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Integrated systems for farm diversification into energy production by anaerobic digestion: implications for rural development, land use & environment

Modelling the profitability of AD, at the farm level, within arable and dairy systems

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Primary objectives

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Assess the economics of farm-based biogas production and any associated land use and farm practice changes.

- Combines outputs from other work packages

Two objectives:

(1) Construct a set of farm level models with integrated AD component

(2) Model a suite of scenarios (to include use of on-farm wastes as digester feedstock)

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Construct farm-level models (1)

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Tasks

1. Develop a UK based digester cost model (UK based)
   - *Capital costs*
   - *Running costs*
   - *Configuration, scale, feedstock*
2. Construct a suite of farm-level models
3. Embed the digester cost model into the farm models

Characteristics

- 4 farm type/farm size combinations
  - ***Med-large arable/mixed***
  - ***Large specialist dairy***
  - *Small livestock farm*
  - *Medium sized horticulture*
- Digester size determined by availability of feedstock
- Real-world data where available
- Performance measure – Net Margin

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Construct farm-level models (2)

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The LP approach: Model allocates land and other resources to enterprises on basis of their contribution to the Net Margin of the farm – model has to maximize this.

Three sources of constraint:

(1) Structural limitations of the farm

- resources available (land, labour, capital)

(2) Rotational practice

(3) Scenario specification

- government policy
- market conditions

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Cereals farm model (farm structure)

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- Specialist cereals farm, eastern counties of England
  - Cereals / arable crops
  - simple rotations, continuous cropping
  - large field sizes, high levels of mechanisation, low labour input
- Dimensions based on FBS data (average for region)
  - 312 ha
  - Labour 1100 M.D. (farmer plus 4 FT staff)
- Number of fields and between field yield variation notional

Cropping enterprises

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Crop enterprise	Seed yield (t/ha)	Residues (t/ha)	Whole-crop yields (t/ha)	Nitrogen (N, kg/ha)	Potassium (K, kg/ha)	Phosphate (P. kg/ha)
Winter wheat	8.3	11.7	38.6	200	70	70
Winter barley	6.4	7.8	37	180	70	70
Winter oats	6.5	8.7	37	120	60	60
Other cereals (triticale)	6.0	4.5	31.3	180	70	70
Oilseed rape	3.4	-	46.2	210	40	40
Field peas	4.4	6.0	40.1	0	50	40
Field beans	3.8	6.0	50.7	0	50	40
Sugar beet	58.6	20	82	100	75	50
Potatoes (maincrop)	45.0	0	45	220	250	150
Maize (forage)	N.A.	0	45.4	130	140	50
Other fodder crops (fodder beet)	60.0	35.0	91	125	150	60
Field-scale veg (swedes)	75.0	20.0	95	80	125	125
Grass silage	45.0	0	45	220	150	90
Fallow	N.A.	N.A.	N.A.	0	0	0

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Crop rotations

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Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
First wheat	Second wheat	Potatoes	First wheat	Barley	OSR

- Adopted a 6 year rotation
- Any crop not susceptible to the same diseases as cereals is considered a break crop
- Model reflects average over whole rotation, ie. contains average area of all crops grown over 6 years
- Restraints require that:
  - wheat+barley+maize < 66% of area (ie min. 33% break crops)
  - No single crop > 33% of area
  - Potatoes and veg. < 15% of area

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Methane yields

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Crop enterprise	Methane yield of seed (m^3/t FM)	Methane yield of crop residues (m^3/t FM)	Methane yield of whole (green) crop (m^3/t FM)
Winter wheat	298	142	125
Winter barley	307	125	82
Winter oats	307	213	76
Other cereals (triticale)	307	213	110
Oilseed rape	285	253	50
Field peas	-	254	47
Field beans	-	254	47
Sugar beet	71	34	81
Potatoes (maincrop)	27	0	27
Maize (forage)	232 (grain)	164	99
Other fodder crops (fodder beet)	42	34	74
Field-scale veg (swedes)	42	31	74
Grass silage	74	74	70
Fallow			

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The AD unit

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Dimensions

- Any scale up to capacity of 500 kW
  - ‘med-large’
- operating time (347 days p.a.)
- Conversion efficiency (35%)
- Electricity output 4,161,000 kWh
- Methane requirement 1.4M m^3
- Feedstocks:
  - Seed/grain
  - Crop residues
  - Whole-crop

Operating costs

- Total interest charge £175k p.a.
  - AD unit - 4% interest and repayment over 10 years = £114,268 (av.)
  - Silage clamp of 8400t capacity (£500k) - Interest £61,500
- Maintenance £29,000
- Labour £10,850
- Total operating costs £215k

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Digestate

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- Digestate available as fertilizer
  - Nutrients assumed to remain unaltered by digestion
- Nutrient content (N, P, K) estimated of each crop separately on bases of:
  - nutrients levels applied to crop each year
  - Proportion of plant remaining in (or on) land
- Difference between the nutrients available from digestate and the nutrient requirements of crops is made up by fertilizer purchases

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Scenario requirements

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- Scenario modelling:
  - Test the financial viability of AD under a range of conditions
  - Farm types, AD scales etc
  - Test likely success of range of government policies to encourage AD
  - Viability under a range of market conditions
  - Allow calculation of impact on energy balances of above options

