

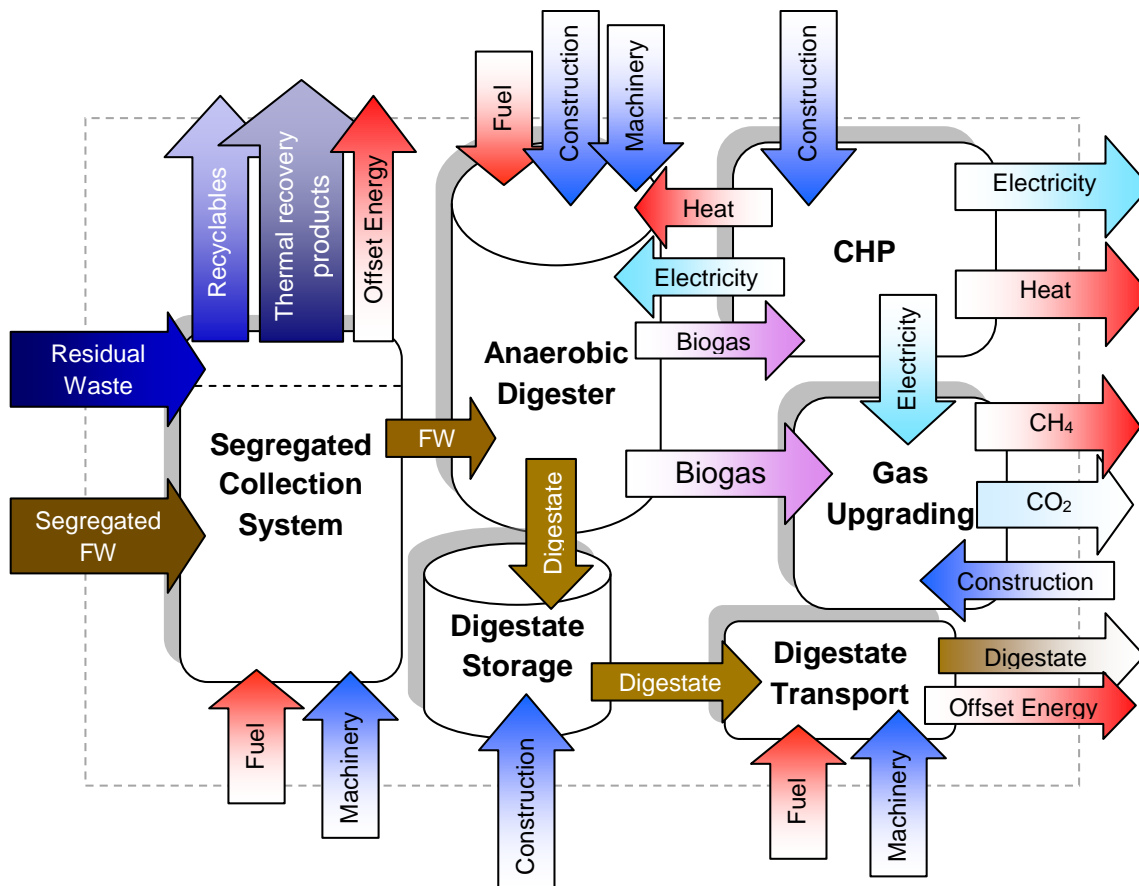
# VALORGAS project – Collection and AD of Food Waste

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University of Southampton

## Valorisation of food waste to biogas - Project 241334

Sponsored by FP7 ENERGY.2009.3.2.2



13 partners in 6 countries  
 3.5 M€ from 2010 – 2013  
 Coordinator Soton

**Aim:**  
 To valorise the energy from food waste by anaerobic digestion (AD), with full evaluation of the associated whole-life energy balances from collection to product utilisation.

# FW recovery

- Allows efficient recovery of a second-generation fuel product with multiple end-uses
- Returns nutrients to agriculture, with associated economic, energy and carbon gains from offsetting of artificial fertilisers
- Reduces moisture content of residual waste, improving CV and efficiency of thermal recovery, and increasing the range of thermal technologies
- Increases potential for recovery of commodity grade recyclables



# Today's presentation

- FW collection systems in Europe
  - Energy in FW collection
- FW characterisation
  - Compositional characteristics
  - Biochemical composition
  - Contaminants
- Anaerobic digestion of FW
- How it joins up

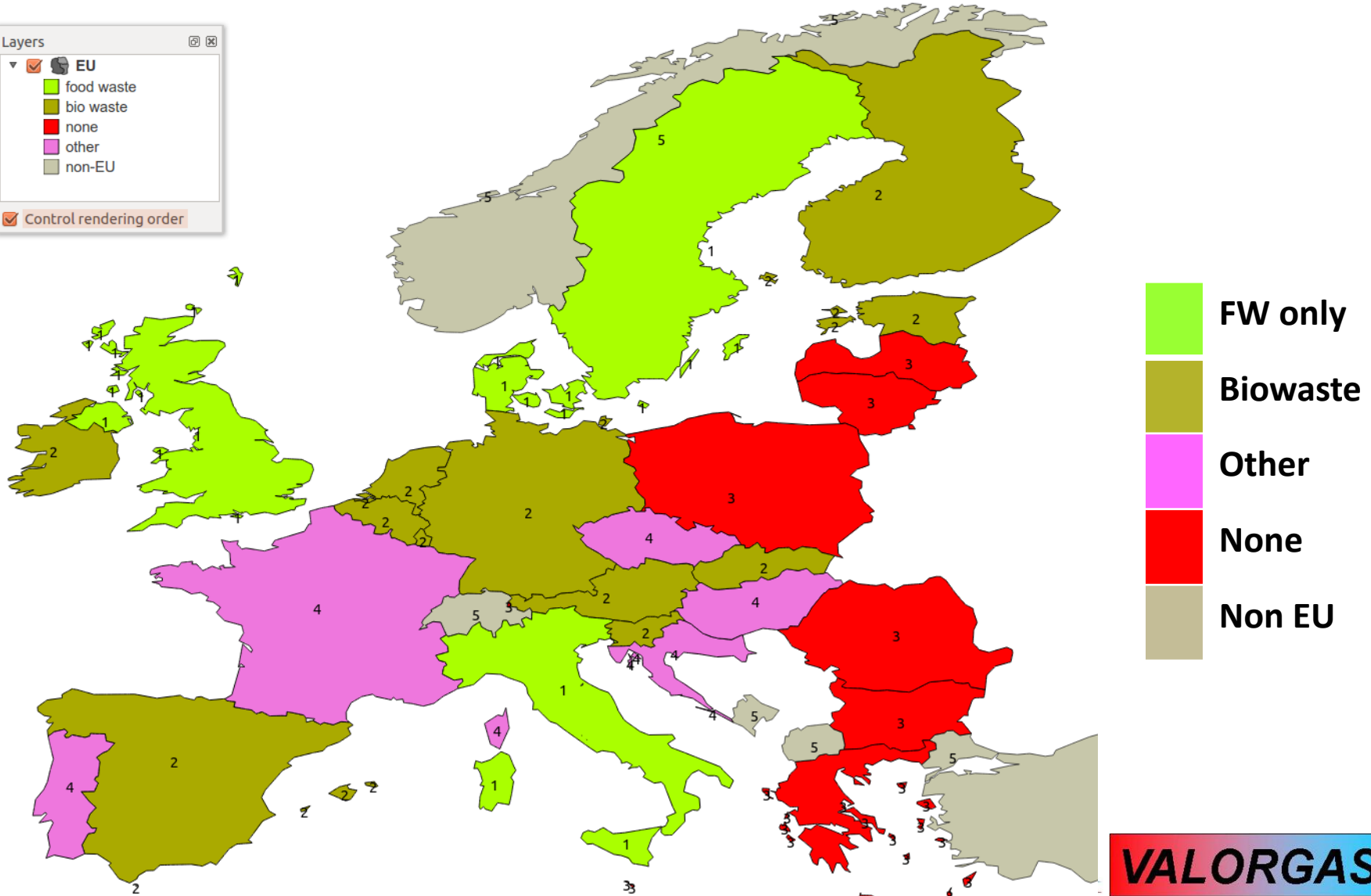
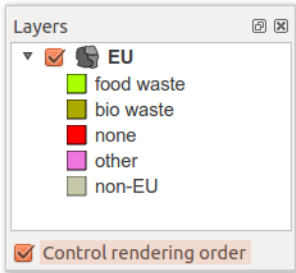
# FW collection schemes in Europe

