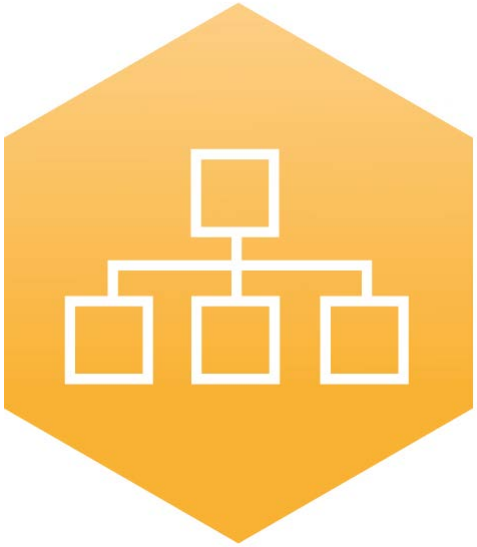
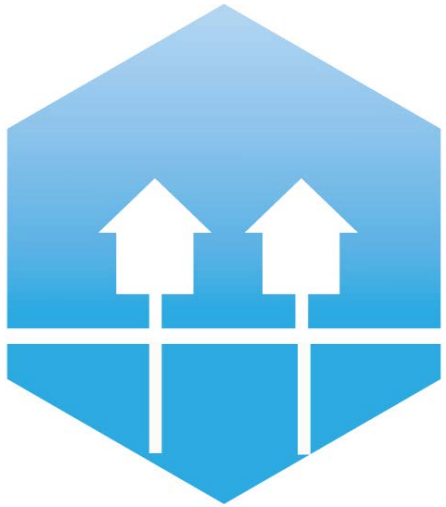
International Conference on Smart Energy Systems and 4th Generation District Heating, Copenhagen, 25-26 August 2015

Current and future prospects for heat recovery from waste in European district heating systems: A literature and data review

Urban Persson
Halmstad University





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How much waste will be available for European district heating systems in the future (2030)?

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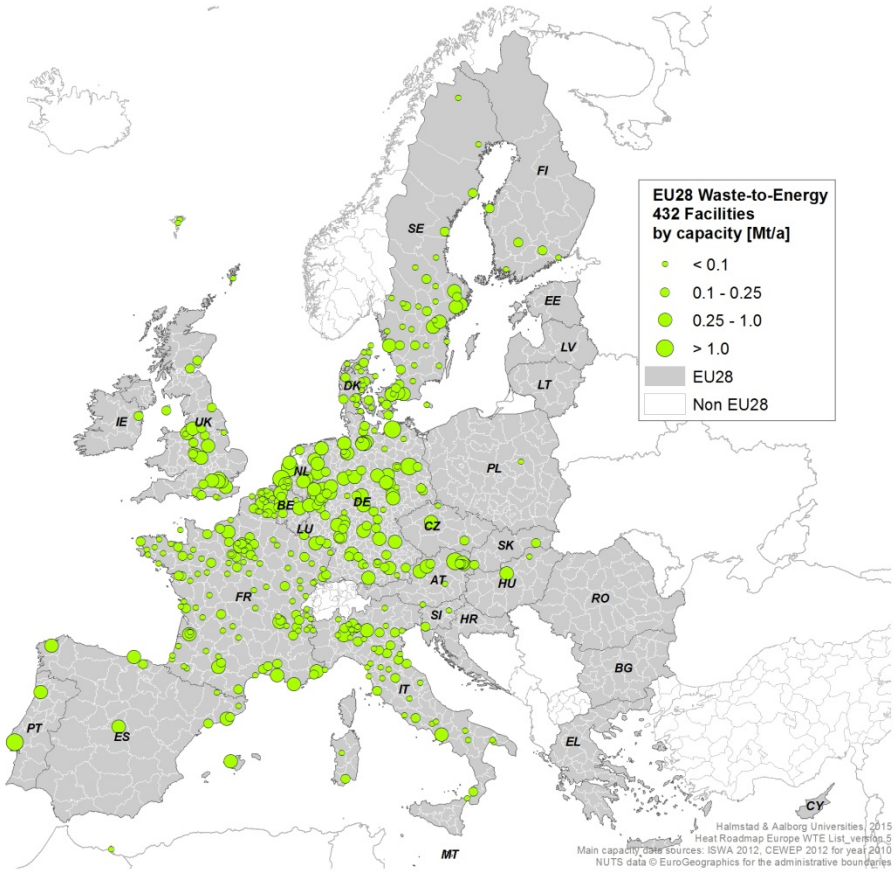
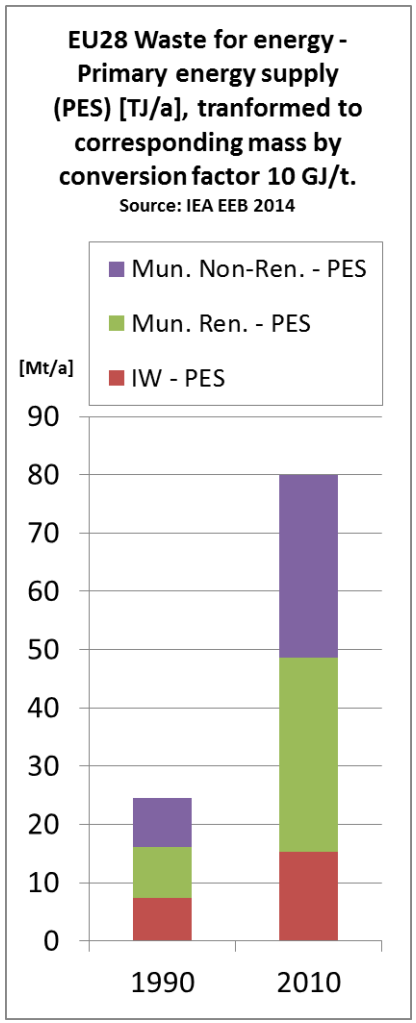
Heat Roadmap Europe – WtE study



- HRE – EU28 WtE list v5, Oct, 2013 (Ref. year 2010)
- Comprehensive assembly of European WtE facilities by synchronisation of several sources:
  - ISWA (e.g. SR 2012)
  - E-PRTR (emissions DB)
  - CEWEP
  - Other reports, websites, etc.
- 432 dedicated WtE facilities in operation
- Anticipated total annual incineration capacity: ~86 Mt/a

