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Preparing Leicester Businesses for the Smart Energy Revolution

- 3rd November 2017
- Leicester Castle Business School

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Welcome

Rick Greenough

Professor of Energy Systems – De Montfort University

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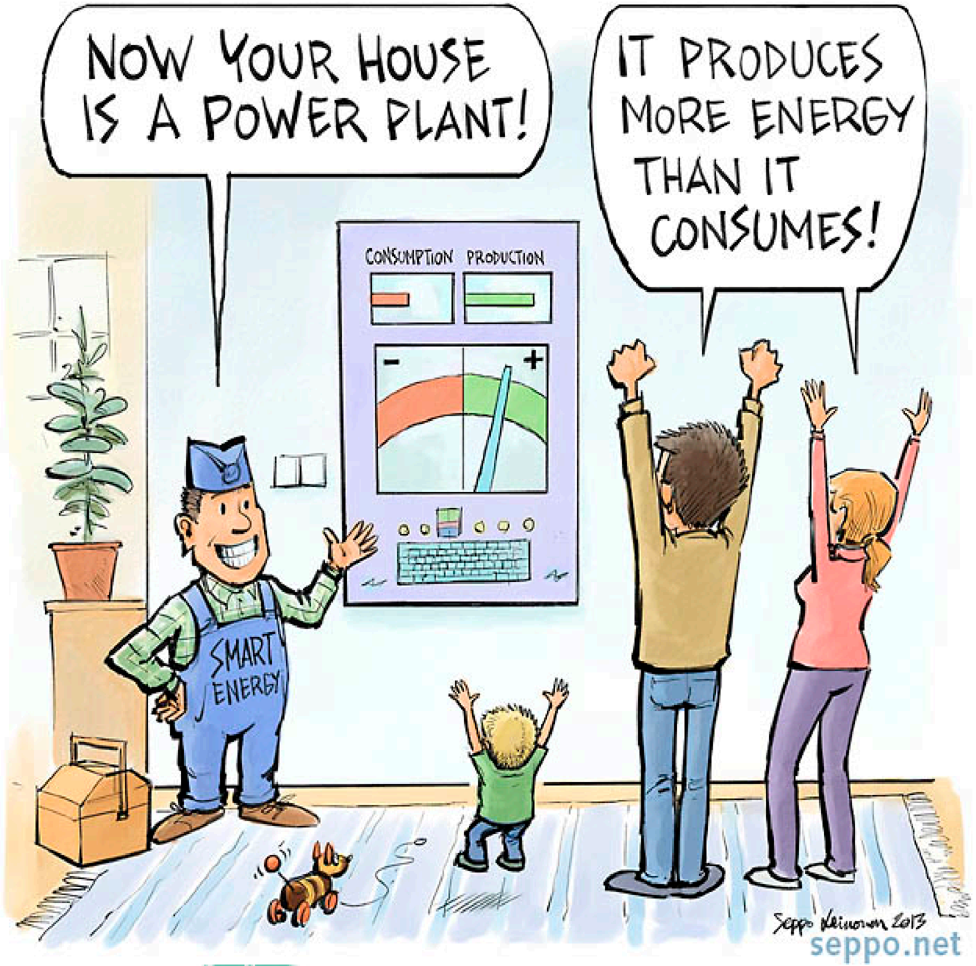
Introduction - 2017

- 2017 continues to be an 'interesting' year!
- First subsidy-free solar farm in UK (Bedfordshire)
- Tesla model 3 announced (£1000 deposit)
- Petrol & diesel car bans (Paris, Oxford, Copenhagen)
- Scottish government's not-for-profit energy company
- US pulls out of Paris climate agreement
- Economic uncertainty (Brexit, interest rates…)



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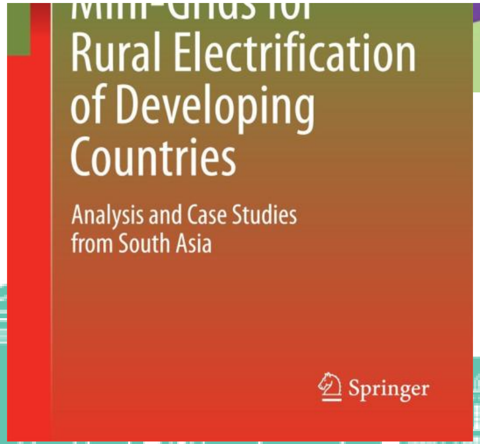
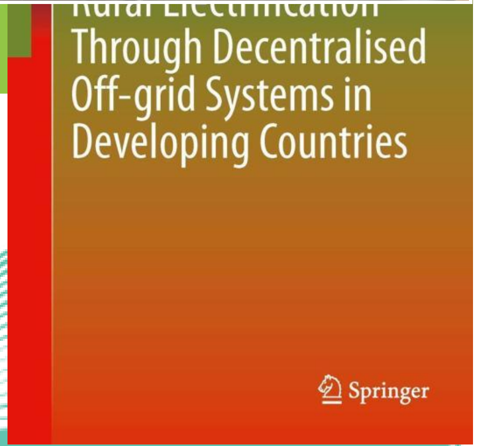
Energy Institute 4 Ds