- Key factors that affect performance
  - Gross weight, contamination, participation, capture rate etc
- Questions
  - Who collects it?
  - How is this done?
  - What type of information is available and how easy is it to get?

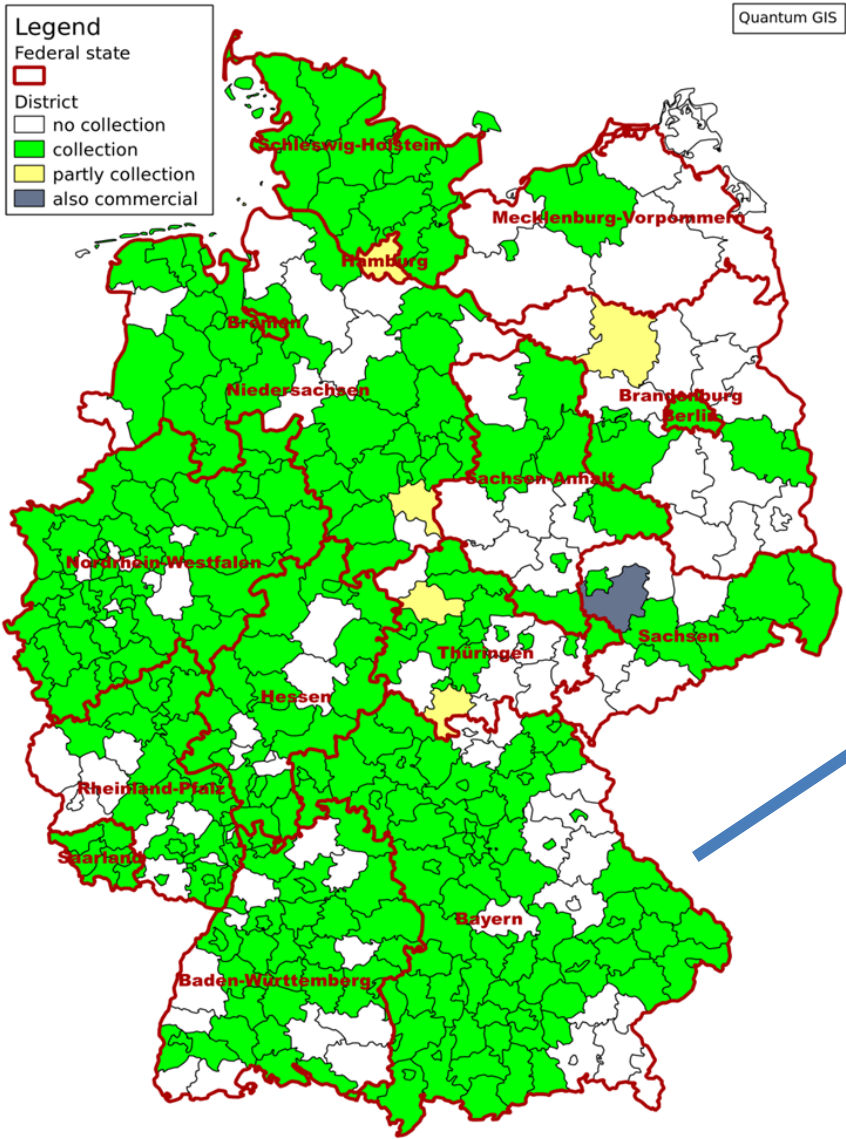
# FW collection schemes in Europe

- Methodologies
  - quantitative compositional analysis, observational studies, public opinion surveys
- Web-based surveys
  - Organisations
  - Search terms
- Pilot
- Modifications
- QA

# Survey results



# Survey results





# Survey results



restes de pa

marro de café i restes d'infusions.

Ogni rifiuto ha il suo giorno di gloria.



can go in here

will be delivered in September.

recycle

Towards Zero Waste Dundee



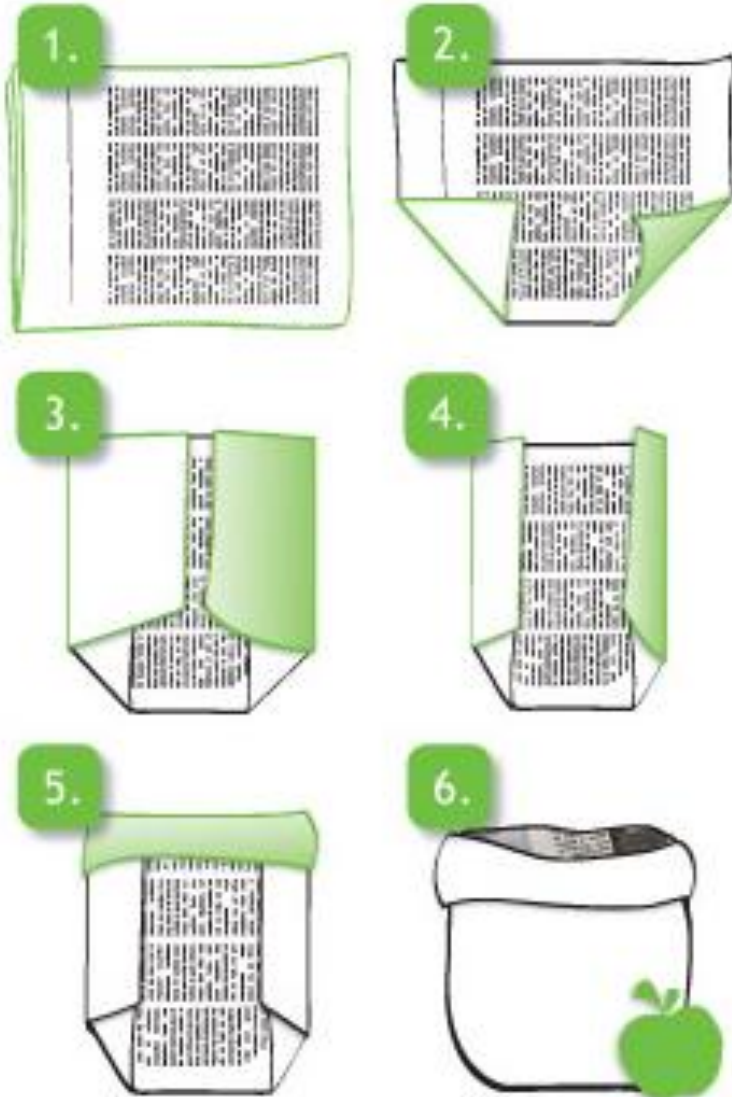
La differenziata porta a porta è vincente.