IEA extended energy balances



- IEA EEB, v2014 (Ref. year 2010)
- Reports on waste volumes for energy purposes:
  - Municipal – Non-renewable
  - Municipal – Renewable
  - Industrial waste (IW)
- Total PES in 2010: ~80 Mt
  - 1990: ~25 Mt
- Correspondning volumes 2010:
  - at conv. factor 10 GJ/t
  - PES_{Mun+IW}: 800 PJ
  - PES_{Mun} ≈ 648 PJ
  - Electricity out: 130 PJ/119 PJ
  - Heat out: 171 PJ/159 PJ
  - Overall efficiency: η_{tot} ≈ 38%/43%
  - Heat recovery: η_{heat} ≈ 21%/25%

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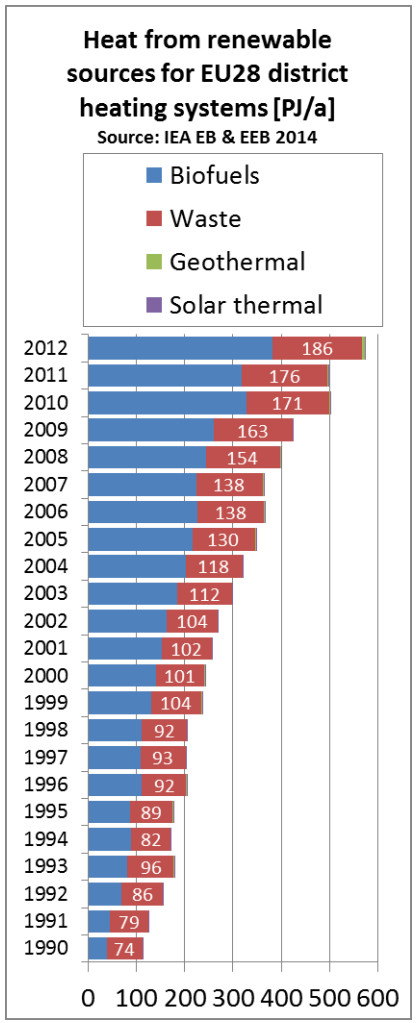

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Main study concerns & Overview

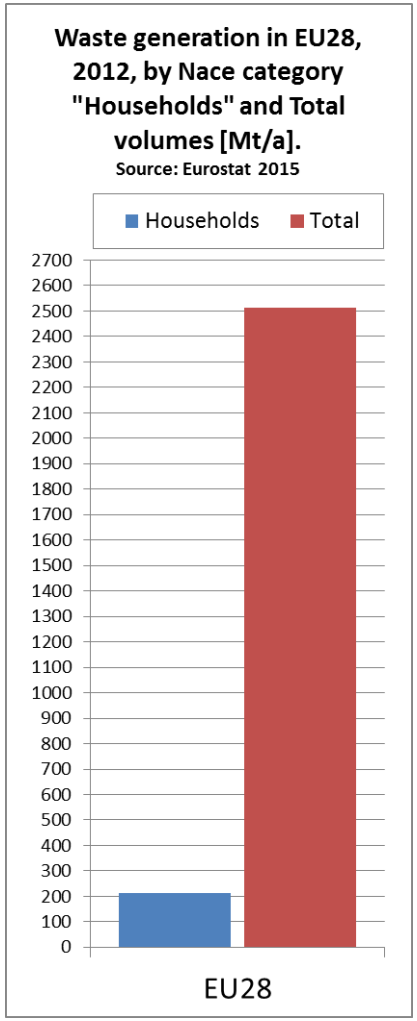
- How much waste will be generated in Europe in 2030?
  - Generation and treatment – So far…
  - Generation in the future – Modelling…
- How much district heating will Europe have in 2030?
  - District heating – So far…
  - District heating in the future - Modelling…
- How much of the generated waste in 2030 will be available for incineration and heat recovery?
  - Circular Economy and Energy Union
  - New targets under discussion…
- One answer of many possible answers…
- Future work & Conclusions

4DH work Programme 2014-2015: Item 19: Model the waste available for district heating (WP2)

Generation of waste is a symbiotic, unfortunate, and potentially detrimental consequence of producing and consuming material goods and services in the world today

Generation and treatment – So far…

- Household waste is just a fraction of total waste volumes!
  - Household waste, 2012: ~215 Mt
  - All waste generated, 2012: ~2.200 Mt



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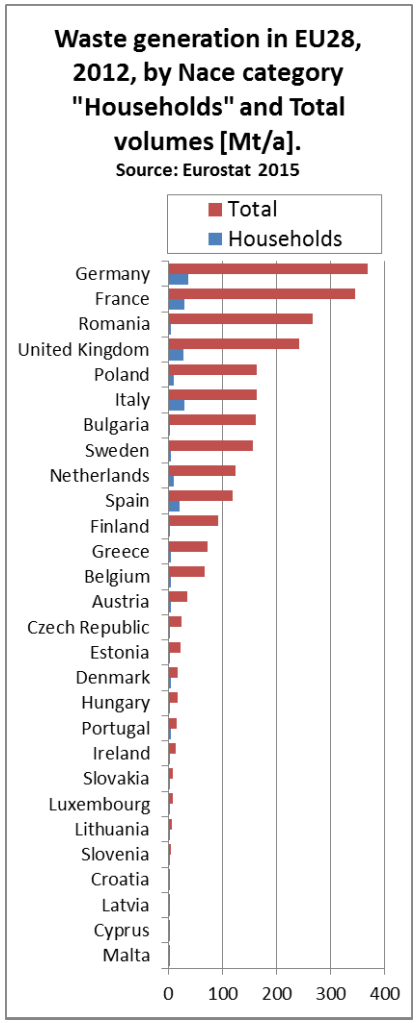