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Scenario definitions

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Scenario objectives	Scenario definition
Farming objectives	
o Personal benefits o Societal benefits	o **Max farm net margin (S1)** o Max energy output
Market conditions	
o Agricultural commodities o Renewable energy	o H**igher commodity prices (S2)** o Lower/higher energy prices
Government policies	
o Agric./rural/environment o Renewable energy	o Pillar II funding changes o **50% lower feed-in tariff (S3)** o **Abolition of feed-in tariff (S3)**
o Imported AD feedstocks	o **Forage maize (S4)** o **Slurry (S4)** o Food waste

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Reference run: arable farm model (no AD)

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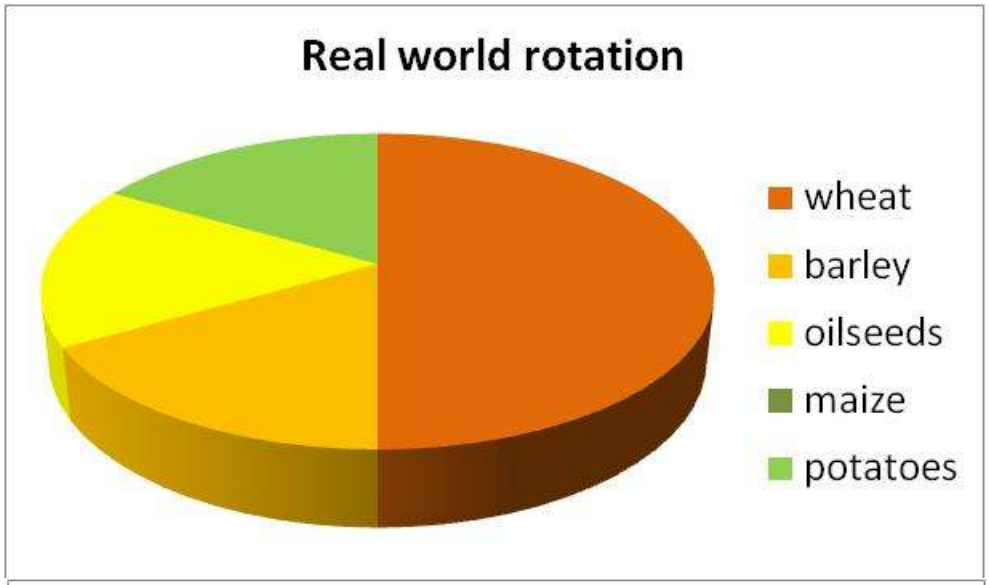

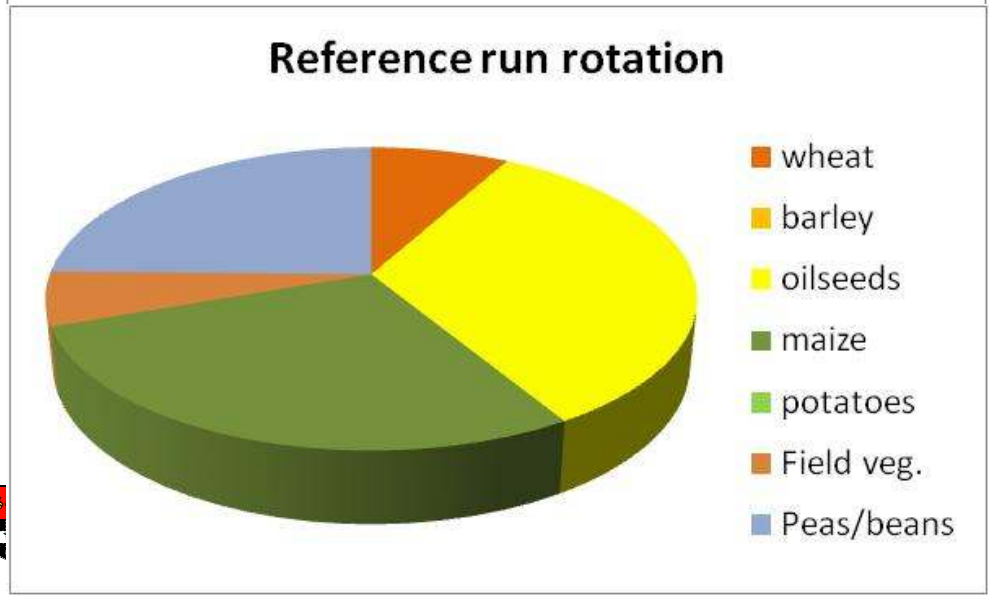

- Differences in cropping pattern due to price signals in 2009.
  - Loss of wheat
- 2/3 farm in cereals/oilseeds/ maize
- 1/3 in break crops
- New crops added: field veg & peas/beans