**A TRENTO**  
la differenziata bussa alla porta



**VALORGAS**

# Survey results

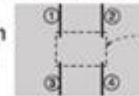


## Lining your kitchen bucket

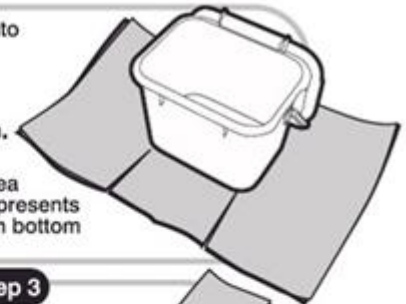
### Step 1

Place the kitchen bucket onto two sheets of newspaper. (or one sheet folded if its a broadsheet paper)  
Cut or tear 4 lines as shown.

cut/tear in 4 places

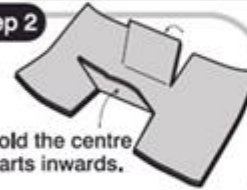


area represents bin bottom



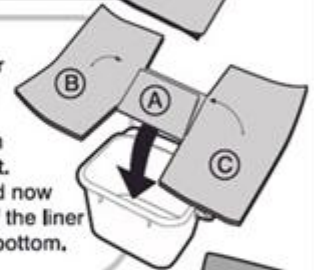
### Step 2

Fold the centre parts inwards.



### Step 3

Bring the outer parts (B & C) inwards, and place (A) down into the bucket. (B & C) should now be the walls of the liner and (A) is the bottom.



Trim

### Step 4

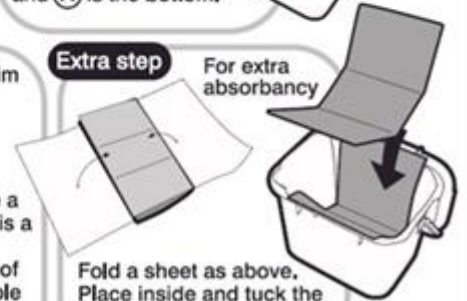
After Step 3 your liner may be a bit creased. This is normal. It is a good idea to trim off excess paper hanging over the edge of the bucket so that the lid is able to close properly.



### Extra step

For extra absorbency

Fold a sheet as above. Place inside and tuck the excess inside the bucket.



# Survey results



# Survey results



# Survey results

**Don't Forget**

**STOP!!! WHAT ARE YOU DOING? USE THIS...**

**HOW YOU CAN HELP US RECYCLE YOUR CARDBOARD**

**RECYCLE WITH VICTORY FACT**

**YOUR FOOD WASTE CONTAINERS**

**WHAT CAN I PUT IN MY FOOD CADDIES?**

## Biogas

Biogas är ett nytt matrester. Pot utmärkt att goda

Att vi pratar om både biogas och fordonsgas beror på att det finns en skillnad i själva begreppen. Och för att förklara till det lite ytterligare så tänker vi blanda in ett begrepp till, naturgas. Här kommer en förklaring:

Biogas = metangas som görs av biologiskt nedbrytbara material, exempelvis avloppsslam och matrester.  
 Naturgas = metangas som hämtas från jordens inre och är därmed fossil.  
 Biogas = naturgas + fordonsgas.

På Ekoby reningverk gör vi den biogas som används till Eskilsmåns lokala bussar, våra egna avfallsbilar, kommunens tjänstebilar och privata bilar. Vill du köra bil miljövänligt ska du köra på fordonsgas. Det är mycket bättre för miljön jämfört med både diesel och bensin, dessutom kostar det mindre.

För att tanka ditt gasfordon får du åka till Fabriksgränd 12 i Eskilstuna. Du kan betala med ÖK/GS, E-Ön eller VISA-kort.

**Priset på biogas**

13,58 kr/km<sup>3</sup> inkl. moms; 10,87 kr exkl. moms

1 Nm<sup>3</sup> Biogas motsvarar 1,2 liter bensin  
 Biogaspris som beräknats utifrån 12,37 kr inkl. moms, 9,89 kr exkl. moms

KAN MAN KÖRA BIL PÅ ÄPPELSKRUTTAR?  
**JAPP!**



# Survey results

- 3 types but merge
  - **critical** for plant design and operation
- Container size a significant factor
  - plastic bags
- Inconsistent definitions
- Good practice information
- Methodology

# FW Collection

- Energy out > Energy in 😊
- Energy out < Energy in ☹️
- Multiple factors
  - Climate, population size and density, vehicle type, working hours, collection frequency, participation rate, segregation efficiency: no information



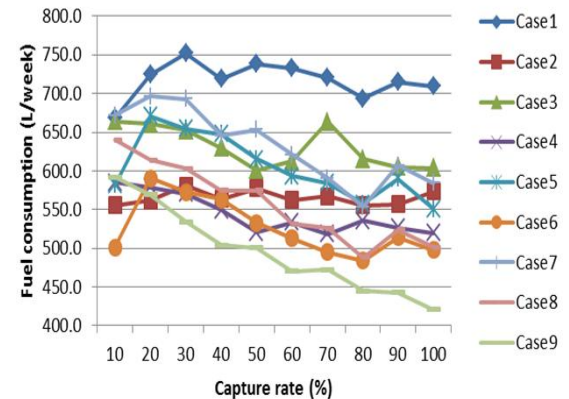
# Mechanistic model

- **Input**
  - No. of households, housing density, FW generation rate, participation rate, collection frequency etc
- **Select**
  - Vehicle type, crew size, no. of bins etc
- **Outputs**
  - fuel consumption, collection hours (staff time), no. of vehicles required



# Mechanistic model

- Fuel savings of 25% and more
- Insights on vehicle design
  - pod better than split



## Scoping tool

- Best: weekly food waste collection with AWC of recyclable and residual waste by compartmentalised vehicle
- Worst: weekly separate collection of recyclables, residual and food waste by single-compartment RCV