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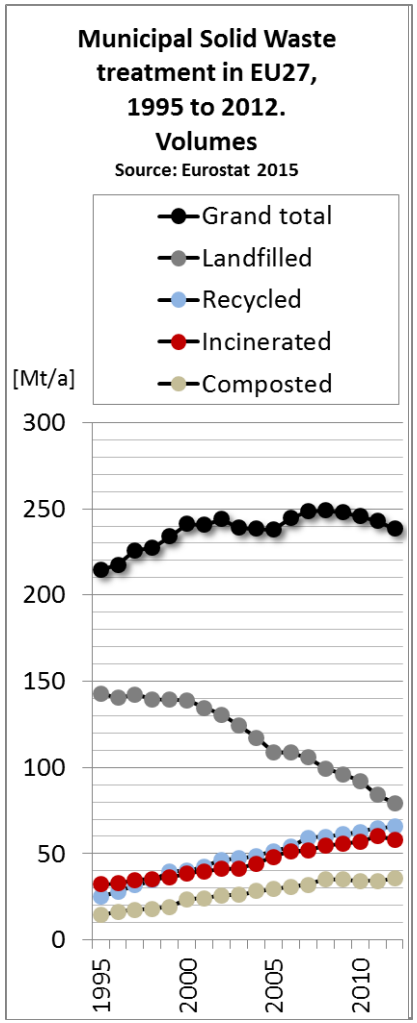
  - Volumes
    - ~250 Mt, declining briefly…
    - 58 Mt for incineration (2012)!



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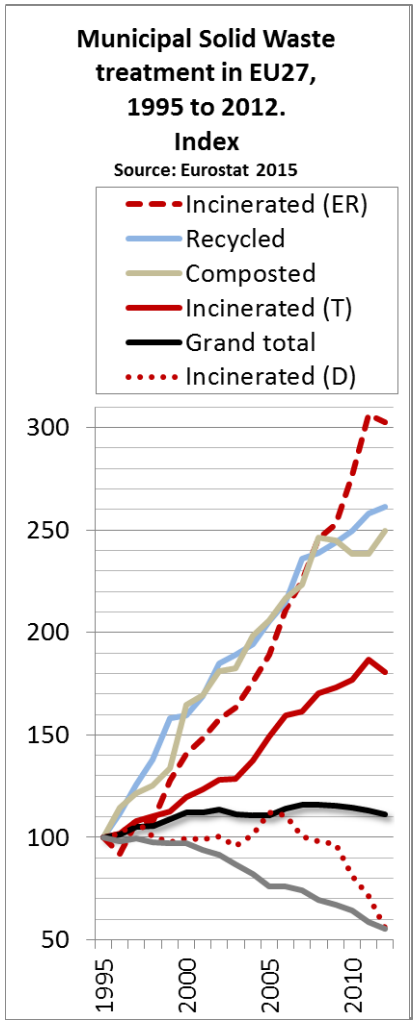
    - Incineration (ER), 3/1 increase



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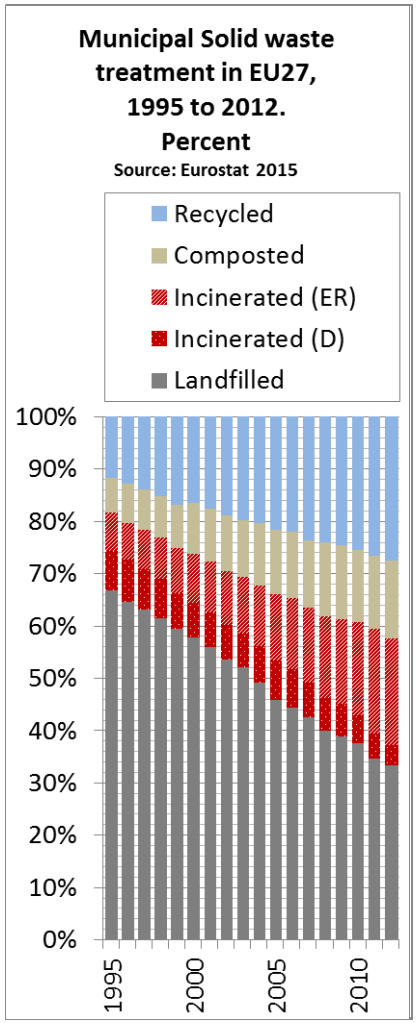
  - Index
    - Incineration (ER), 3/1 increase
  - Percent
    - Landfill: -34% since 1995



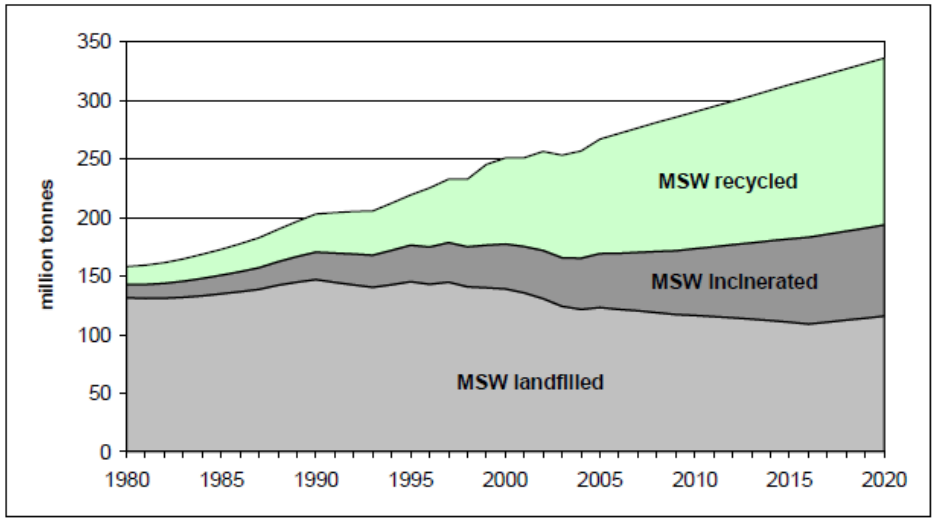
Generation in the future – Modelling…

- General equilibrium models
  - 1990s: Using material balances (input/output) in industry sectors to assess total waste generation in given industries.
    - National studies (Norway, USA, e.g. Alfsen, Bruvoll and Ibenholt, Ayres)
  - Waste generation modelled on the basis of different production factors (material, capital etc.) and composite commodities (products, fuels etc.).
    - National studies (Sweden, e.g. Sjöström, Östblom, Sundqvist)
- Econometric models
  - 2000s: Constant elasticity models: Multiple linear regressions analyses with key variables household consumption, GDP per capita etc.
    - European studies (e.g. Andersen, Skovgaard, Larsen. ETC Copenhagen)
  - Non-linear regressions: Extending independent variables to structural and socio-economic contexts. Squared and cubed variables.
    - European studies (e.g. Mazzanti, Zoboli)
- The Europan Reference Model (EC/EEA)
  - 2014: A system of operational modules (e.g. Fischer, Bakas, Gentil (exETC))