- Decarbonisation
- Decentralisation
- Digitalisation
- Democratisation





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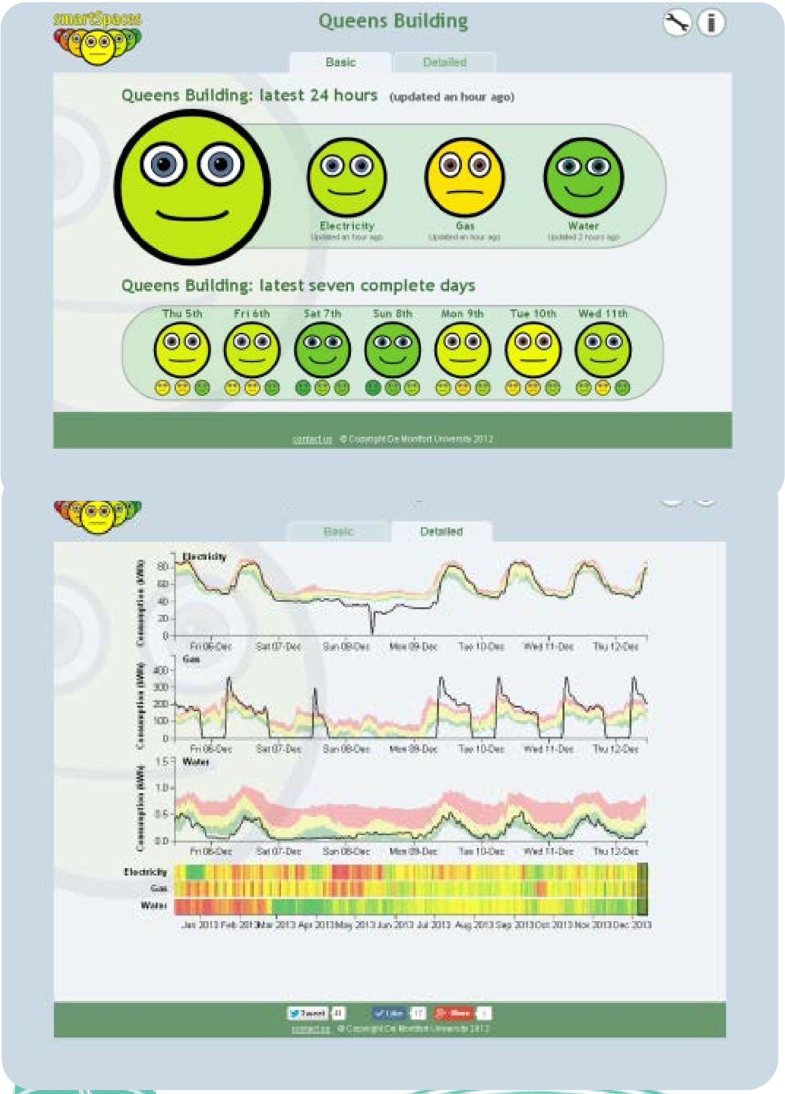
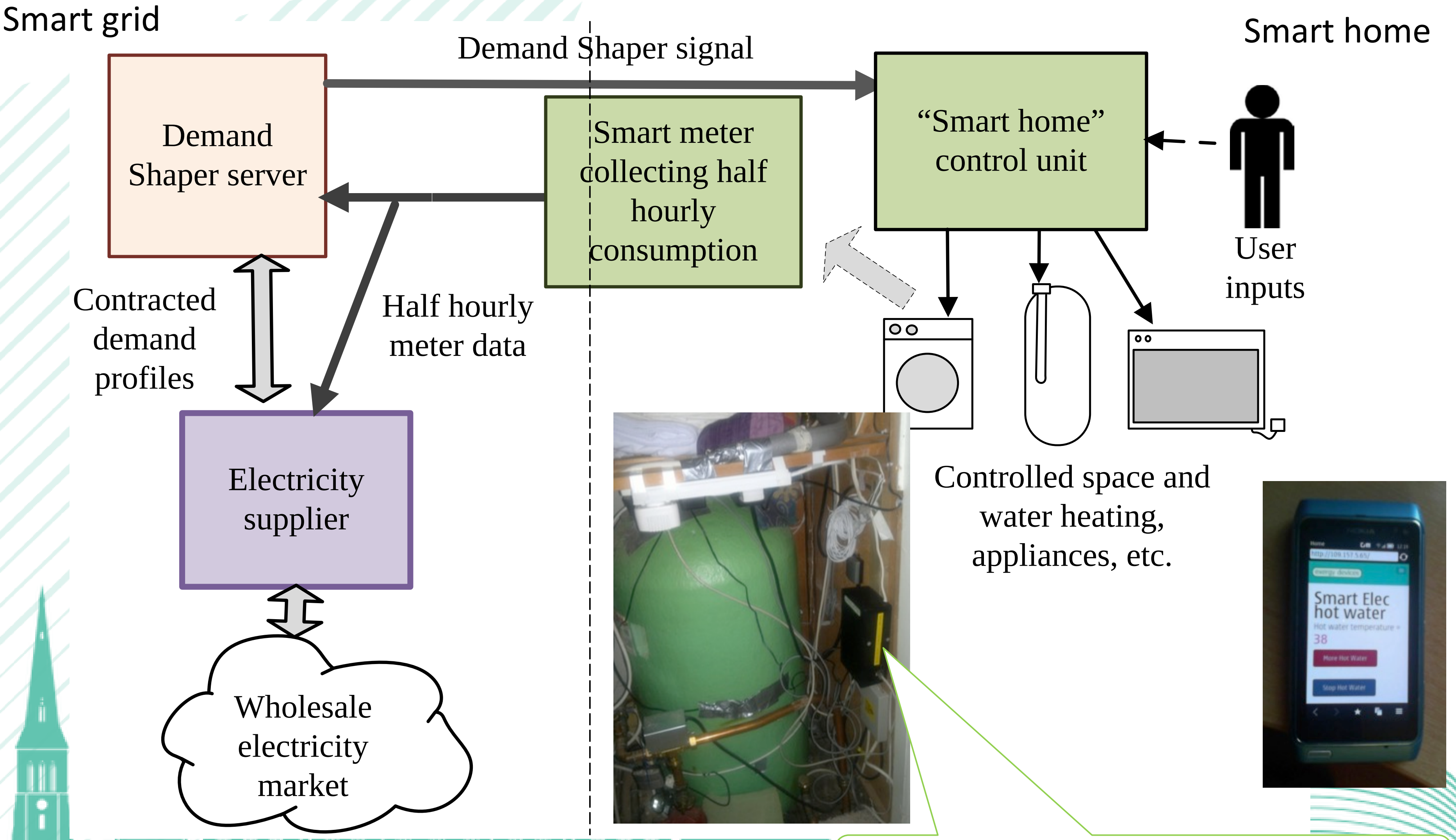
Energy behaviour change

- EU Competitiveness and Innovation Programme
  - €6.98M
- Saving energy in Europe's public buildings using ICT
  - 11 pilot sites in 8 countries
  - Developed 11 unique systems
- IESD developed an energy performance dashboard for public buildings in Leicester
- Now being commercialised



Smart grid and smart home



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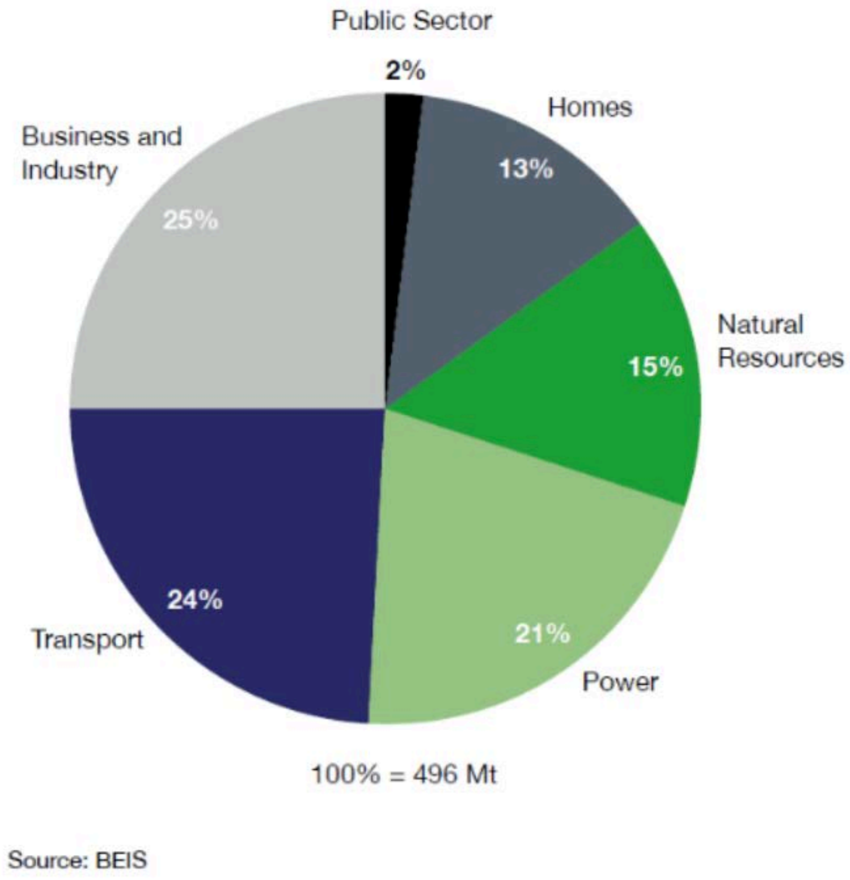
Clean Growth Strategy