# FW composition

- Approaches
  - Compositional characterisation
  - Physico-chemical analyses
- Composition – categories?
  - WRAP and other studies
  - Partner systems

# Compositional characterisation

WRAP revised (2009)	WRAP original (2008)	VALORSUL	VALORGAS	Greenfinch
1 Fresh vegetables and salads 3 Fresh fruit 8 Processed vegetables and salad 14 Processed fruit	7 Vegetables 5 Fruit 6 Salads	1 Vegetables 13 Fruit 3 Salads	1 1a Fruit and vegetable waste 1b Fruit and vegetables (whole) 1c Large stones, seeds and fibrous materials	1 Fruit & veg peelings 2 Fruit & veg whole 17 Seeds & stones
10 Staple foods	4 Dried foods/powders	8 Dried foods/powders	2 Pasta/rice/flour/cereals	3 Pasta/rice/flour 9 Cereal
4 Bakery	1 Bakery	10 Bakery	3 Bread and bakery	4 Bread and bakery
6 Meat and fish	2 Meat and fish	9 Meat and fish 32 Special - bones	4 4a Meat and fish 4b Bones	5 Meat and fish 6 Bones
7 Dairy and eggs	3 Dairy	7 Dairy	5 5a Dairy 5b Egg shells	8 Dairy 7 Eggs
2 Drinks	9 Drinks	4 Drinks	6 Drinks	10 Tea bags & coffee
13 Confectionery and snacks 11 Cake and desserts	8 Confectionery and snacks 11 Desserts	5 Snacks	7 7a Confectionery and snacks 7b Desserts	11 Sweets & desserts
9 Condiments, sauces, herbs and spices 5 Meals (homemade and pre-prepared)	10 Condiments, sauces, herbs and spices 12 Mixed foods	12 Condiments, sauces, herbs and spices 6 Mixed meals	8 8a Condiments  8b Mixed meals	16 Mixed meals
15 Other 12 Oil and fat	13 Other	11 Other food	9 Other food	12 Other food material
			10 Biodegradable bags	14 Biodegradable bags
		2 Garden waste	11 Garden waste	13 Non food biodegradable v
		14 Paper 15 Cardboard - packaging 16 Cardboard - non packaging	12 Paper and card	
		17 Plastic - film bags 18 Plastic - bottles 19 Plastic - polystyrene 20 Plastic - other 23 Ferrous metals 24 Non ferrous metals 21 Glass - packaging 22 Glass - non packaging 25 Composites 26 Textiles 27 Sanitary textiles 28 Combustibles - wood 29 Combustibles - other 30 Incombustibles 31 Special - packaged organics 33 Special - other	13 13a Plastic containers 13b Plastic film (non-biodegradable)  13d Metals  13e Glass  13f Miscellaneous	