Generation in the future – Modelling…

- Econometric models
  - Constant elasticity models: Multiple linear regressions with key variables:
    - Household consumption
    - GDP per capita
    - Population
  - ETC/RWM WP 2008/1
    - Ref. 2030: DG TREN 2006

Figure 7.3 Municipal waste management in the EU-27



Source: Skovgaard, M., Hedal, N., Villanueva, A., Andersen, F.M., Larsen, H., 2008. Municipal waste management and greenhouse gases, ETC/RWM working paper 2008/1. European Topic Centre on Resource and Waste Management. Copenhagen.

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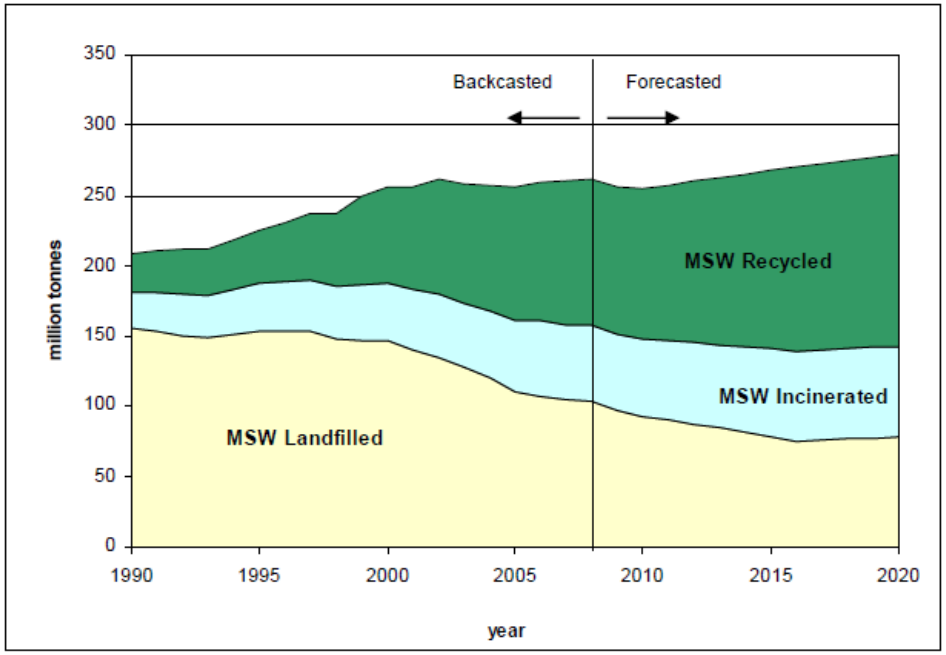
    - Ref. 2030: DG ENER 2010

Figure 1.1 Projected generation and management of municipal waste in the EU-27 + Norway and Switzerland



Source: Bakas, I., Sieck, M., Hermann, T., Andersen, F.M., Larsen, H., 2011. Projections of Municipal Waste Management and Greenhouse Gases, ETC/SCP working paper 4/2011. European Topic Centre on Sustainable Consumption and Production. Copenhagen.

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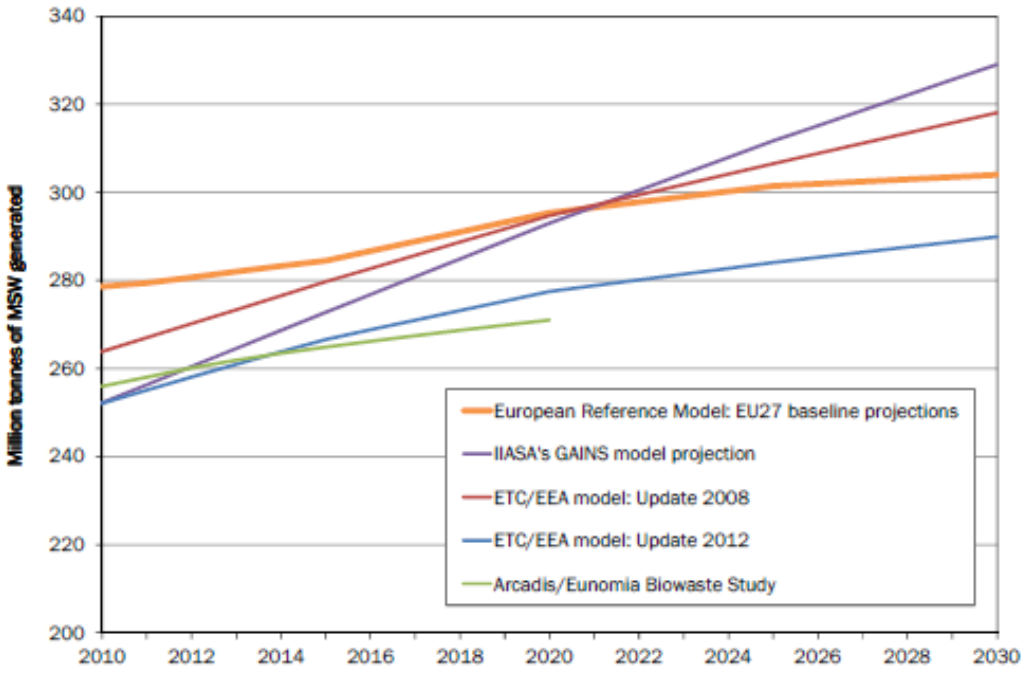
  - ETC/RWM WP 2008/1
    - Ref. 2030: DG TREN 2006
  - ETC/SCP WP 4/2011
    - Ref. 2030: DG ENER 2010
- The Europan Reference Model (EC/EEA)
  - EU27 Baseline scenario