Scenario 1 – AD activity available

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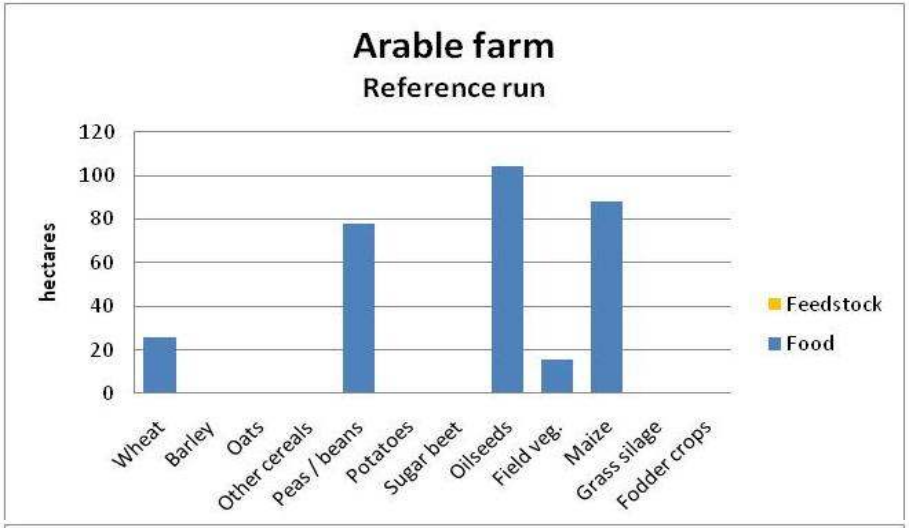

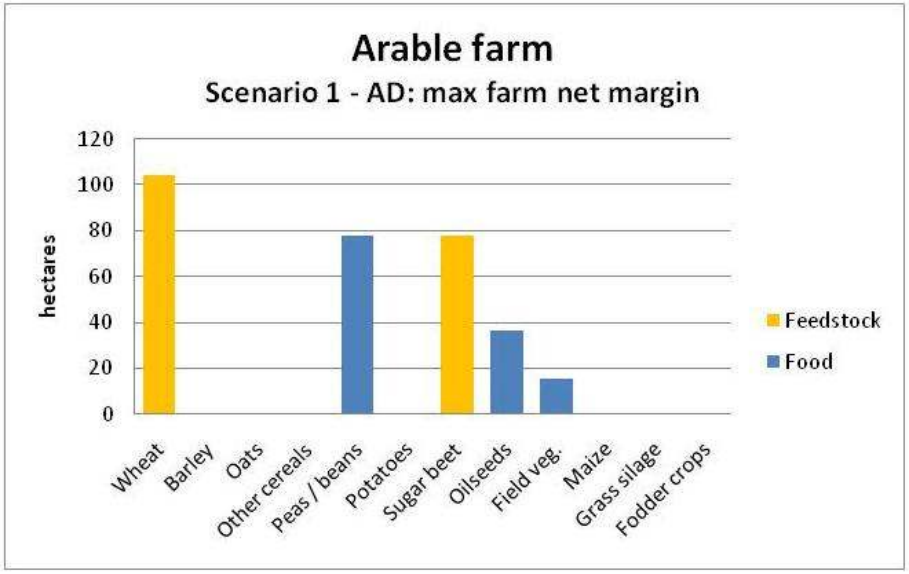

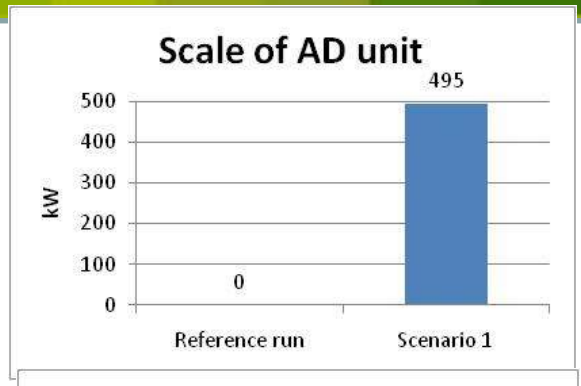

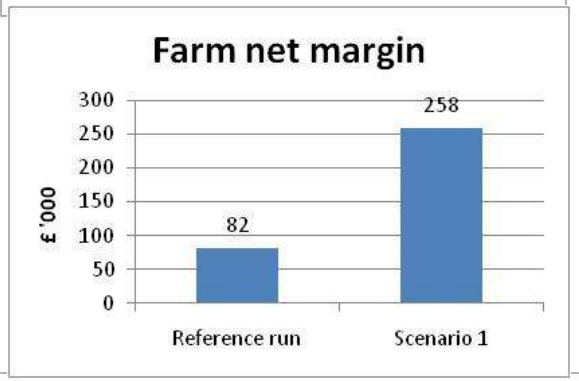

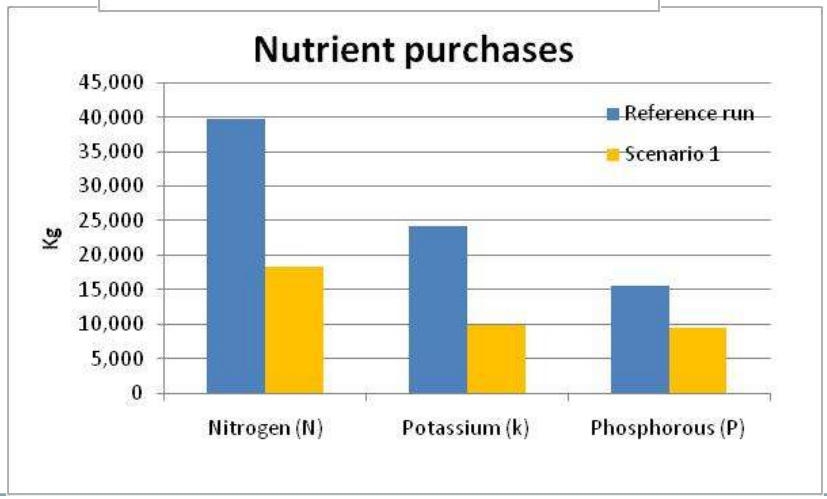

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Scenario 2 – Higher commodity prices