# Compositional characterisation

- VALORGAS partners
  - Finland, Portugal, Italy, UK
- Multiple studies in UK

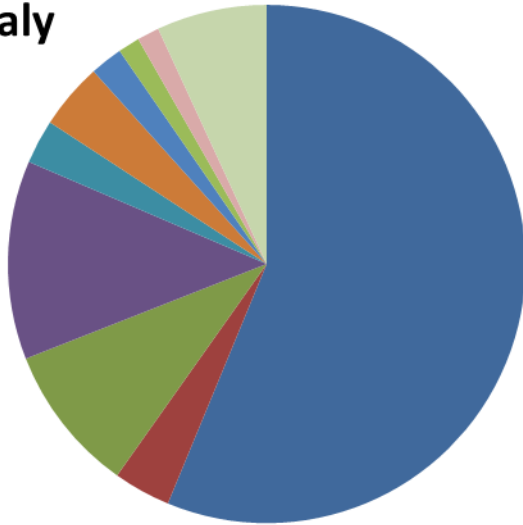


# Compositional characterisation

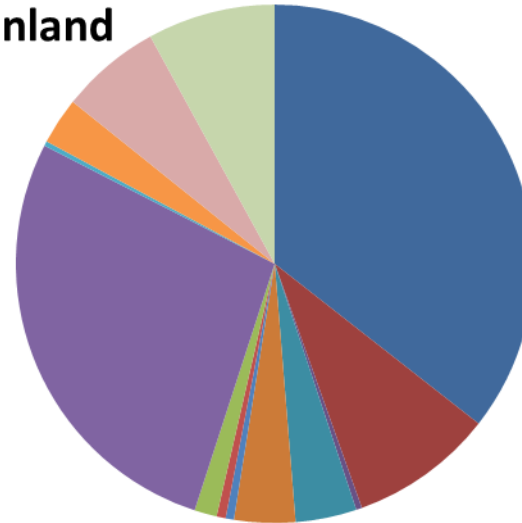


# Compositional characterisation

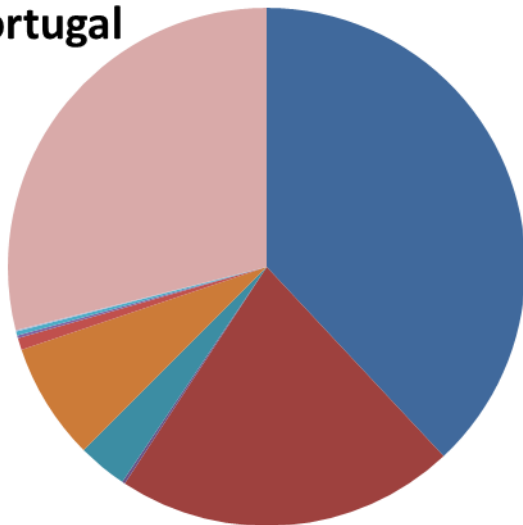
Treviso, Italy



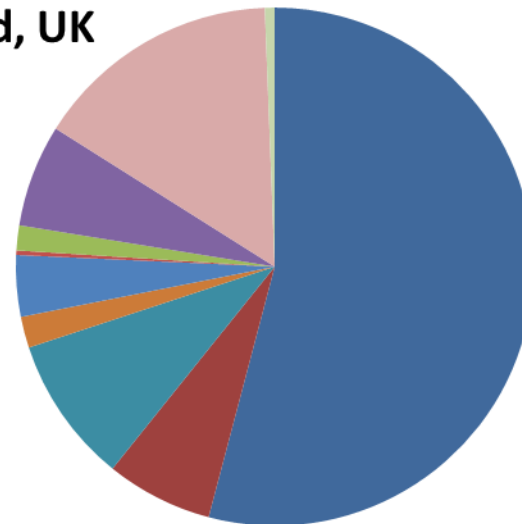
Forssa, Finland



Loures, Portugal

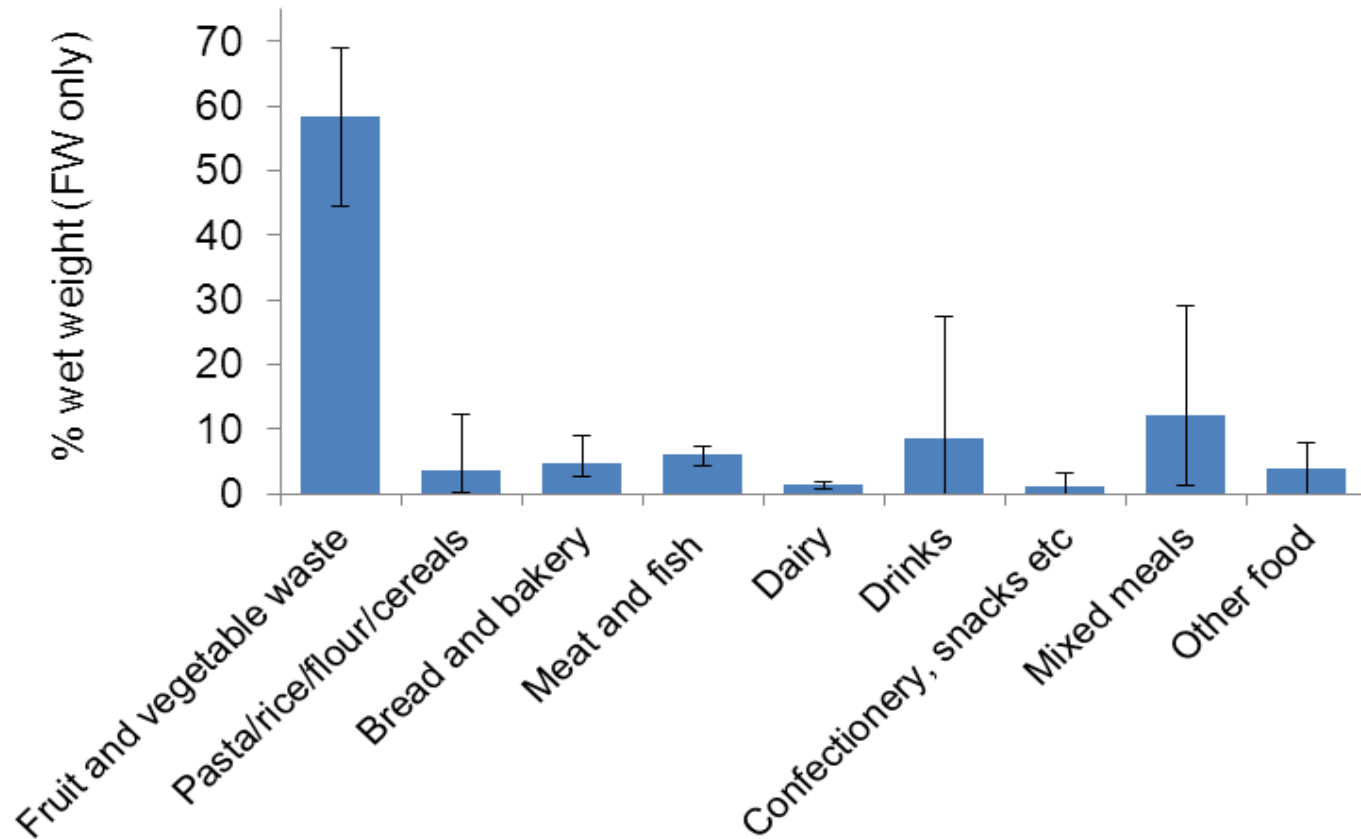


Richmond, UK



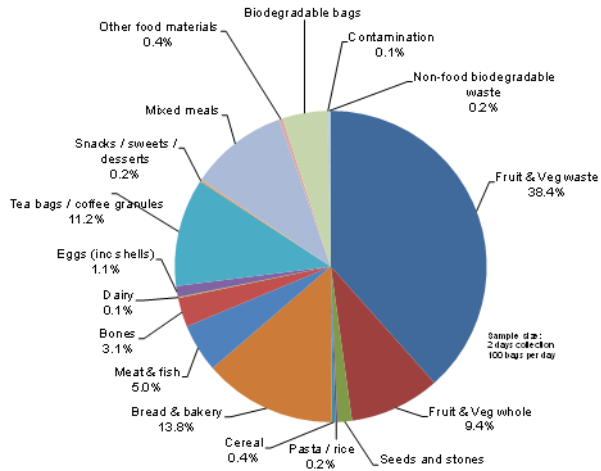
- Fruit & veg waste
- Fruit & veg whole
- Stones & seeds
- Pasta/rice/flour/cereals
- Bread & bakery
- Meat & fish
- Bones
- Dairy
- Egg shells
- Drinks
- Confectionery & snacks
- Desserts
- Condiments
- Mixed meals
- Other food

# Compositional characterisation

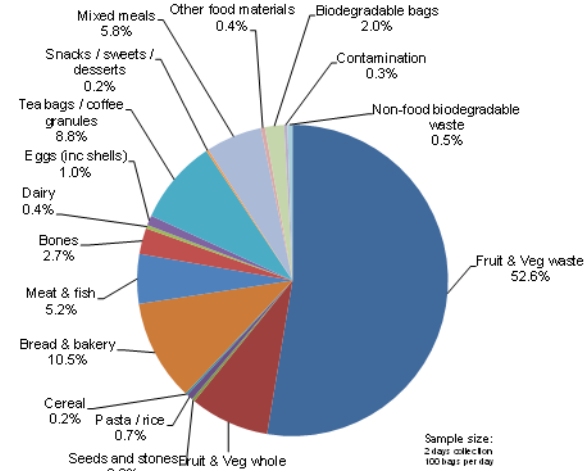


# Compositional characterisation

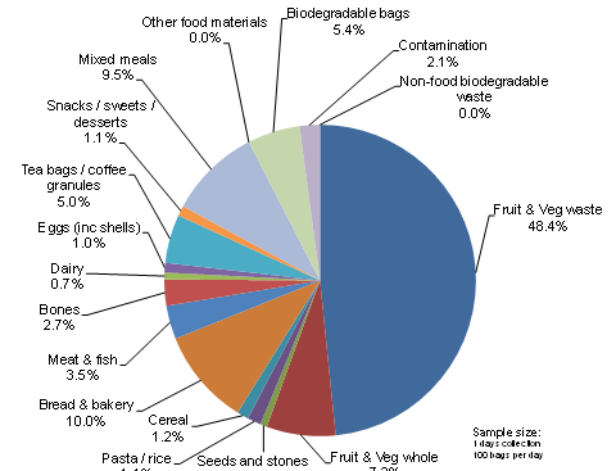
Food waste composition, Presteigne, 2 day average / % by weight



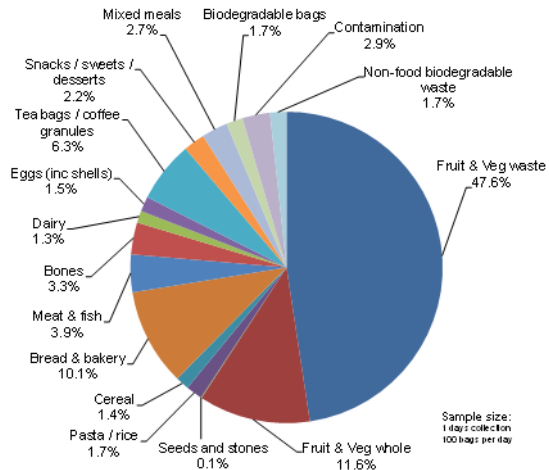
Food waste composition, Ceredigion, 2 day average / % by weight