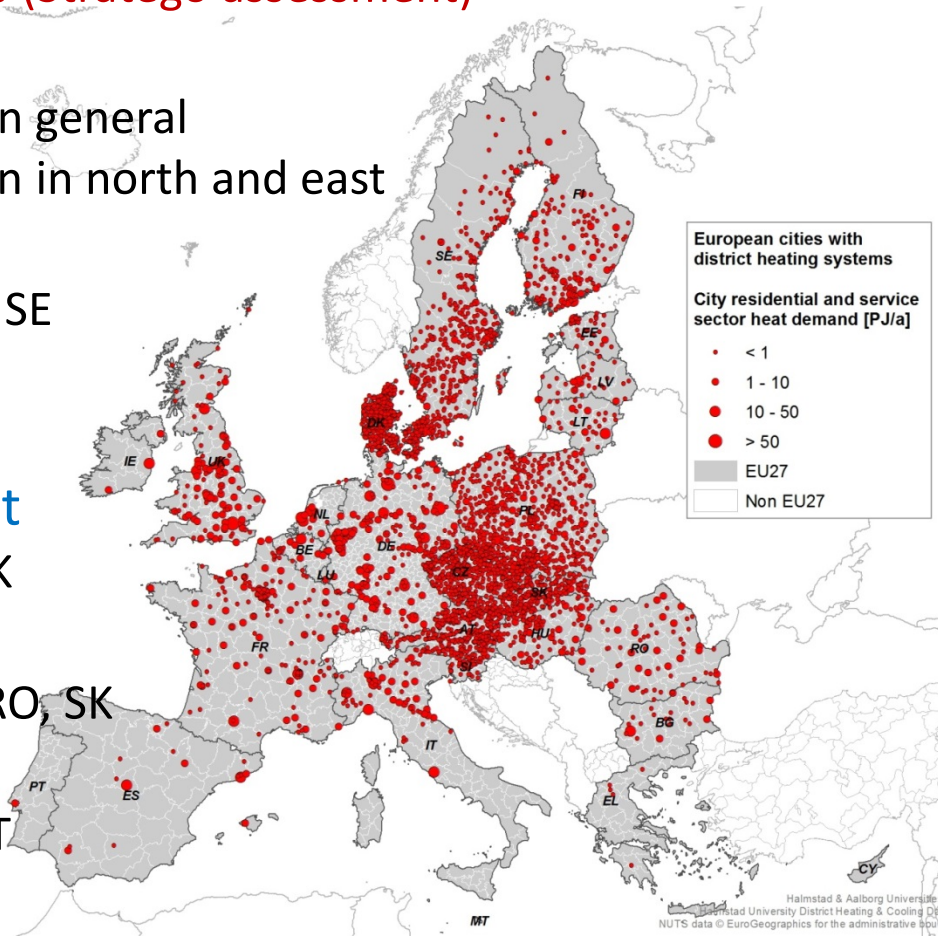
Figure 4-1 Historical and Projected MSW Generation in EU-27

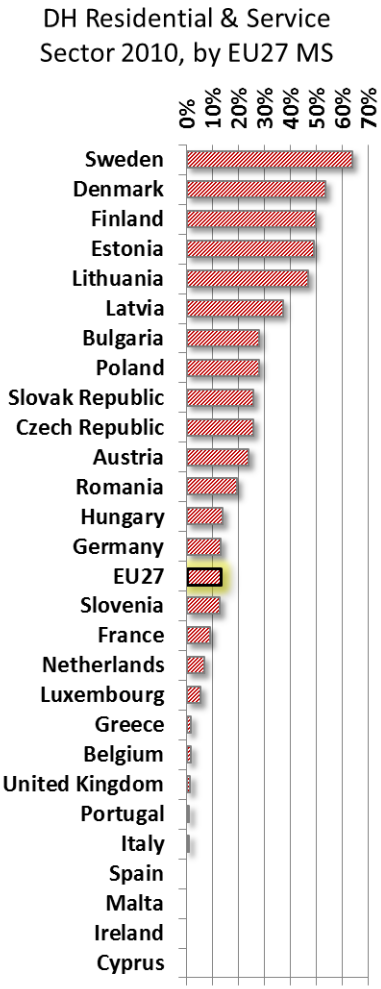


Source: Gibbs, A., Elliot, T., Vergunst, T., Ballinger, A., Hogg, D., Gentil, E., Fischer, C., Bakas, I., 2014. Development of a Modelling Tool on Waste Generation and Management. Headline Project Report. Final Report for the European Commission DG Environment under Framework Contract No ENV.C.2/FRA/2011/0200. 07/02/14, Eunomia Research & Consulting (UK) and Copenhagen Research Institute (DK). Bristol and Copenhagen.

District heating – So far…

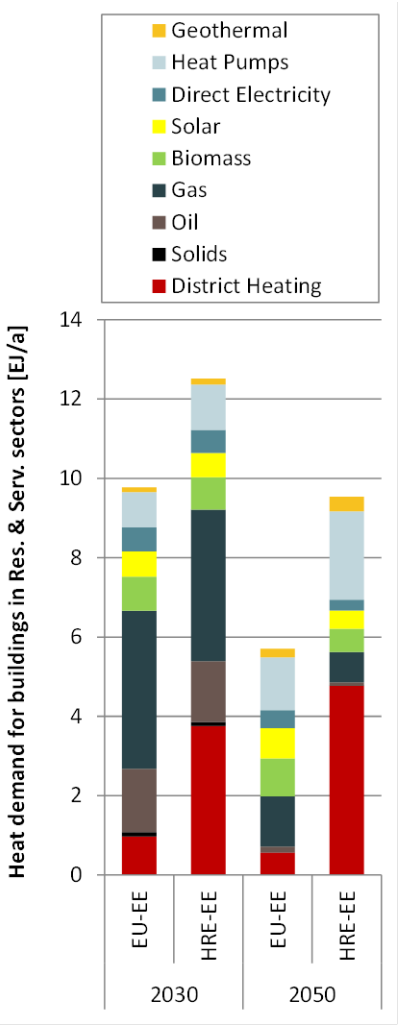
- ~12% of EU building heat market in 2010
  - ~1.6 EJ of 13.1 EJ (Stratego assessment)
- ~6000 systems
  - Widely present in general
  - Large distribution in north and east
- Consolidation
  - DK, EE, FI, LT, LV, SE
- Expansion
  - AT, DE, FR, IT, SI
- New Development
  - BE, IE, LU, NL, UK
- Refurbishment
  - BG, CZ, HU, PL, RO, SK
- Out-of-scope
  - CY, EL, ES, MT, PT