- 25% of UK emissions from business & industry
- Clean growth is at heart of industrial strategy
- Cut emissions by 80% by 2050 (wrt 1990)
- Two objectives:

1. Lowest cost to taxpayers consumers and business (see Helm review)
2. Maximise social and economic benefits



32% of total emissions from heat in buildings and industry

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Electric Vehicles and Charging Strategies

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Business Opportunities from Demand Response

Research into Industrial Energy Efficiency

- **R**esource and **E**nergy **E**fficient **MA**nufactur**IN**g
  - Energy recovery
  - Energy optimisation
  - Integrating renewables
- Funded by EU 7th Framework (4 year project)
- Three industry sectors (food, textiles, foundry)
- 16 partners

REEMAIN
RESOURCE AND ENERGY EFFICIENT MANUFACTURING

SEVENTH FRAMEWORK PROGRAMME
European Commission

DE MONTFORT UNIVERSITY LEICESTER

SCM foundry (Rimini – Italy)

BOSSA textile factory (Adana – Turkey)

Gullon biscuit factory (Aguilar de Campo – Spain)

EST Enerji (Battery technology – Turkey)

Solera (Concentrated solar thermal - Germany)

IES <VE> (Building simulation – UK)

Deliverables

- Public deliverables
  - Technology roadmap
  - Efficiency analysis methodology
  - Best practices book
  - These and others are on www.reemain.eu
- Other deliverables are for consortium only (NDA)
- Regular meetings at partner sites
- Responsible to EC via a project officer

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Technology Roadmap

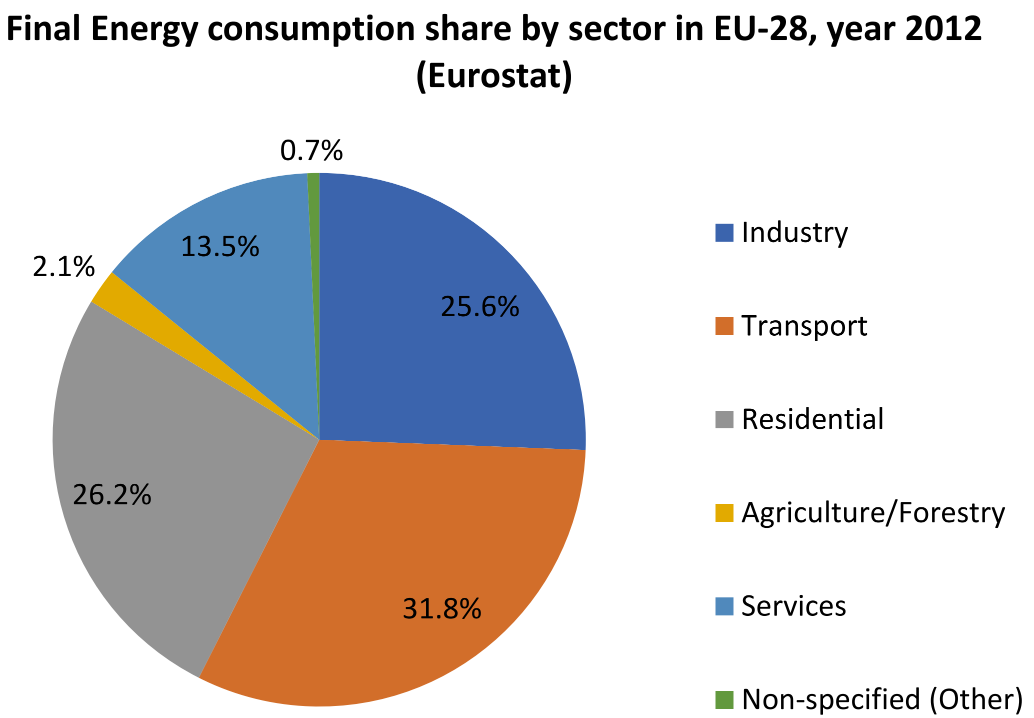
- Wide range of technologies considered
  - Renewable energy technologies
  - Energy storage technologies
  - Waste heat recovery technologies
  - Hybrid systems
- Analysed (SWOT) and ranked
- Classified in clusters

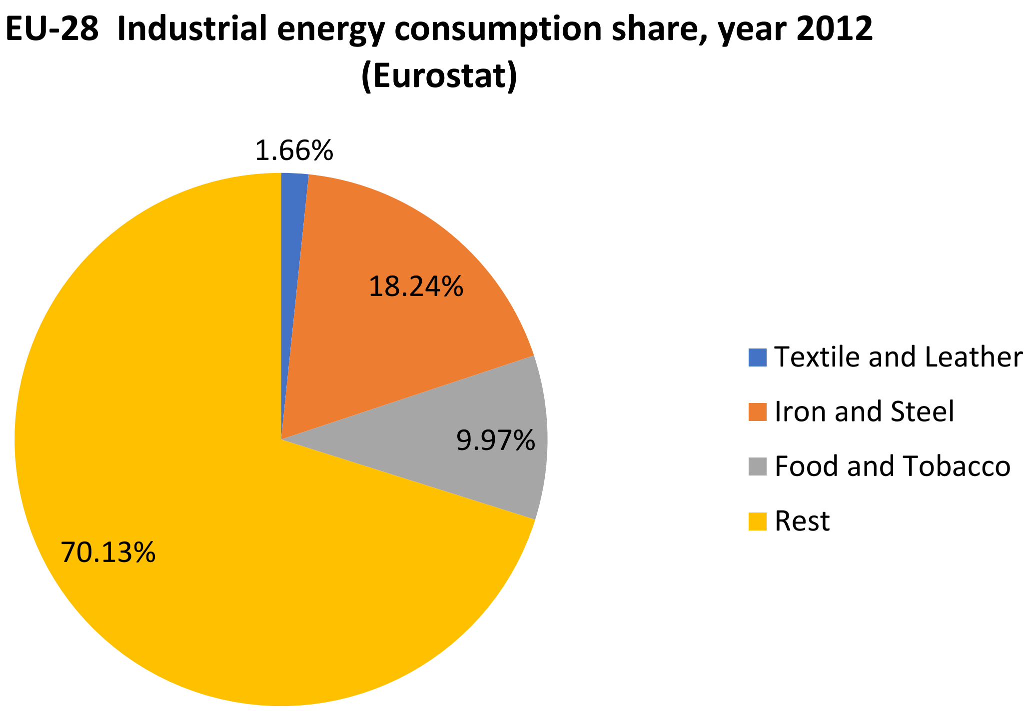
Furthermore, an additional benchmarking for six pre-selected innovative technologies (solar concentrators, PV, solar cooling, CHPC, ORC, battery storage) was carried out based on a survey. In total 14 feedbacks have been received from external reviewers/experts in the different fields as well as 20 completed surveys from REEMAIN experts, which were almost not involved in the preparation of the technology roadmap.