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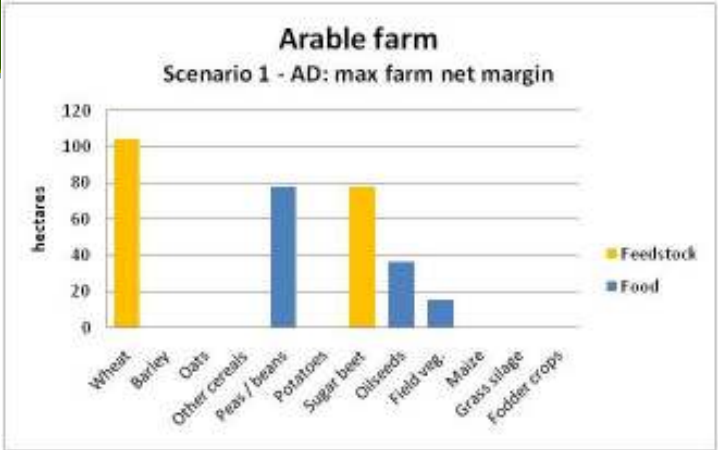

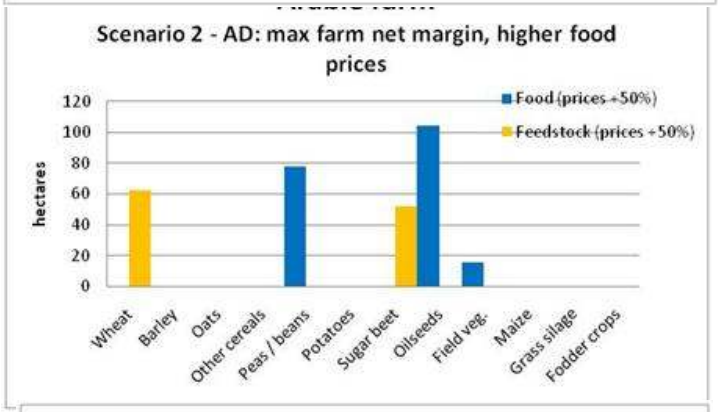

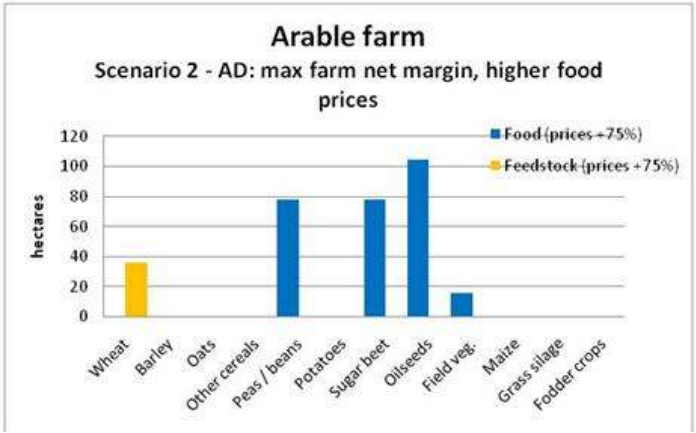

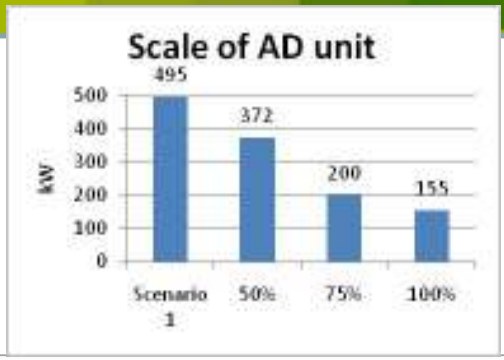