District heating in the future - Modelling…

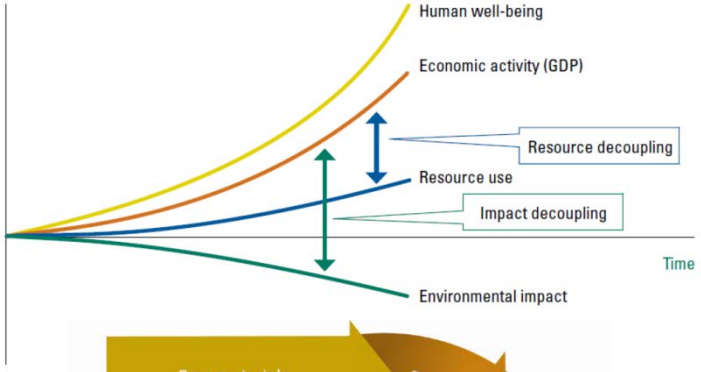
- Heat Roadmap Europe – Pre-study 2
  - WtE potentials
  - Incineration heat:
    - 2030: 330 PJ (~33 Mt)
    - 2050: 585 PJ (~59 Mt)
- Corresponding total waste for energy volumes (MSW)
  - If heat recovery efficiencies are increased to:
    - 25% (2010): 132 Mt/236 Mt
    - 30%: 110 Mt/197 Mt
    - 40%: 83 Mt/148 Mt
    - 50%: 66 Mt/118 Mt

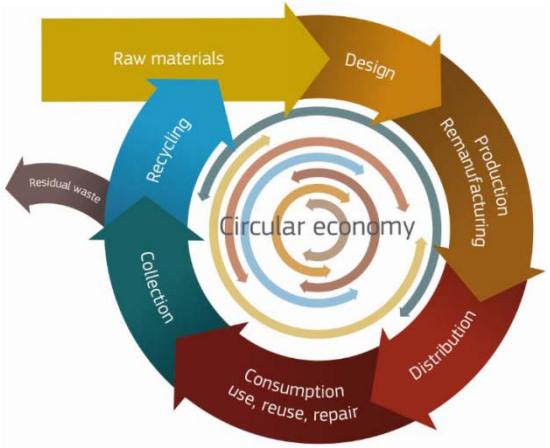


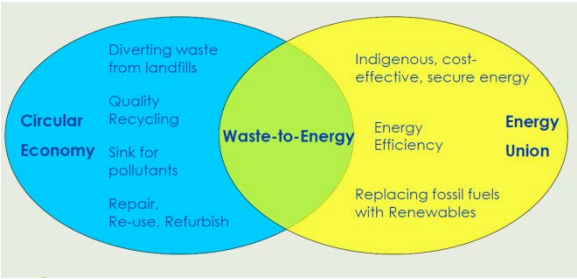
Treatment of waste may provide synergetic, efficient, and environmentally beneficial contributions in terms of materials and energy in the world today

Circular Economy and Energy Union

- Fundamental idea from the EU 6th Environment Action Programme:
  - Decoupling of human well-being and GDP from resource use!
- A circular economy
  - Recycling, reuse, recovery
  - Prio 1: Material perspective
- An energy union
  - WtE – an enabling technology and concept to unite efficiency in both materials and energy!







New targets under discussion…

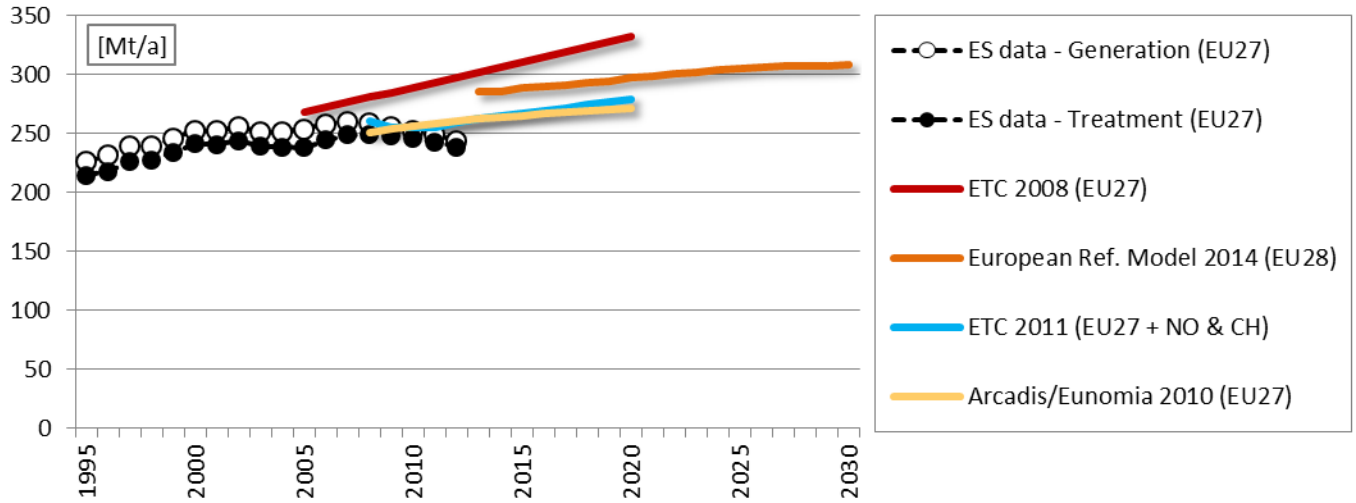
- Discussed EU targets for 2030:
  - 70% recycling of household wastes
    - Previous target: 50%... Collected for recycling
  - 80% recycling and preparation for reuse of packaging waste
  - Landfill ban for recyclable and biologically degradable waste (by 2025)
  - Landfill ban on all recycling waste

Five scenarios for 2030 run in the EU reference model:

- **Scenario 1:** Full implementation of existing targets.
- **Scenario 2.1**: 60% MSW recycling target by 2030.
- **Scenario 2.2:** 70% MSW recycling target by 2030.
- **Scenario 3:** Limiting the landfilling of MSW residual waste to 5% (in addition to scenario 1.0). This is modelled to result in additional incineration capacity.
- **Scenario 4:** Limiting the landfilling of MSW residual waste to 5% with 70% recycling target in 2030 (i.e. Scenario 3 + scenario 2.2).