The following innovative technologies are finally identified through the assessment and ranking within this Technology Roadmap for Efficient Manufacturing as highly interesting technologies for manufacturing processes depending on different applications:

Cold generation	Solar Cooling systems
Electricity generation	Photovoltaic
Heat generation	Solar Thermal Collectors and Solar Concentrators
Poly generation	ORC and CHPC systems
Storage	Hot Water Thermal Storage and the Lithium-ion Battery

Industrial energy in EU28



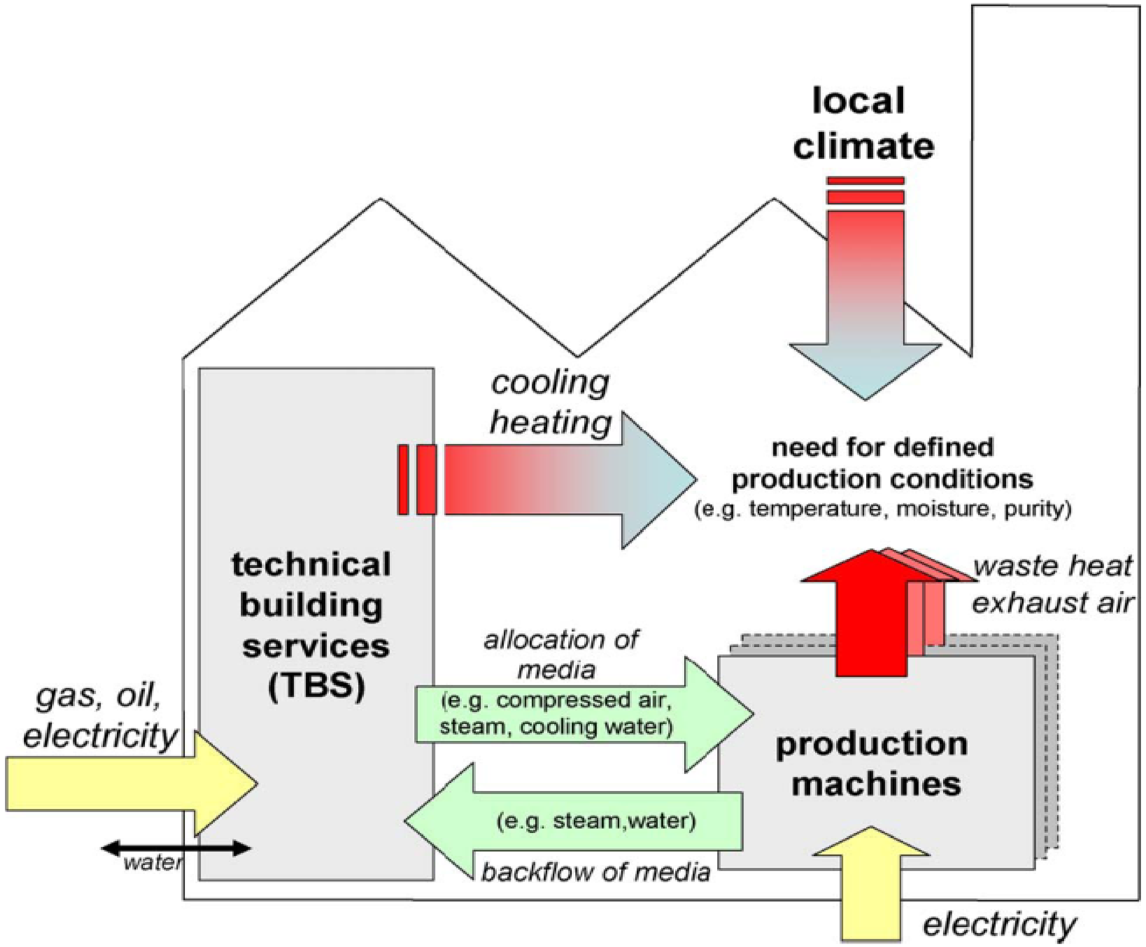


Note: Eurostat data for 2014 shows industry at **25.9%**, transport at 33.2% and residential at 24.8%

Energy systems in industry

(Herrmann & Thiede, 2009)

- Production system
  - Process energy and ancillary processes
- Technical building services
  - Compressed air, gas, coolant etc.
- Building shell
  - Air conditioning, dust extraction, lighting etc.



Complex interactions!