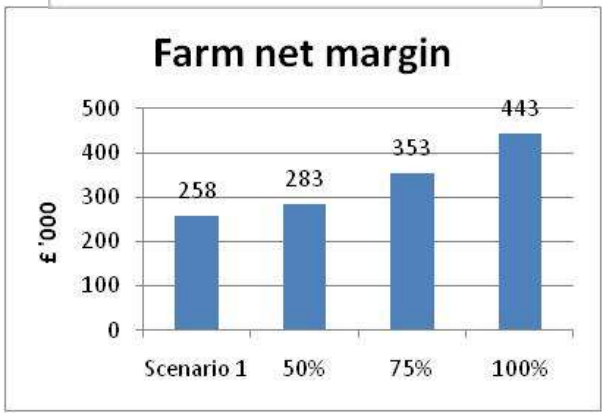

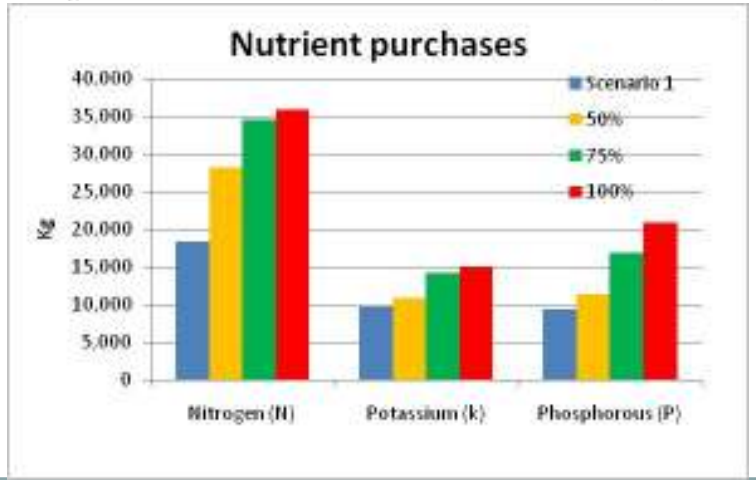

Scenario 3 – Reduced Feed-in tariff

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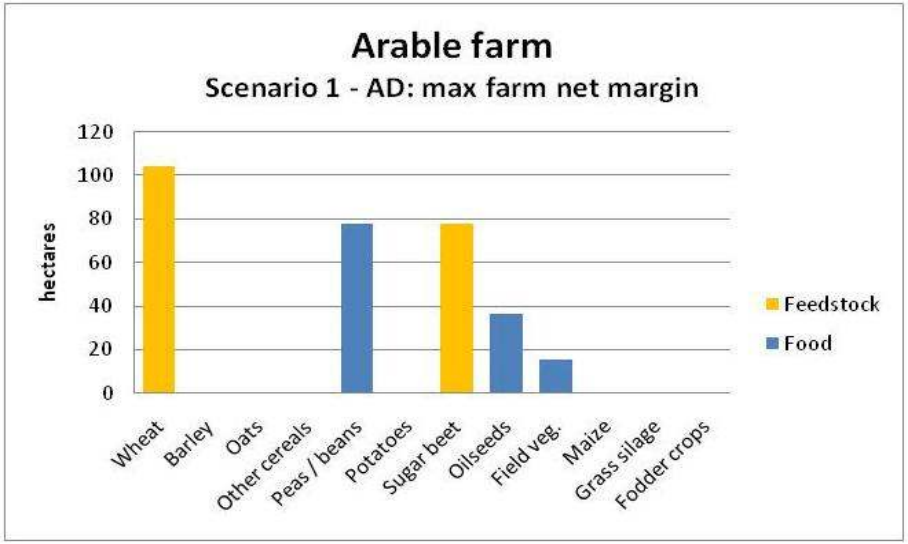

