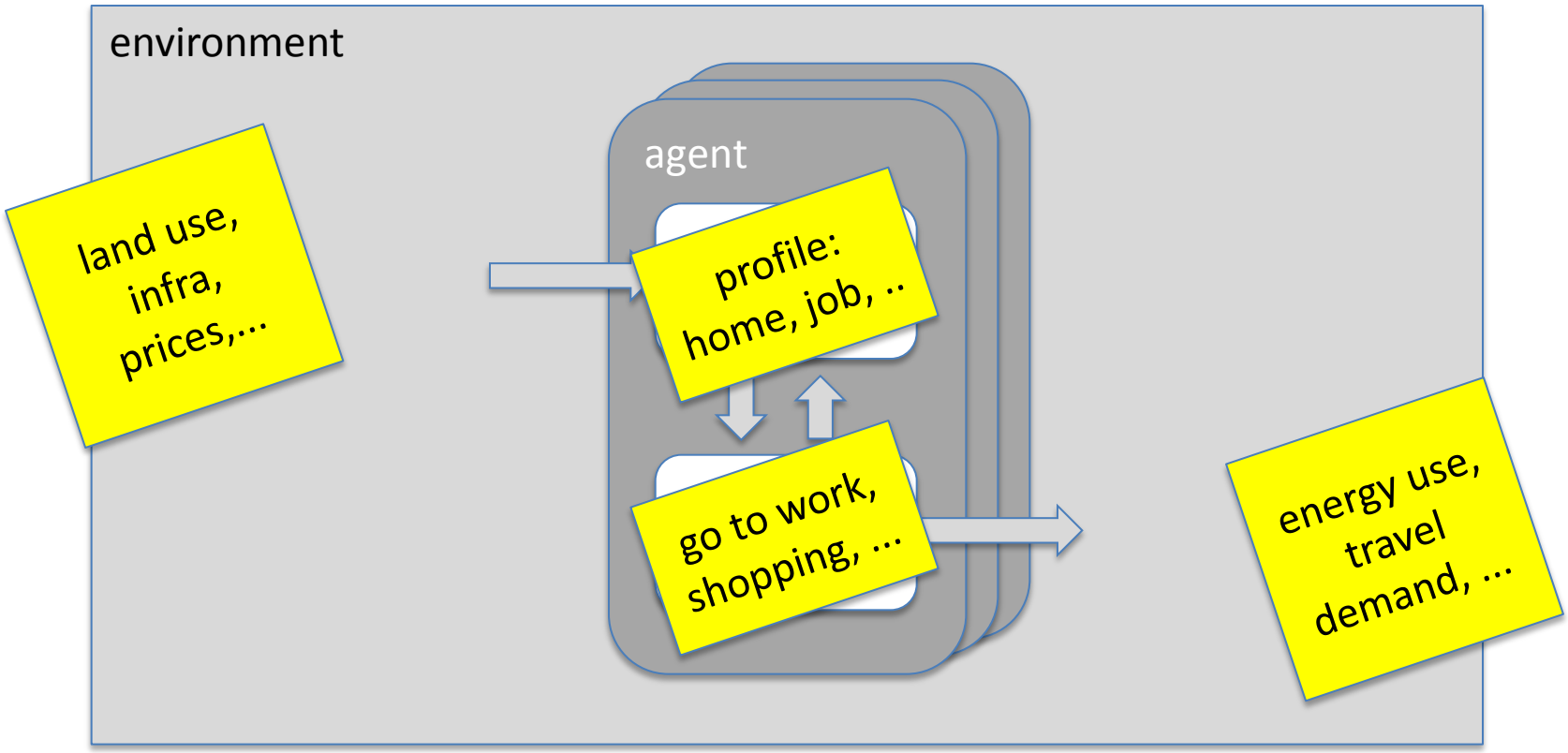
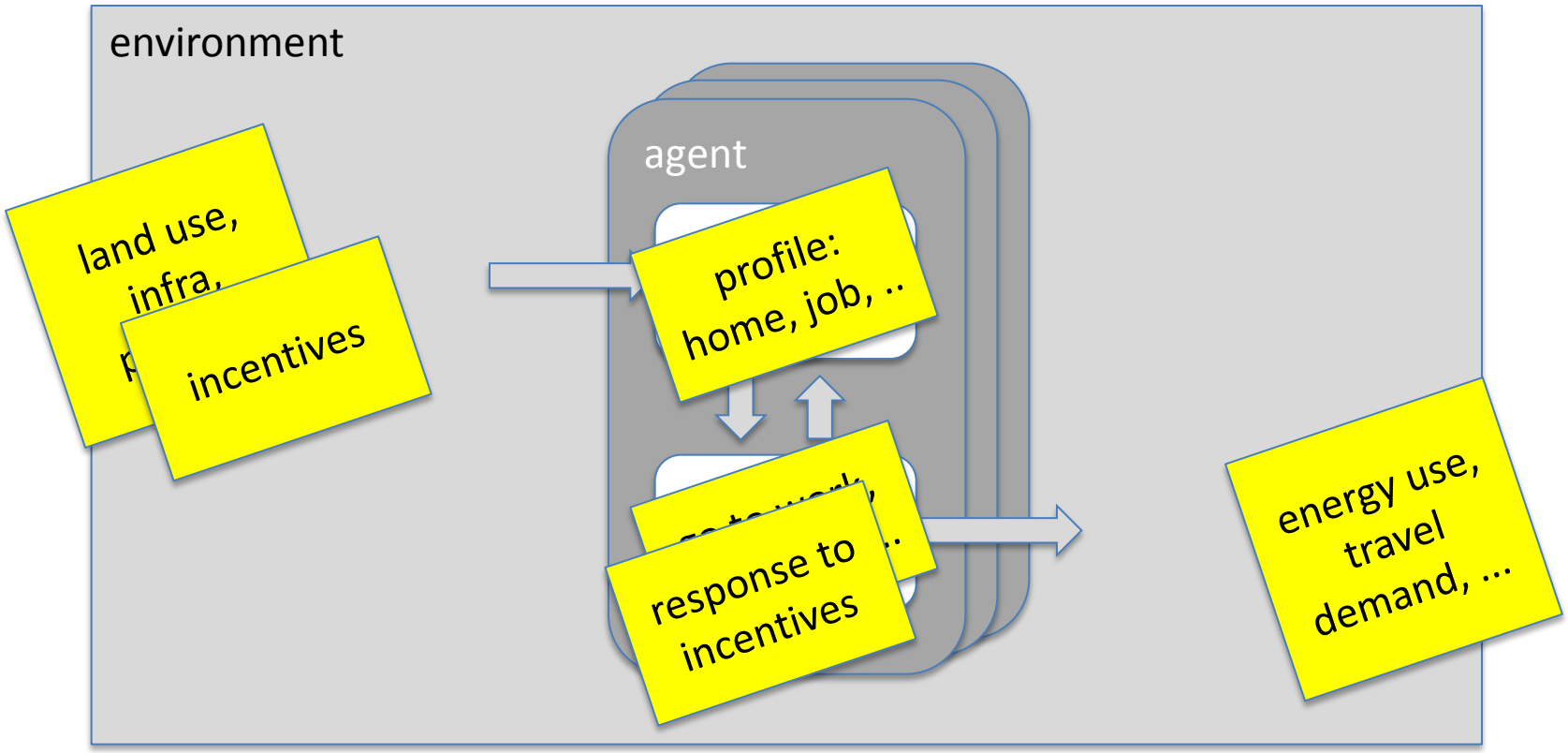

environment
agent
state
behaviour


environment
agent
profile:
home, job, ..
go to work,
shopping, ...


environment
land use, infra, prices,...
agent
profile: home, job, ..
go to work, shopping, ...
energy use, travel demand, ...


environment
land use,
infra,
incentives
agent
profile:
home, job, ..
response to
incentives
energy use,
travel
demand, ...