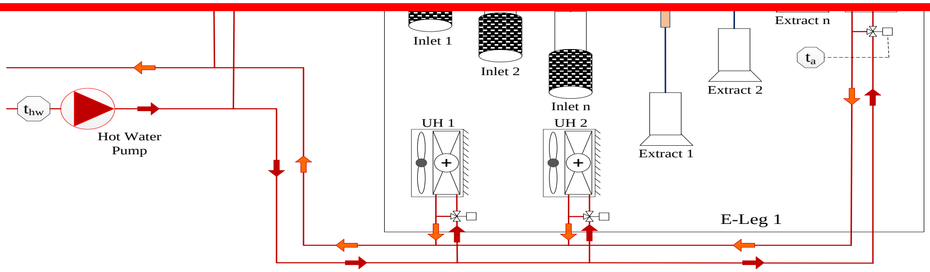
Modelling in factories

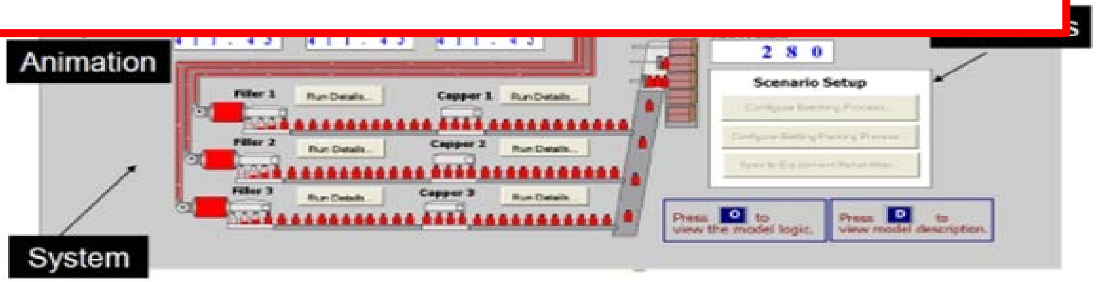
Building energy simulation

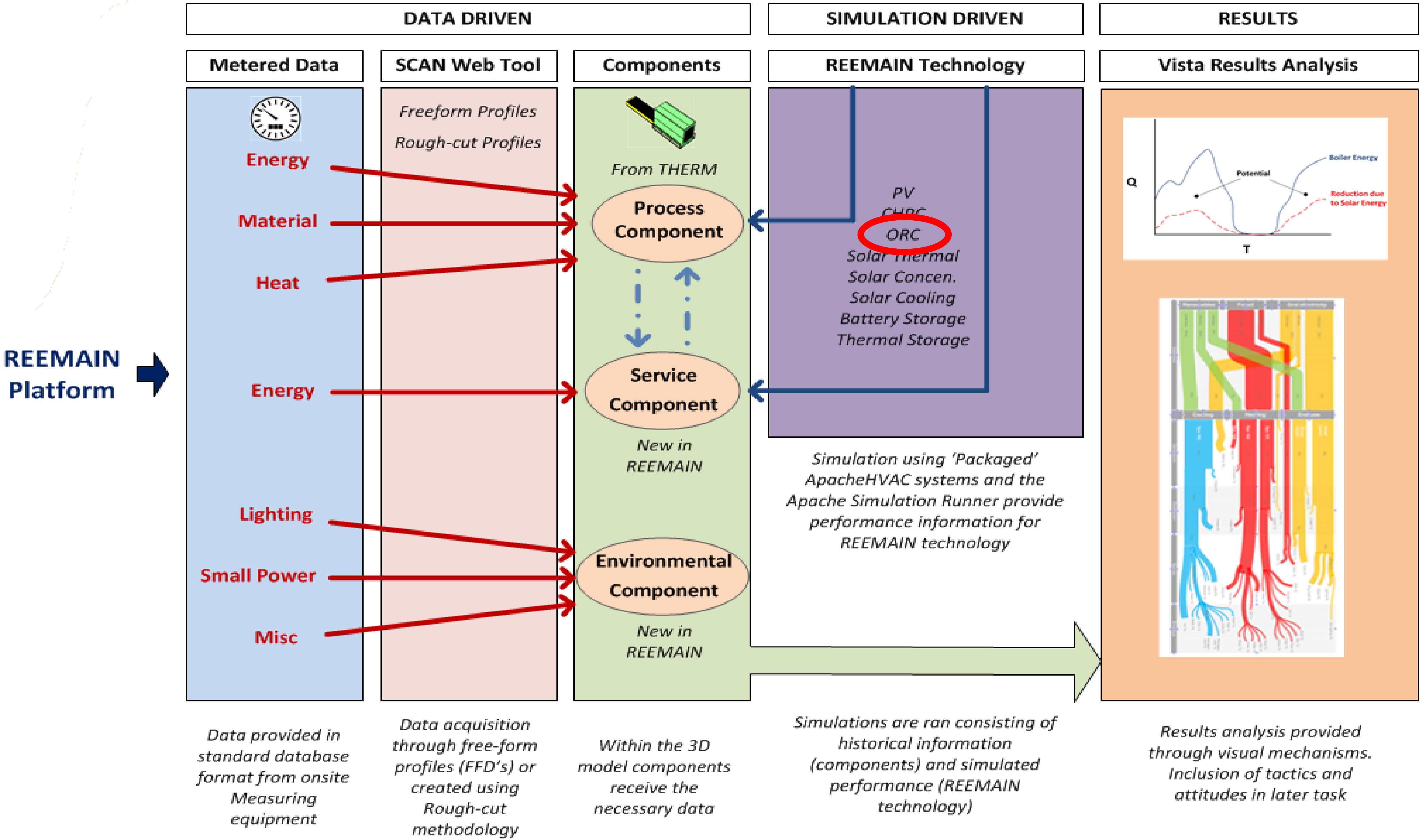
- Based on building physics
- Continuous solution of differential equations
- Ideal for modelling interactions with the environment
- Can be time consuming to model a whole year (computationally intensive)
- Can be used to optimise building design

Manufacturing system simulation

- Based on Monte-Carlo simulation
- Models transitions between discrete events
- Ideal for modelling queue behaviour and stochastic events
- Can deliver rapid results for a whole year if animation if not used
- Can be used to optimise system design







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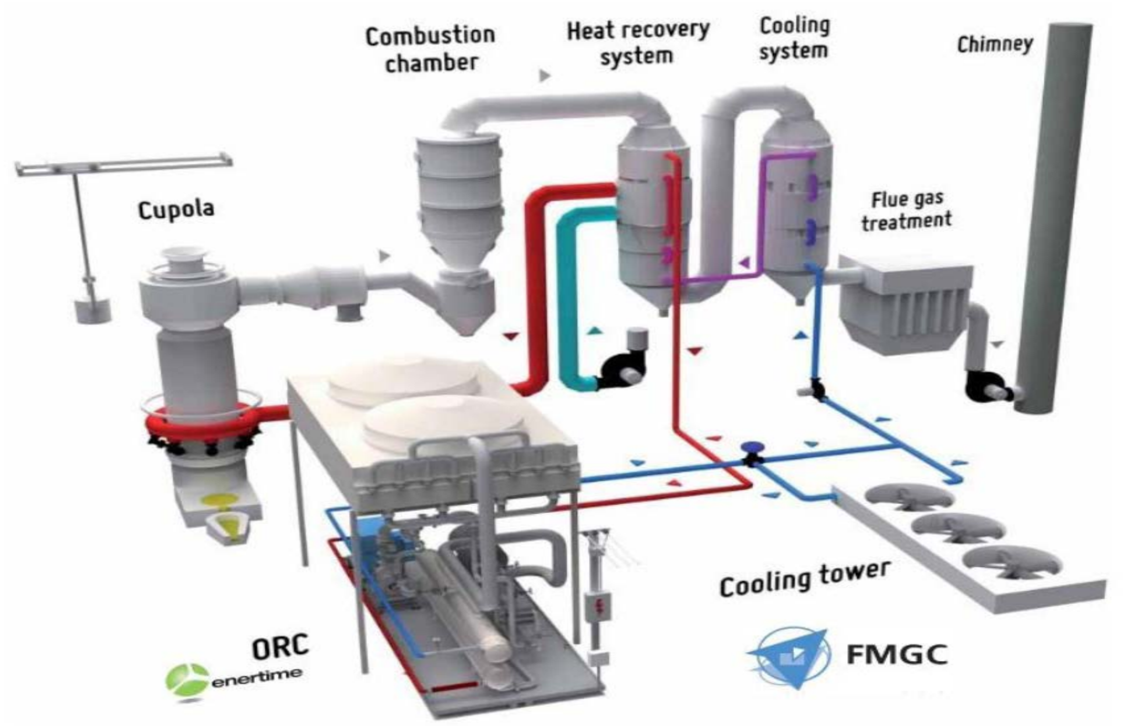
SIMULATION DRIVEN
RESULTS
Metered Data
SCAN Web Tool
Components
REEMAIN Technology
Vista Results Analysis
REEMAIN Platform
Energy
Material
Heat
Energy
Lighting
Small Power
Misc
Freeform Profiles
Rough-cut Profiles
From THERM
Process Component
Service Component
New in REEMAIN
Environmental Component
New in REEMAIN
PV
ORC
Solar Thermal
Solar Concen.
Solar Cooling
Battery Storage
Thermal Storage
Simulation using 'Packaged' ApacheHVAC systems and the Apache Simulation Runner provide performance information for REEMAIN technology
Q
T
Potential
Boiler Energy
Reduction due to Solar Energy
Data provided in standard database format from onsite Measuring equipment
Data acquisition through free-form profiles (FFD's) or created using Rough-cut methodology
Within the 3D model components receive the necessary data
Simulations are ran consisting of historical information (components) and simulated performance (REEMAIN technology)
Results analysis provided through visual mechanisms. Inclusion of tactics and attitudes in later task