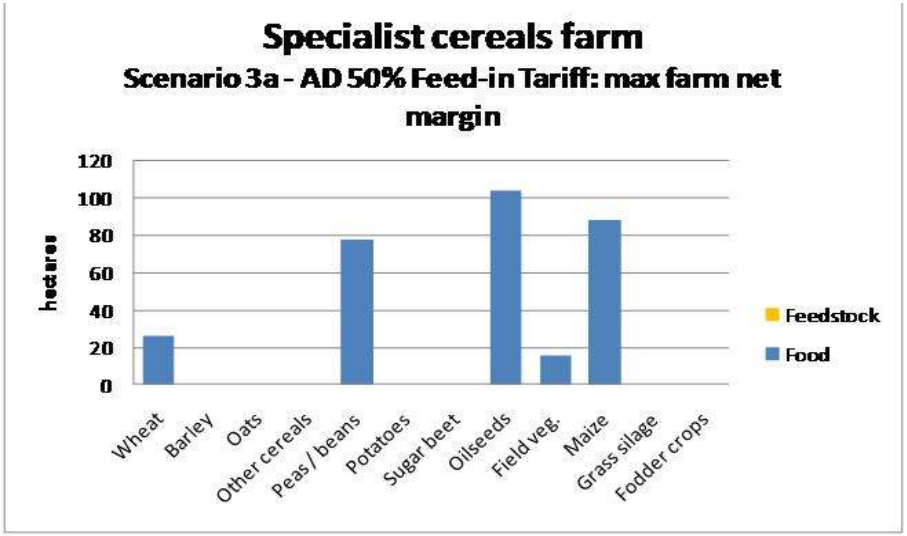

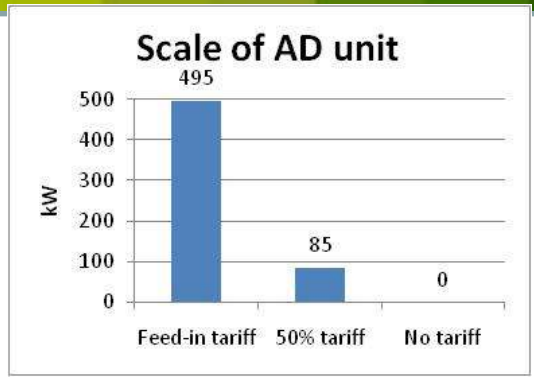

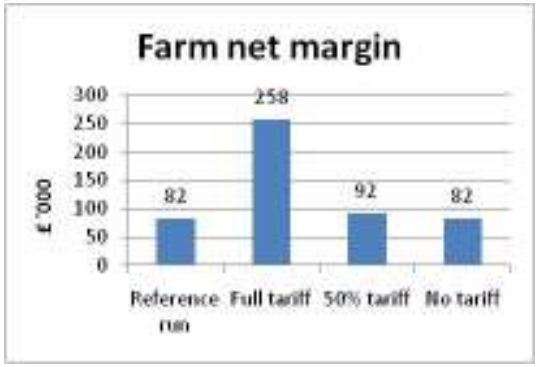

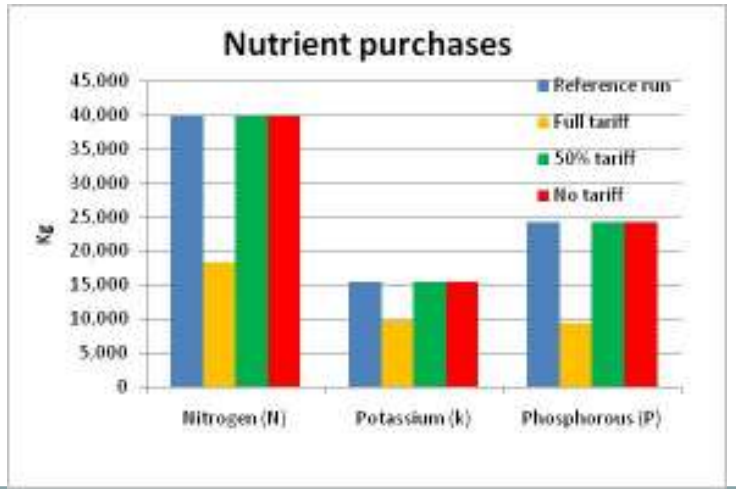

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Scenario 4 – Importation of feedstocks

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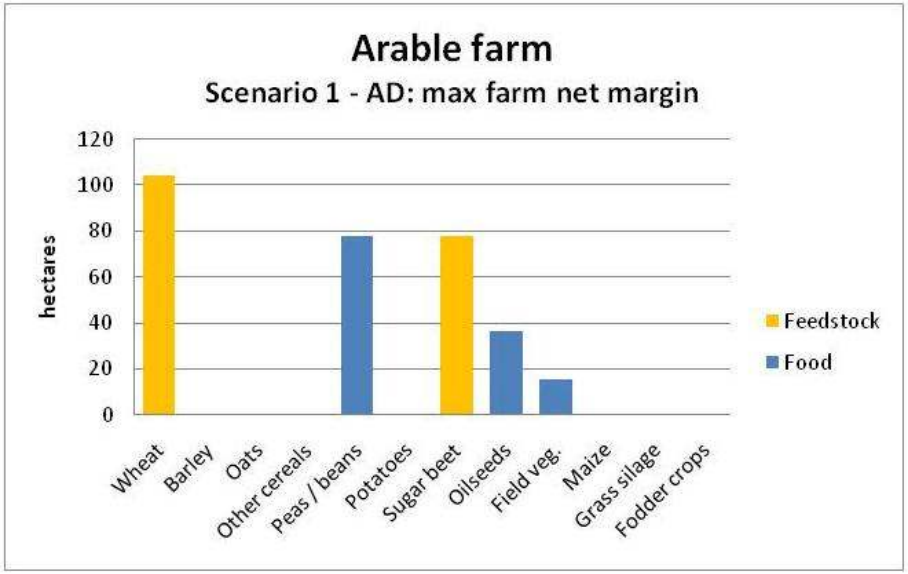