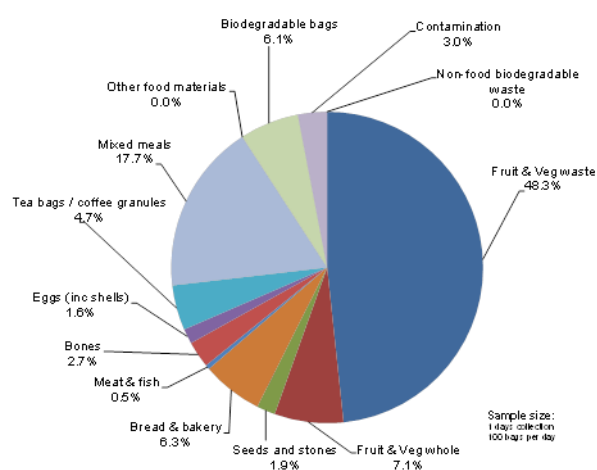
Food waste composition, Leatherhead, 1 day / % by weight



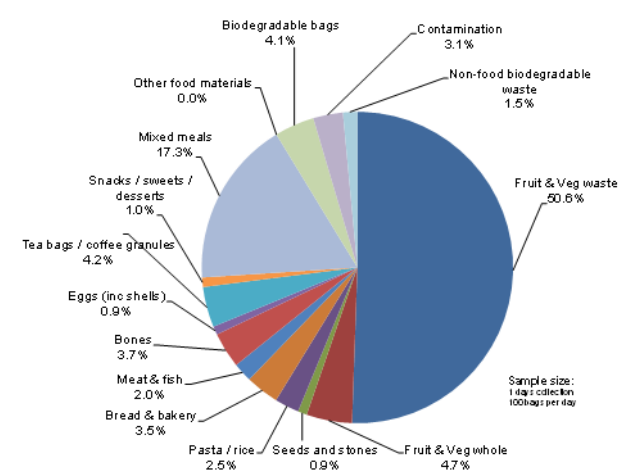
Food waste composition, Central Beds, 1 day / % by weight



Food waste composition, Surrey, 1 day / % by weight



Food waste composition, Ealing, 1 day / % by weight





# Physico-chemical analysis

	UK				Finland		Italy		Portugal			
	Luton <sup>a</sup>	Hackney <sup>a</sup>	Ludlow <sup>a</sup>	Eastleigh	Eastleigh	Forssa	Treviso	Treviso	Lisbon raw waste	Lisbon to digester	Lisbon to digester	
	(Lab 2)	(Lab 2)	(Lab 2)	(Lab 2)	(Lab 1)	(Lab 1)	(Lab 1)	(Lab 3)	(Lab 3)	(Lab 1)	(Lab 3)	
<i>Fundamental characteristics for anaerobic digestion</i>												
pH	5.12 ± 0.01	5.18 ± 0.01	4.71 ± 0.01	5.02 ± 0.01	5.70	5.34	6.16					
TS	% WW <sup>b</sup>	23.70 ± 0.06	25.74 ± 0.18	23.74 ± 0.08	25.89 ± 0.01	28.62 ± 0.07	27.02 ± 0.12	27.47 ± 0.03	24.43 ± 4.57	33.80		
VS	% WW	21.84 ± 0.10	23.47 ± 0.31	21.71 ± 0.09	24.00 ± 0.03	26.83 ± 0.16	24.91 ± 0.05	23.60 ± 0.09	20.16 ± 3.75	27.60	22-27%	
VS	%TS	91.28 ± 0.20	91.17 ± 0.91	91.44 ± 0.39	92.70 ± 0.12	94.18 ± 0.42	92.26 ± 0.26	86.60 ± 0.40	83.32 ± 5.87	81.7		
TOC	%TS	51.2 ± 1.2	51.3 ± 0.2	48.3 ± 1.0	48.76 ± 0.87							
TKN		3.12 ± 0.01	3.13 ± 0.03	3.42 ± 0.04	2.91 ± 0.05	2.74 ± 0.05	2.39 ± 0.04	2.55 ± 0.03	2.84 ± 0.76	1.5	6.93 ± 0.07	4.30
TKN	g kg <sup>-1</sup> WW	7.39 ± 0.02	8.06 ± 0.08	8.12 ± 0.09	7.53 ± 0.13	7.84 ± 0.16	6.45 ± 0.1	7.02 ± 0.1	7.19 ± 2.06	5.1	4.37 ± 0.05	2.72
CV	kJ g <sup>-1</sup> TS	21.43 ± 0.12	21.64 ± 0.11	20.66 ± 0.18	20.97 ± 0.02	21.32 ± 0.08	21.39 ± 0.11	20.50 ± 0.01			25.23 ± 0.26	
<i>Biochemical composition</i>												
Lipids	g kg <sup>-1</sup> VS	148 ± 4	157 ± 2	151 ± 1	149 ± 1	152 ± 2	156 ± 0.5	202 ± 0.5			314 ± 0.4	
Crude protein	g kg <sup>-1</sup> VS	213 ± 1	213 ± 2	235 ± 3	197 ± 4	183 ± 4	162 ± 0.4	186 ± 3				
<i>Nutrients</i>												
TKN (N)	g kg <sup>-1</sup> TS	31.2 ± 0.1	31.3 ± 0.3	34.2 ± 0.4	29.1 ± 0.5	27.4 ± 0.5	23.9 ± 0.4	25.5 ± 0.3	28.44 ± 7.62	15	23-30%	
TP (P)	g kg <sup>-1</sup> TS	4.87 ± 0.08	6.41 ± 0.12	5.41 ± 0.32	2.82 ± 0.13	2.94 ± 0.01	2.73 ± 0.05	3.47 ± 0.06	3.26 ± 1.54	5.0		
TK (K)	g kg <sup>-1</sup> TS	12.3 ± 0.1	12.9 ± 0.6	14.3 ± 0.8	8.59 ± 0.27	11.2 ± 0.2	10.0 ± 0.2	10.0 ± 0.1				
<i>Elemental analysis</i>												
N	%TS	3.12 ± 0.01	3.13 ± 0.03	3.42 ± 0.04	2.91 ± 0.05	2.80 ± 0.02	2.46 ± 0.03	2.58 ± 0.05			5.72 ± 0	
C	%TS	51.2 ± 1.2	51.3 ± 0.2	48.3 ± 1.0	48.8 ± 0.9	50.6 ± 0.2	49.4 ± 0.04	47.2 ± 0.01			54.8 ± 0.1	
H	%TS	6.56 ± 0.04	6.67 ± 0.13	5.53 ± 0.63	6.37 ± 0.19							
S	%TS	0.21 ± 0.00	0.23 ± 0.03	0.15 ± 0.01								
O	%TS	30.7 ± 1.2	29.8 ± 0.4	34.3 ± 2.5	34.7 ± 0.9							