Renewable energy options for a foundry

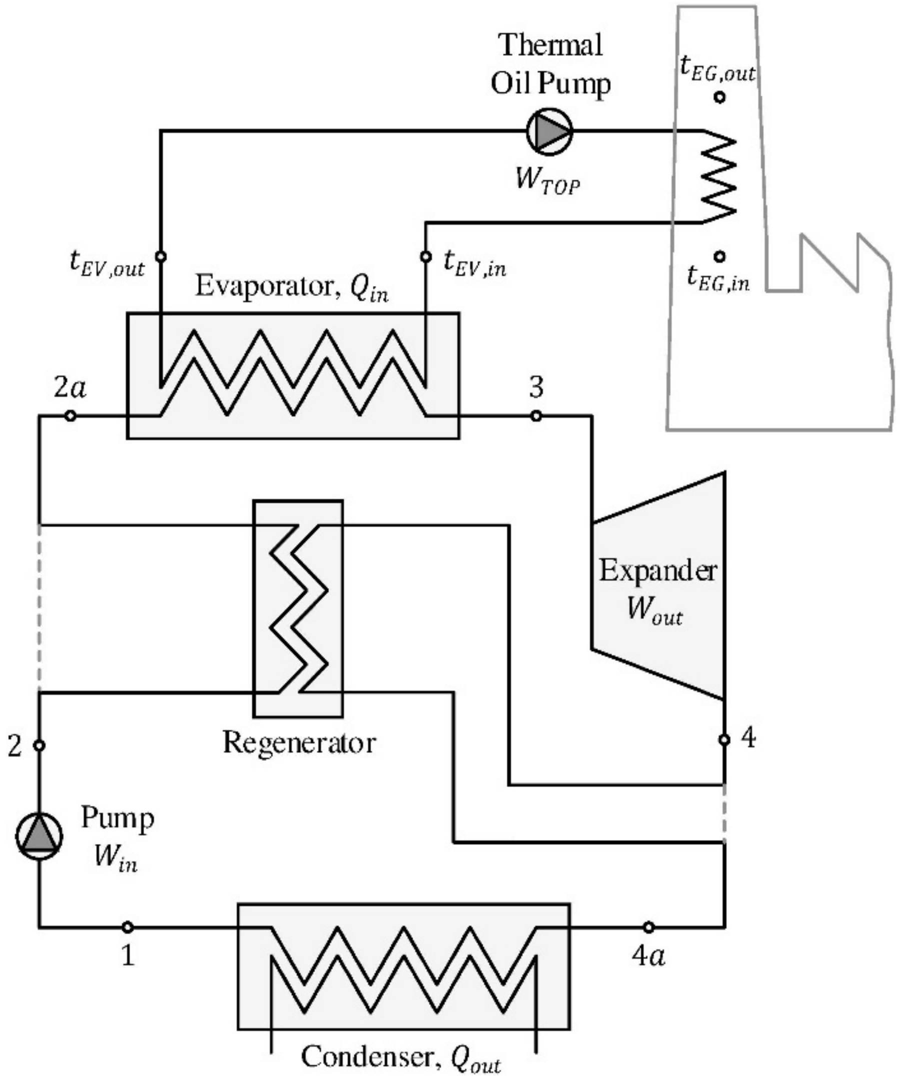
- High temperature processes
  - To melt iron needs 1600°C
  - Aluminium melts at 660°C
- Use (lots of) PV for an electric furnace?
- Use waste from cupola flue for:
  - Space heating in the core shop
  - To generate electricity via Organic Rankine cycle (ORC)
- Example: FMGC foundry (France)
  - Flue gases exchange heat with air and thermal fluid which drives ORC
  - 5.6 MW of thermal power available
  - Generates 1MW of electric power



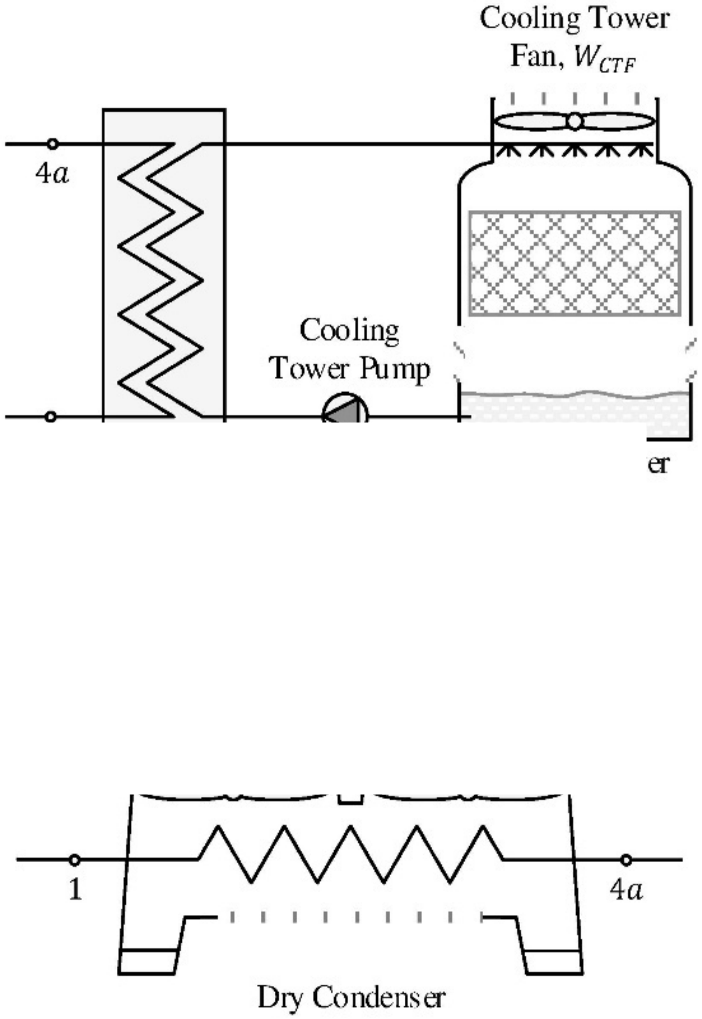
Organic Rankine cycle

- Similar principle to steam Rankine cycle
  - Heat is used to raise temperature and pressure of working fluid
  - Fluid expanded in a turbine to drive a generator
- Use of organic fluid lowers temperatures so can be used to generate from waste heat
- Generally much less efficient than steam cycle
- Many different working fluids and configurations of ORC