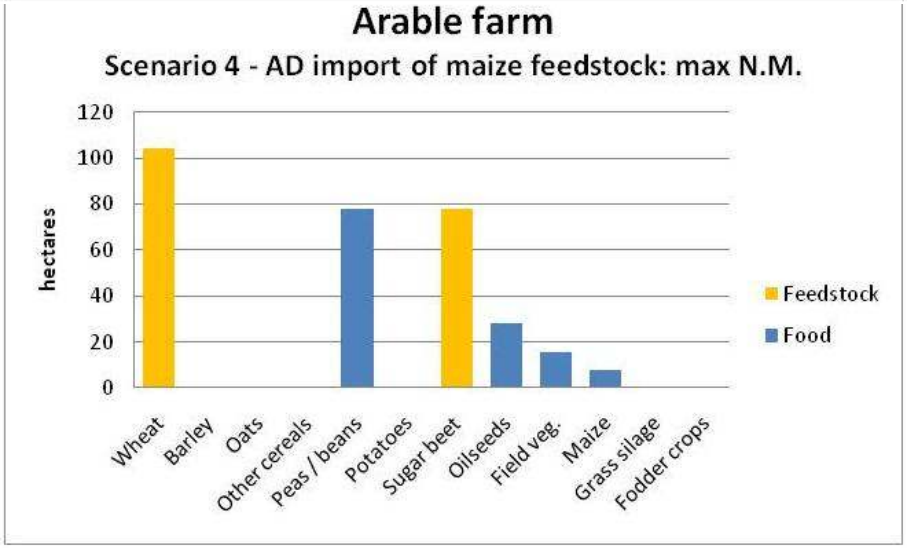

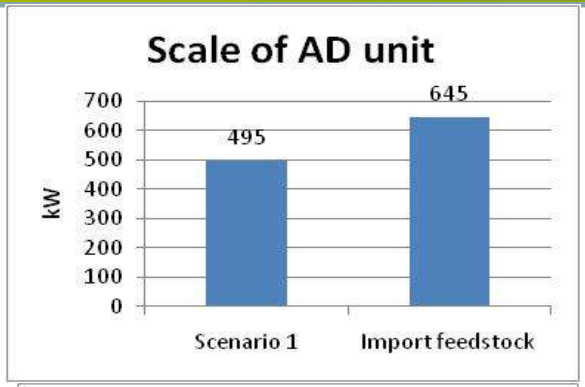

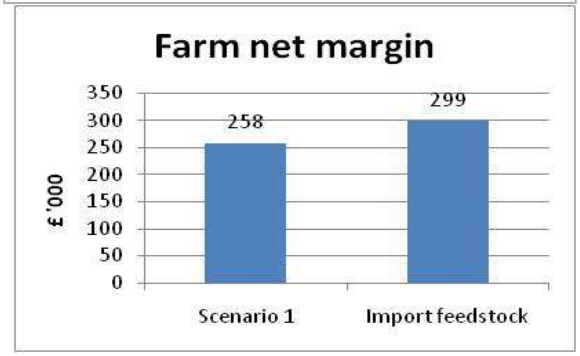

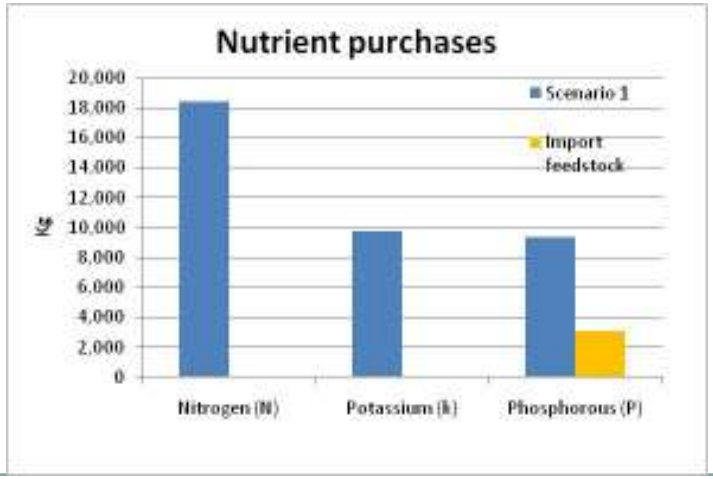

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Conclusions

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- AD out-performs alternative uses of 4 feedstock crops - fodder beet, wheat, sugar beet and forage maize
  - Also true at significantly higher commodity prices
  - AD use of slurry does not have to compete with other uses.
- At the farm level, for these two farm types and sizes, AD is comfortably economic
  - Biggest improvement in N.M. seen in arable farm
- Two modes of AD operation (competing and complementary)
  - Arable farm – AD main commercial focus
  - Dairy farm – milk production main focus
- Significant nutrient cost savings can made (esp. N)
- Modelling confirms slurry use as rational choice, but wheat and sugar beet preferred to forage maize
- Scale limit set by availability of land to spread digestate

Further information

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- Full report coming soon to project website:

  http://www.ad4rd.soton.ac.uk/

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Scenario 1 – AD activity available

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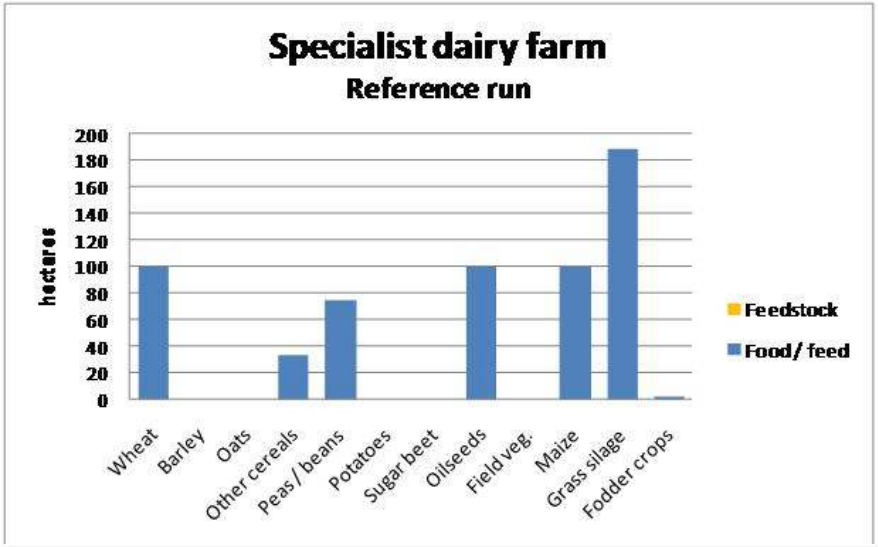