One answer of many possible answers…

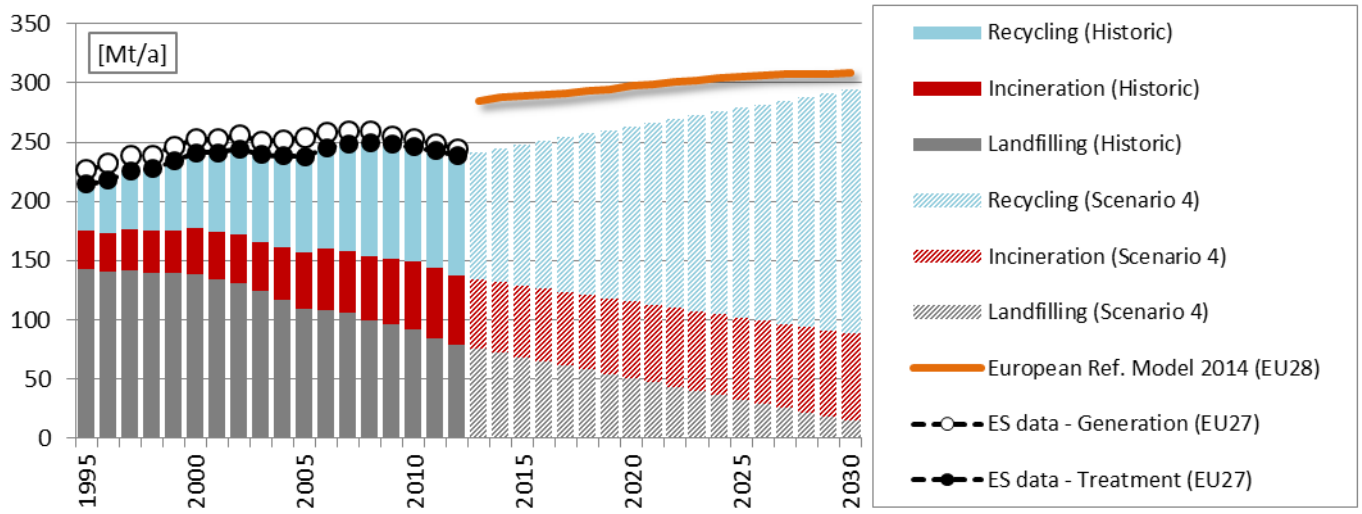
- A closer look at the waste model projections
  - EU ref. model, 2030: 294 Mt treatment (308 Mt generation, 95.6%)
  - Real data might indicate decreasing trends from 2008 (?)



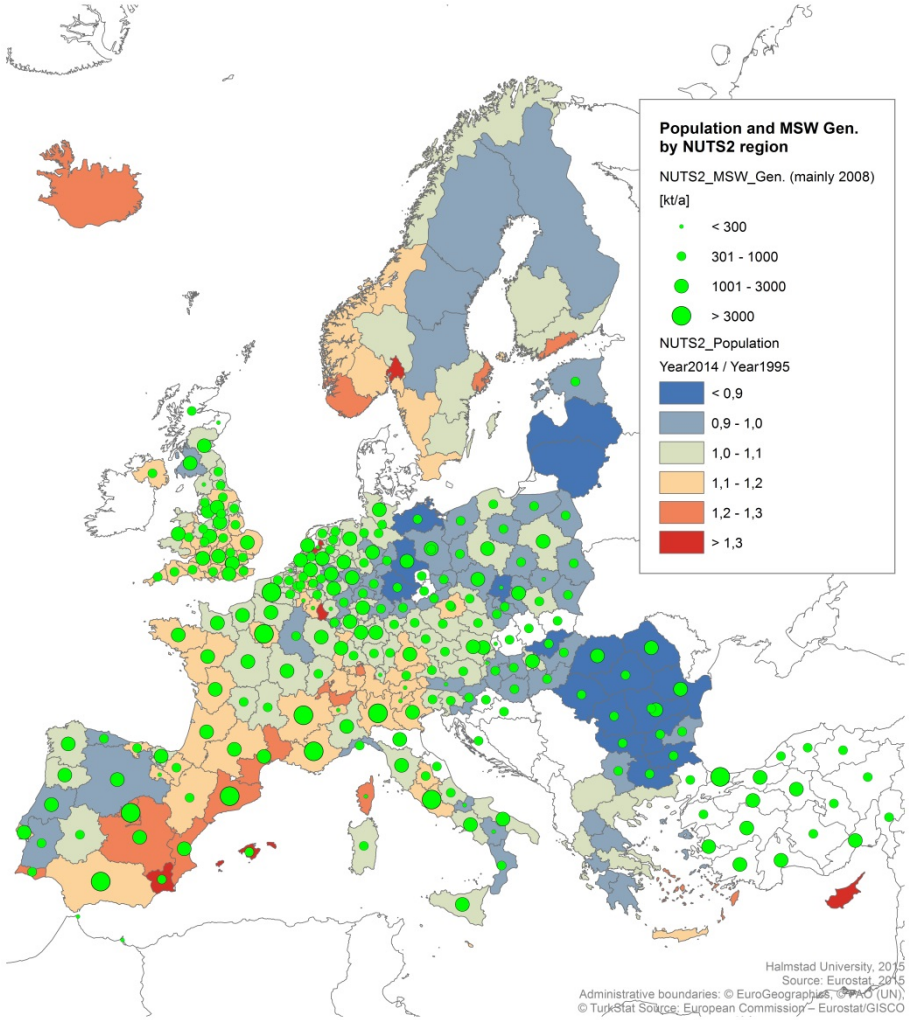
One answer of many possible answers…

- A closer look at the waste model projections
  - EU ref. model, 2030: 294 Mt treatment (308 Mt generation, 95.6%)
  - Real data might indicate decreasing trends from 2008 (?)
- EU reference model (Scenario 4)
- Linear interpolation:
  - 70% recycling: 206 Mt
  - 5% landfilling: ~15 Mt
  - 30% Incineration: ~74 Mt

We repeat:
86 Mt Cap. – HRE WtE List (2013)
58-65 Mt MSW for Inc. in 2010
~16 Mt (159 PJ) for heat in 2010
At η_{heat} = 50%: 37 Mt (~370 PJ)!