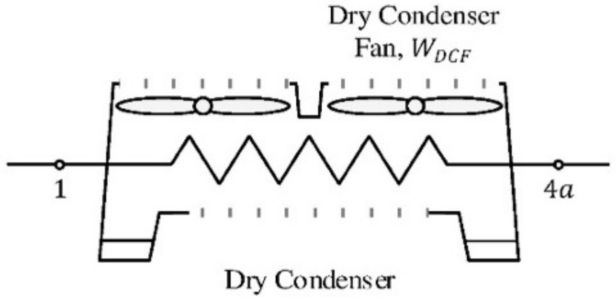
Components of ORC system

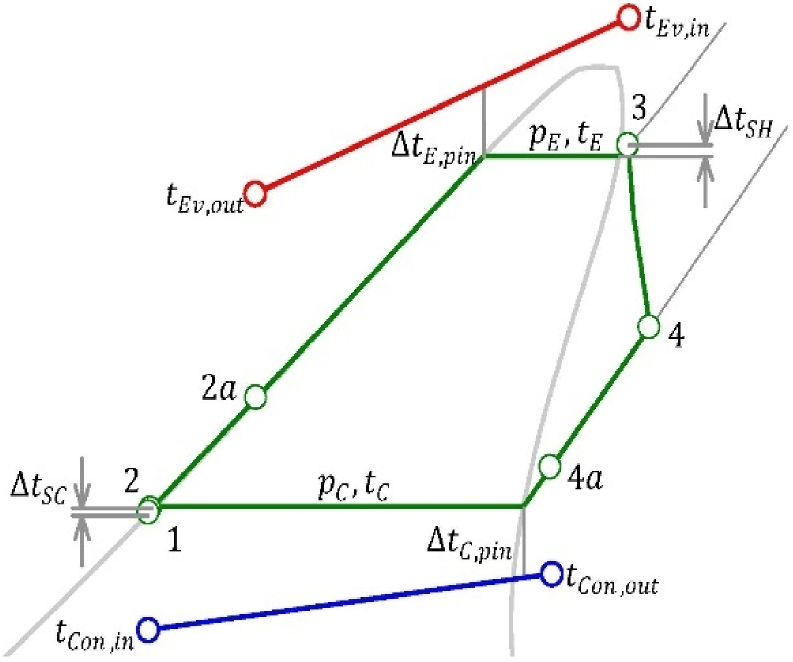


a) Water-cooled condenser



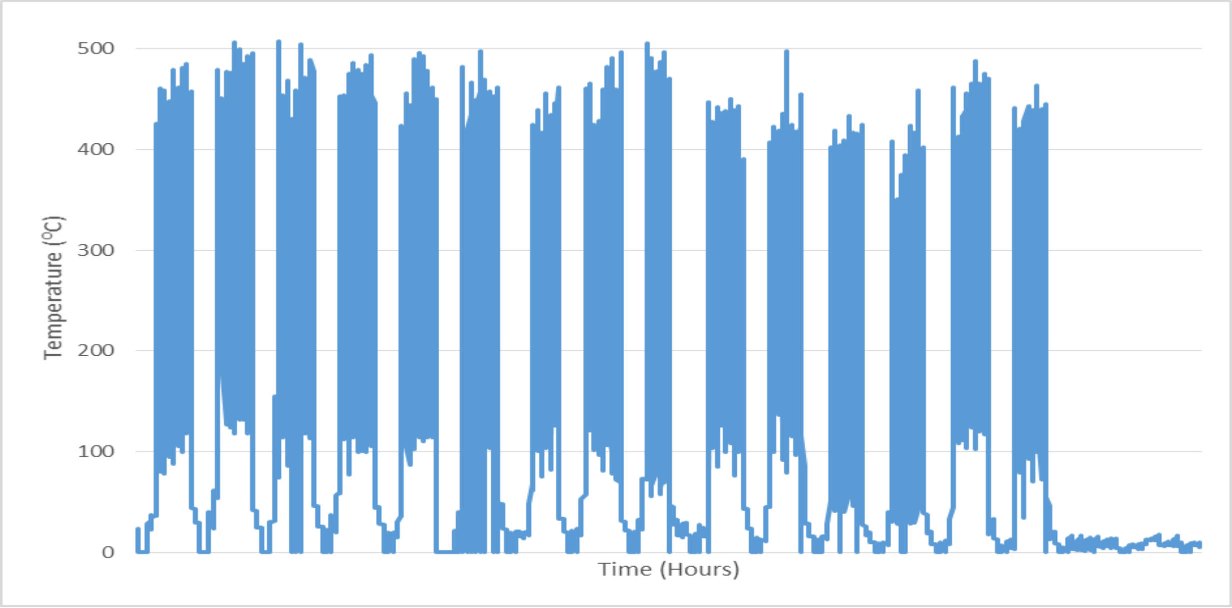
b) Air-cooled condenser

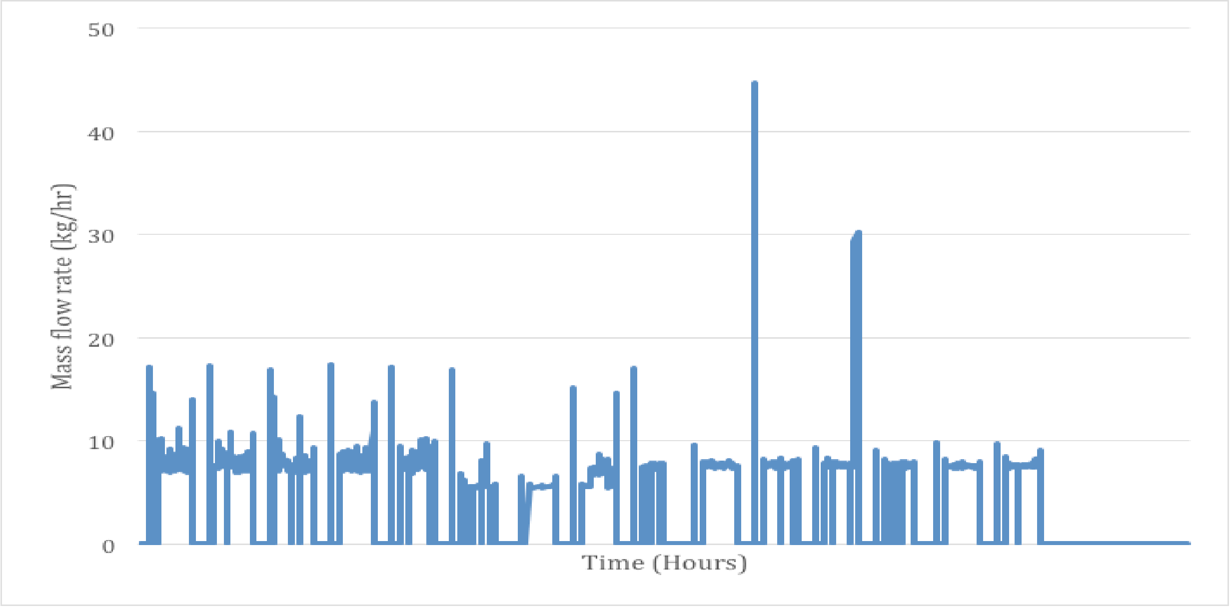




Temperature-entropy diagram for ORC

Variability of mass flow and temperature





Available energy from waste heat is highly dependent on manufacturing schedule.

Can be generated synthetically if schedule and dependency are known

Results for air-cooled condenser

	ORC settings				ORC results				
Simulations	ORC Type	ORC Refrigerant	Heat recovery	Condensation pressure limit	Waste heat used in ORC (MWh)	ORC generated electricity (MWh)	Thermal oil pump electricity consumption (MWh)	Dry cooler fan electricity consumption (MWh)	System seasonal COP
Test_001	Air-cooled	Isopentane	Yes	1.1atm	1974.74	334.42	1.28	0.22	0.17
Test_002	Air-cooled	R245fa	Yes	1.1atm	1974.74	257.37	1.28	0.25	0.13
Test_003	Air-cooled	1-Butene	Yes	1.1atm	1974.74	235.25	1.28	0.26	0.12
Test_004	Air-cooled	n-Pentane	Yes	1.1atm	1974.74	352.24	1.28	0.22	0.18
Test_005	Air-cooled	Isopentane	Yes	No	1974.74	334.42	1.28	0.22	0.17
Test_006	Air-cooled	R245fa	Yes	No	1974.74	257.38	1.28	0.25	0.13
Test_007	Air-cooled	1-Butene	Yes	No	1974.74	235.26	1.28	0.26	0.12
Test_008	Air-cooled	n-Pentane	Yes	No	1974.74	352.24	1.28	0.22	0.18
Test_009	Air-cooled	Isopentane	No	1.1atm	1974.74	281.64	1.28	0.14	0.14
Test_010	Air-cooled	R245fa	No	1.1atm	1974.74	238.08	1.28	0.20	0.12
Test_011	Air-cooled	1-Butene	No	1.1atm	1974.74	224.68	1.28	0.23	0.11
Test_012	Air-cooled	n-Pentane	No	1.1atm	1974.74	297.16	1.28	0.14	0.15
Test_013	Air-cooled	Isopentane	No	No	1974.74	281.64	1.28	0.14	0.14
Test_014	Air-cooled	R245fa	No	No	1974.74	238.08	1.28	0.20	0.12
Test_015	Air-cooled	1-Butene	No	No	1974.74	224.69	1.28	0.23	0.11
Test_016	Air-cooled	n-Pentane	No	No	1974.74	297.17	1.28	0.14	0.15