<sup>a</sup> Samples analysed as part of the Defra funded project WR1208 (Banks et al., 2011)

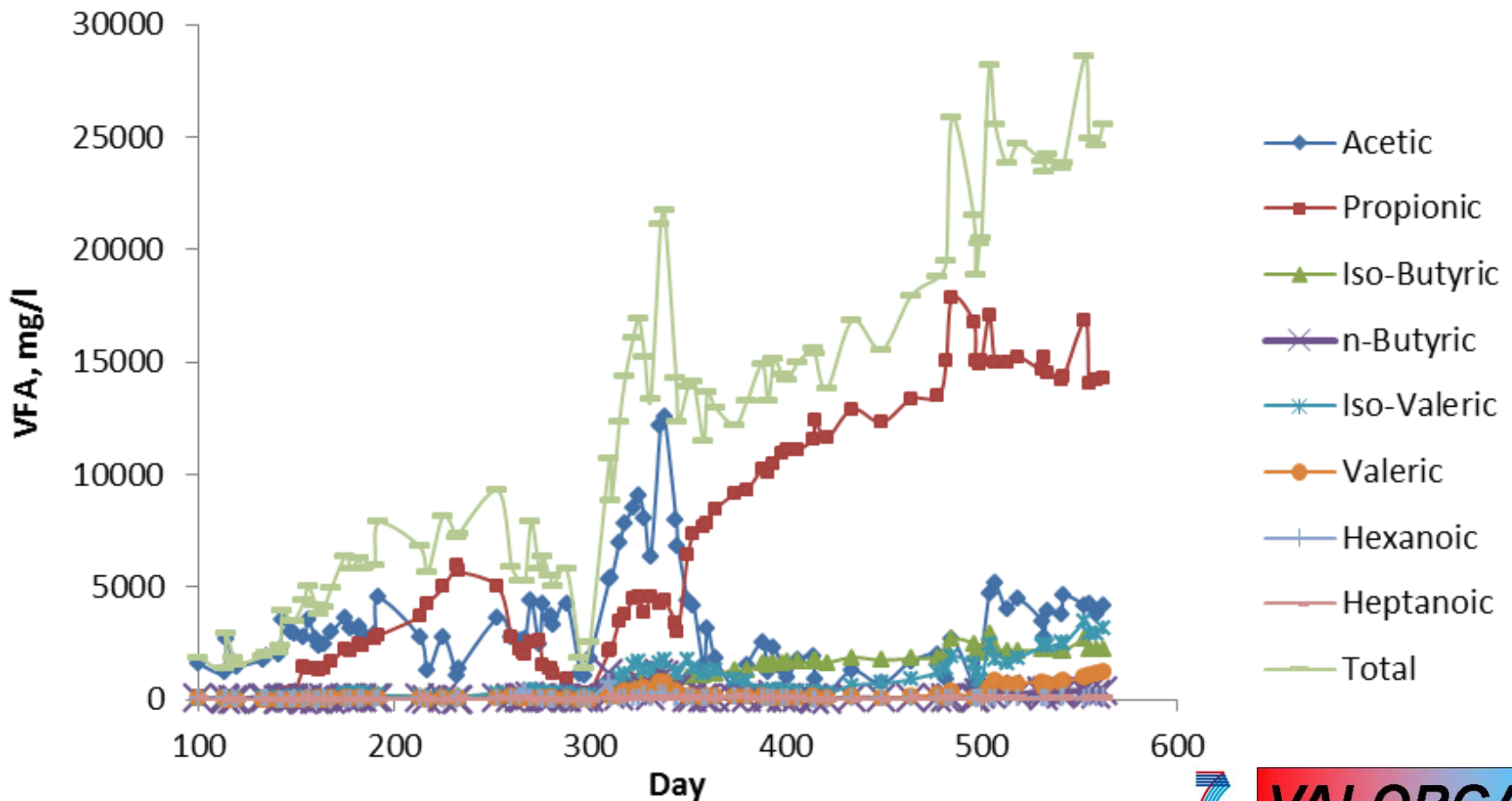
<sup>b</sup> WW = wet weight

# Overall characterisation

- Similar  
...but may be changing?

# AD of Food waste

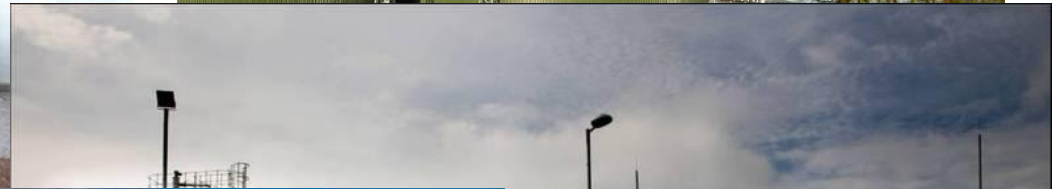
- Early problems associated with this feedstock



# AD of Food waste

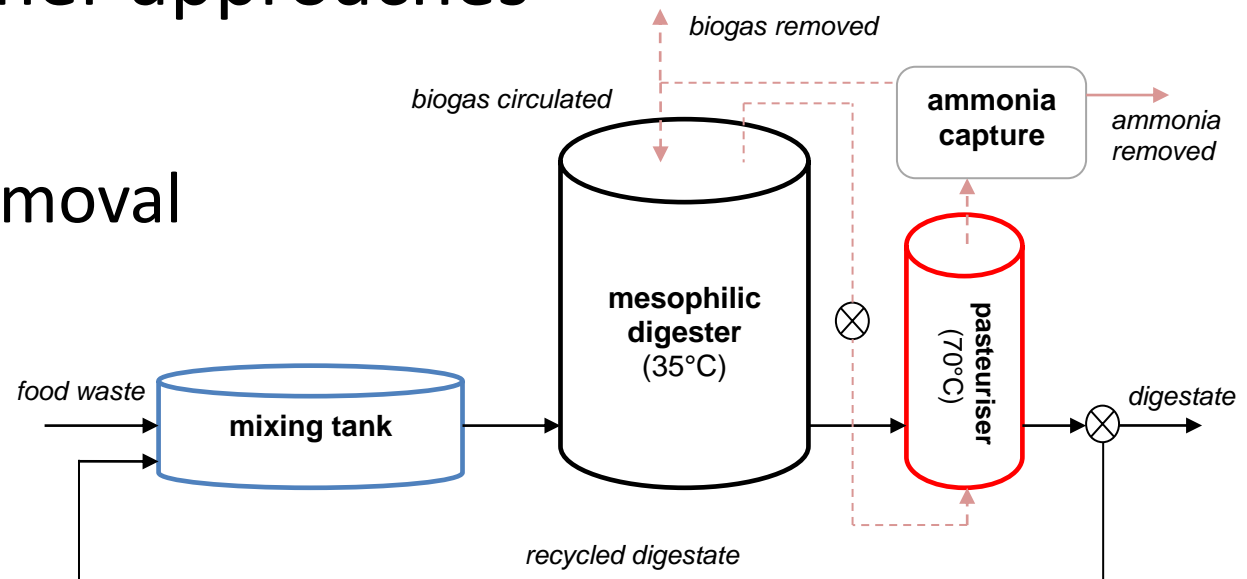
- ... now **resolved** at mesophilic temperatures
  - hypothesis on metabolic pathway and role of hydrogenotrophic methanogens proven
- Laboratory-scale reactors running at up to 7 kg VS m<sup>-3</sup> day<sup>-1</sup>, compared to < 2 kg VS m<sup>-3</sup> day<sup>-1</sup>
- Robust under varying loading