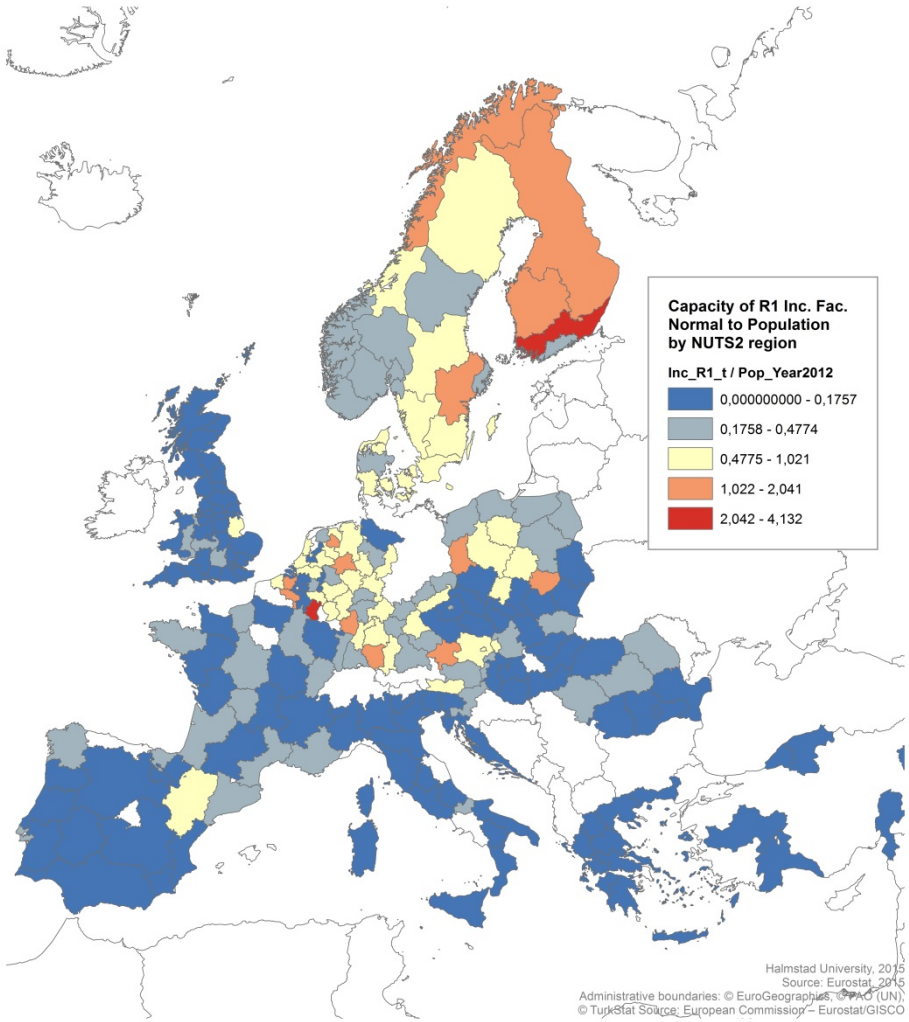


Future work & Conclusions



- But, there are also other concerns than total generation volumes and heat recovery efficiencies
  - NUTS2 waste data (Eurostat)
  - Population trends
  - Urbanisation

Future work & Conclusions



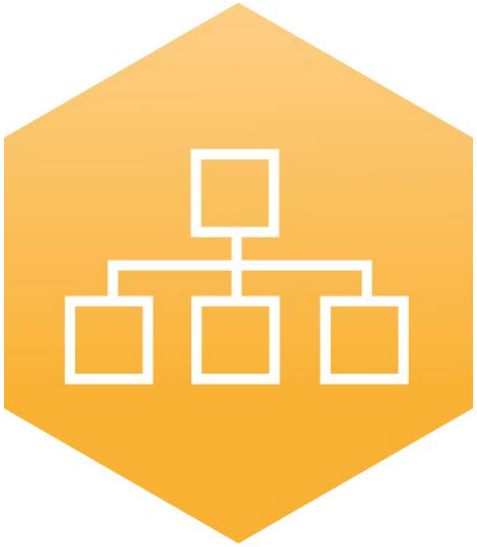
- But, there are also other concerns than total generation volumes and heat recovery efficiencies
  - NUTS2 waste data (Eurostat)
  - Population trends
  - Urbanisation
- Inadequate distribution of incineration capacity
  - High concentration in northern and central MS
  - Exports/Imports of waste?
  - Better with local pollution?

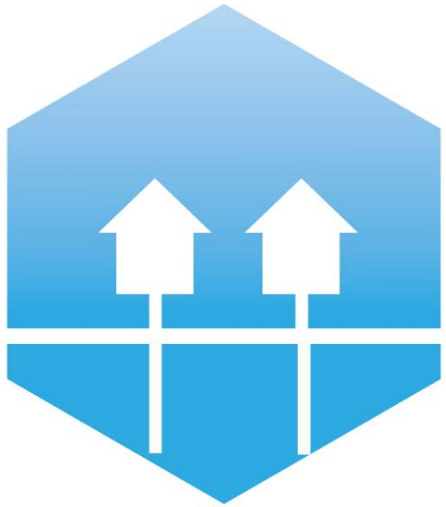
Future work & Conclusions

- Waste for incineration in 2030
  - Current capacity generally sufficient, but geographically non-distributed
  - According to EU reference model, Scenario 4 (308 Mt): ~74 Mt
    - At -20% waste generation (246 Mt): 59 Mt
    - At -50% waste generation (154 Mt): 37 Mt
- Waste modelling
  - Geographically Weighted Regression (in GIS)
    - Regional regression vs. National – Panel data
    - Total waste volumes not alone determinant!
    - Local/regional distribution and temporal development
- District heating
  - The heating and cooling strategy for EU
    - Decisive impact on DHC development in Europe
    - District heating systems – key infrastructures for higher heat recovery efficiencies in WtE!

Thank You for your attention!

Questions...





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