Results for water-cooled condenser

	ORC settings				ORC results					
Simulations	ORC Type	ORC Refrigerant	Heat recovery	Condensation pressure limit	Waste heat used in ORC (MWh)	ORC generated electricity (MWh)	Thermal oil pump electricity consumption (MWh)	Coolong tower pump electricity consumption (MWh)	Coolong tower fan electricity consumption (MWh)	System seasonal COP
Test_017	Water-cooled	Isopentane	Yes	1.1atm	1975.15	370.56	1.28	21.25	0.57	0.18
Test_018	Water-cooled	R245fa	Yes	1.1atm	1975.15	294.38	1.28	22.29	0.59	0.14
Test_019	Water-cooled	1-Butene	Yes	1.1atm	1975.15	272.74	1.28	22.58	0.60	0.13
Test_020	Water-cooled	n-Pentane	Yes	1.1atm	1975.15	384.41	1.28	21.06	0.56	0.18
Test_021	Water-cooled	Isopentane	Yes	No	1975.15	370.56	1.28	21.25	0.57	0.18
Test_022	Water-cooled	R245fa	Yes	No	1975.15	294.38	1.28	22.29	0.59	0.14
Test_023	Water-cooled	1-Butene	Yes	No	1975.15	272.74	1.28	22.58	0.60	0.13
Test_024	Water-cooled	n-Pentane	Yes	No	1975.15	387.74	1.28	21.02	0.56	0.18
Test_025	Water-cooled	Isopentane	No	1.1atm	1975.15	308.39	1.28	22.10	0.59	0.14
Test_026	Water-cooled	R245fa	No	1.1atm	1975.15	269.22	1.28	22.63	0.60	0.12
Test_027	Water-cooled	1-Butene	No	1.1atm	1975.15	258.39	1.28	22.78	0.61	0.12
Test_028	Water-cooled	n-Pentane	No	1.1atm	1975.15	318.61	1.28	21.96	0.59	0.15
Test_029	Water-cooled	Isopentane	No	No	1975.15	308.38	1.28	22.10	0.59	0.14
Test_030	Water-cooled	R245fa	No	No	1975.15	269.22	1.28	22.63	0.60	0.12
Test_031	Water-cooled	1-Butene	No	No	1975.15	258.38	1.28	22.78	0.61	0.12
Test_032	Water-cooled	n-Pentane	No	No	1975.15	323.75	1.28	21.89	0.58	0.15

Conclusions

- Tentative conclusions based on incomplete year
- Recuperator always has a significant impact on output and CoP
- Water-cooled condenser increases max output by 10%, but not CoP
  - At the expense of cost and complexity
- Isopentane or n-pentane are best working fluids of those modelled, in these conditions, depending on choice of condenser
- Ignoring condenser lower pressure limit has no effect for air-cooled condenser but increases output (though not CoP) slightly for water-cooled design
  - Note this might be unwise because it could allow moisture or air contamination of working fluid
- This version of integrated building modelling and decision support tool allows:
  - Analysis of the impact of climate on ORC performance
  - Sensitivity analysis of different design parameters

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Efficiency Analysis Methodology

- Characterising energy demand from factory
  - Electricity demand (power)
  - Heat demand (process heat and space heat)
  - Cooling demand
- Modelling and analysing energy systems
- Modelling factory and manufacturing systems
  - Example: rough-cut energy modelling

demand profiles in Siemens's Plant Simulation software which is an industry standard for modelling production systems and their processes.

5.3.1 IES-VE ROUGH-CUT MODELLING

The main aim of the IES-VE rough-cut modelling tool is to develop more detailed facility's energy consumption profiles (preferably at hourly intervals) from available low-resolution data such as monthly or annual utility bills.

The rough-cut methodology is deployed via a web interface which facilitates collaborative effort and also allows for easy integration with real-time data when it becomes available. First a utility bill or set of utility bills is attached to the project. Figure 40 shows a daily gas bill attached to the web platform. This can be daily, weekly or annual.

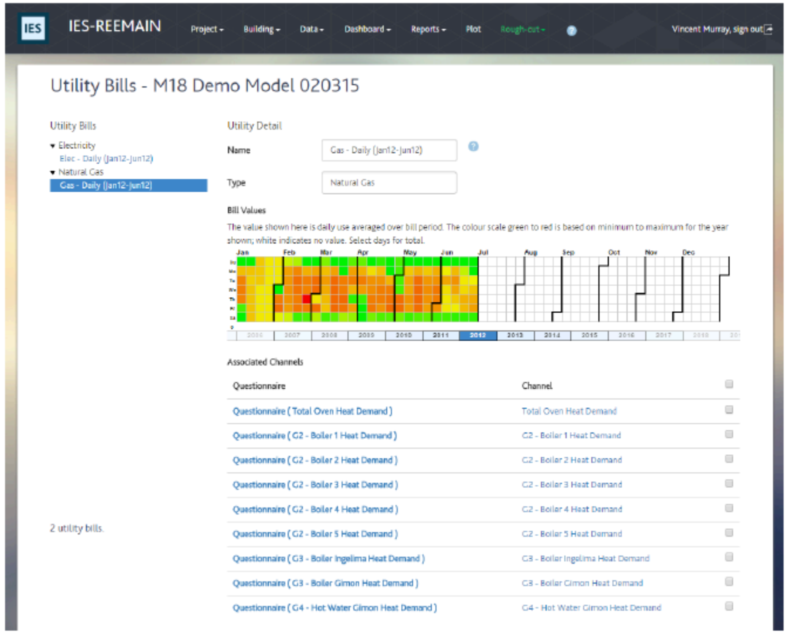

FIGURE 40 UTILITY BILL AND ASSOCIATED ROUGH-CUT DATA CHANNELS IN THE WEB PLATFORM

The tool then allows users to define the performance of each piece of equipment (called components in IES-VE modelling) attached to the utility bill. This can be done in the following ways:

- Manual creation of profiles – experienced users
- Use of standardised profiles from industry e.g. NCM in the UK
- Provide answers to a questionnaire – less experienced users

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Best Practices Book

- 18 best practices summarising project findings
    - Design
    - Operations and maintenance
    - Exploitation and dissemination
- All deliverables available at **www.reemain.eu**


#3 BEST PRACTICE ON DESIGN

REPLICABILITY ●●●●●

FACTORIES: BE PREPARED TO COOPERATE WITH RESEARCH ORGANIZATIONS

Implementation of, for example, energy efficiency measures is not always easy in factories and the expected results are only possible if there is a real commitment from them. As factories do not always have the time or required technical staff in house required for this, they should look into collaborations with research organizations or other experts in the field. Such cooperation should help them define the technical aspects which guarantee project innovation and find the expected results.

STAKEHOLDERS

Designers · Research institutions · Factory owners · Workers · Contractors · Public Bodies · Investors

REEMAIN PRACTICAL EXPERIENCE

In REEMAIN we see quite clearly how important this kind of collaboration was. Production and consumption data from factories are limited and often confidential, limiting the possibilities for information exchange and improvement. Because of this, joining forces with the research organizations is a key factor in order to define the technical improvements and its assessment both before and after measures are installed.

OUR ADVICE

- *Provide as many specific and detailed data as possible. Being generic won't help reaching the efficiency goals.*

CAUTION

- *If you are thinking about a very innovative project don't assume you can do it all by yourself. You may need help, at least on certain aspects.*

IMPACT RATING

Energy consumption	Environmental impact	Planning expenditures	Performance impact	Economic/admin. impact
★★★★☆	★★★★☆	★★★★☆	★★★☆☆	★★★★☆

Funding Opportunities for Low Carbon Projects

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