# AD of Food waste

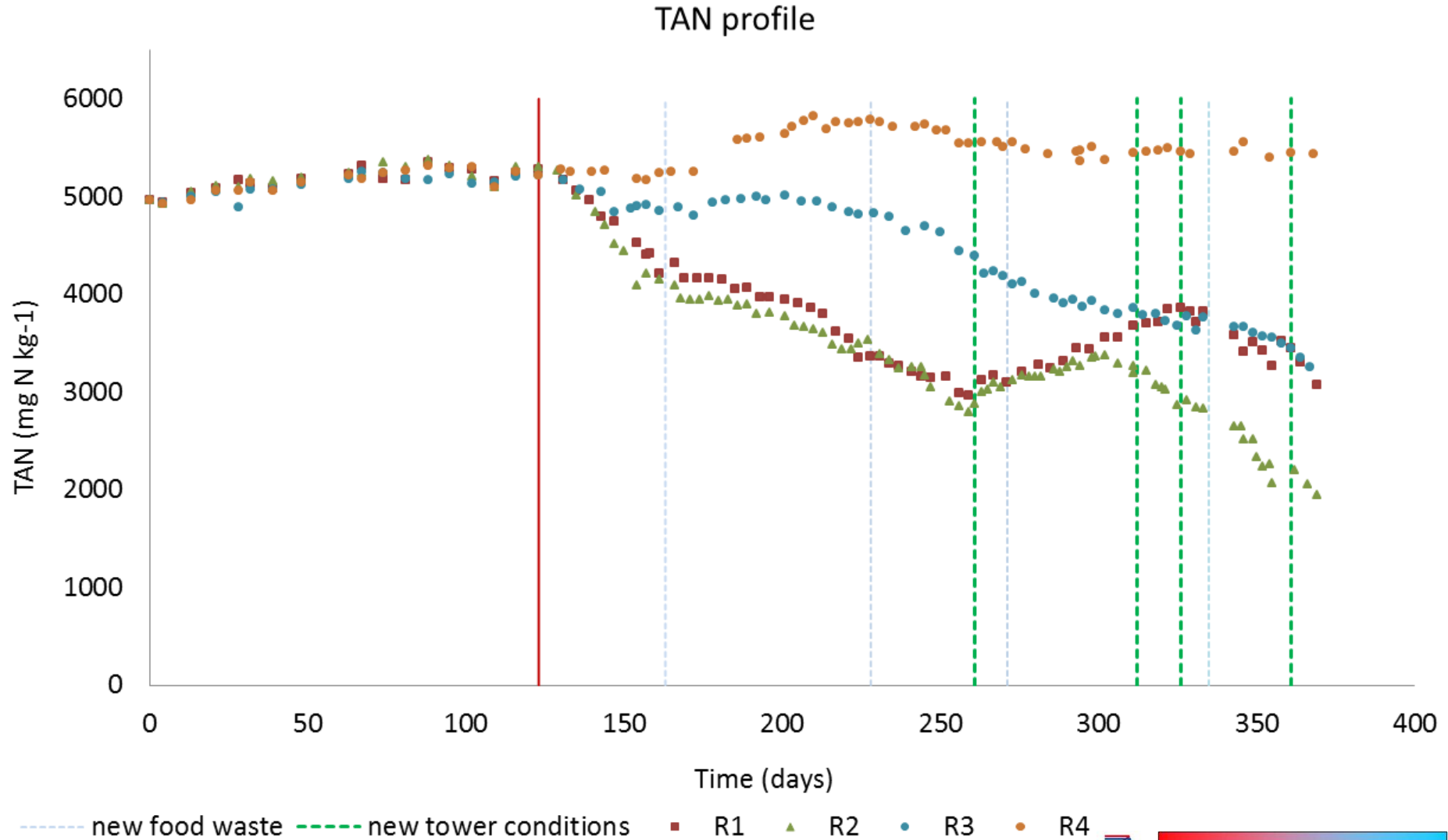


# AD of Food waste

- ... **still unclear** in thermophilic conditions
  - different metabolic pathways and micro-organisms, increased ammonia toxicity
- Looking at other approaches
  - Dilution
  - Ammonia removal



# Ammonia removal



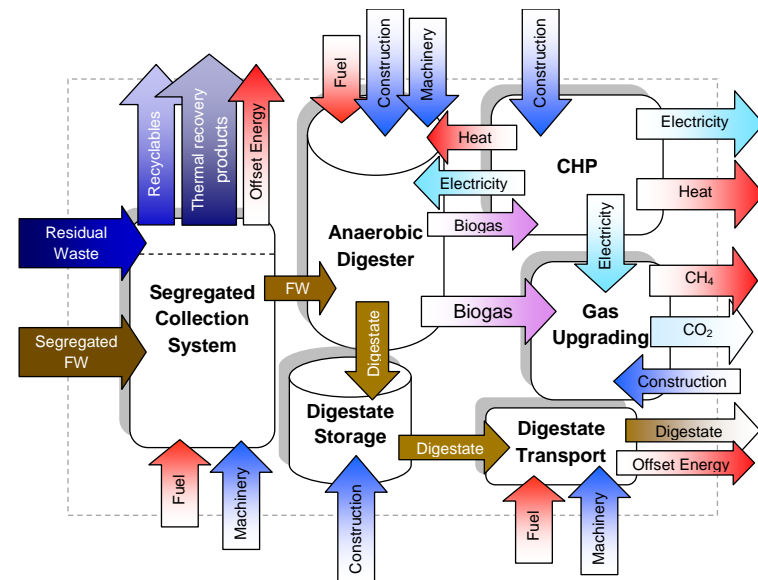
# Ammonia removal

- Potential solution for thermophilic operation
- Opens up possibility of 'designer digestates'
- Application to other feedstocks



# Overall view

- Other activities
  - gas upgrading, use in transport, case studies, residuals
- Energy balance approach
  - energy - carbon - nutrient
  - ‘join up the bits’
  - complex versus simple
  - consequences of decisions



*Thank you!*

[www.valorgas.soton.ac.uk](http://www.valorgas.soton.ac.uk)