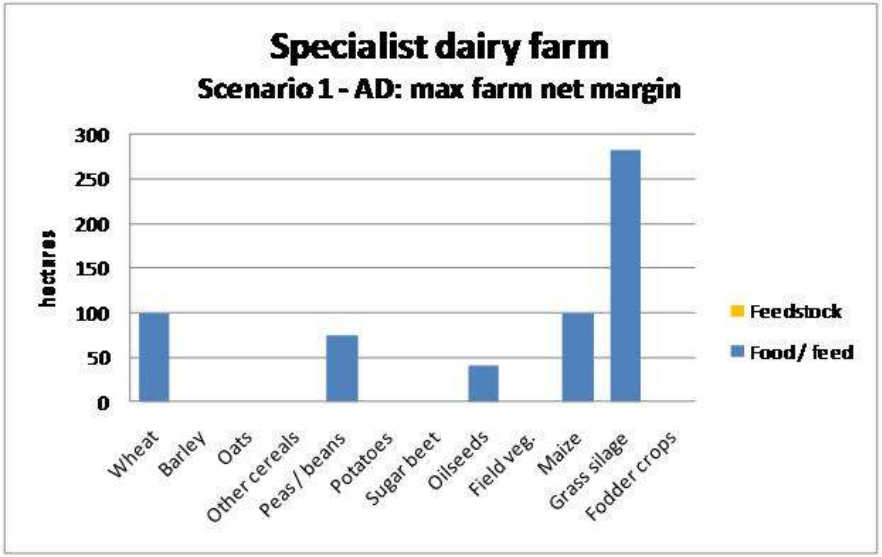

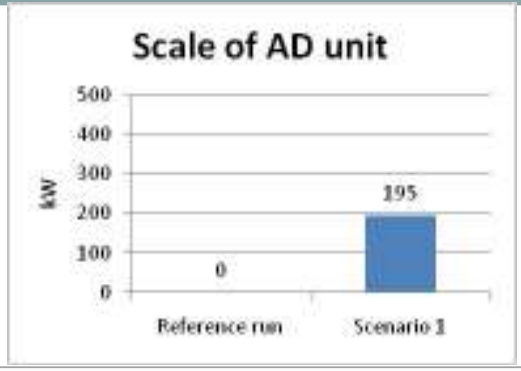

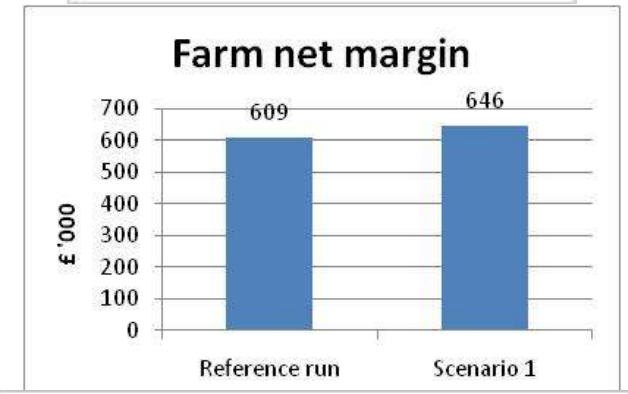

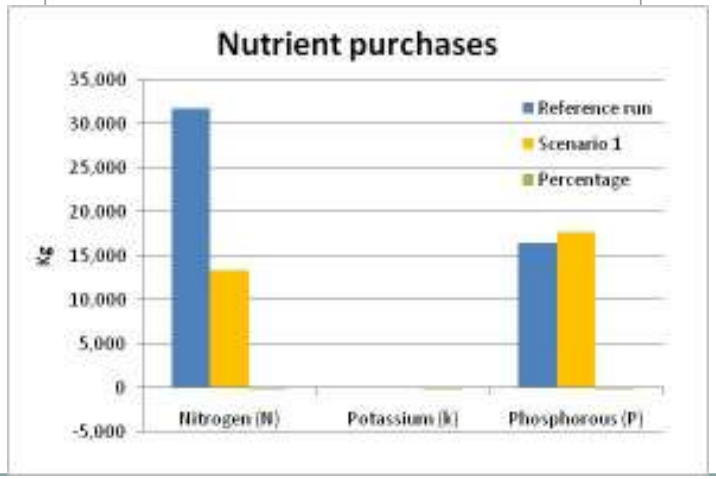

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Scenario 2 – Higher commodity prices

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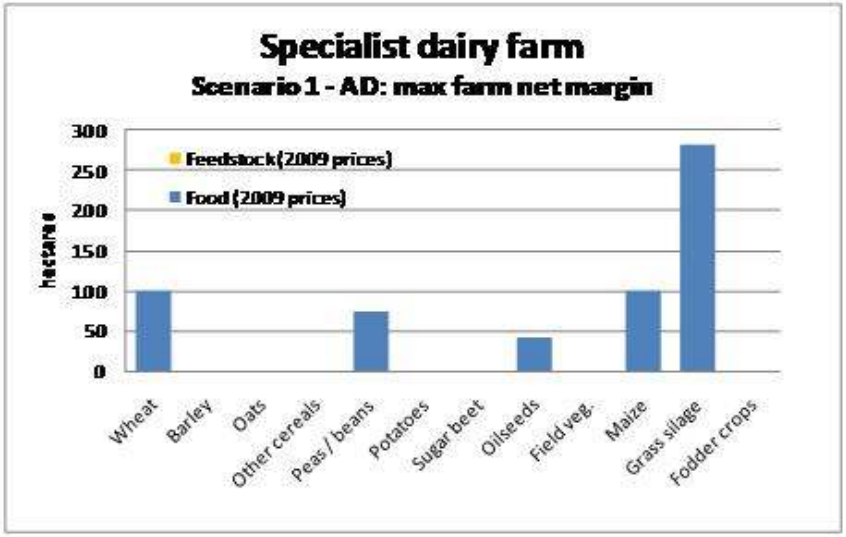

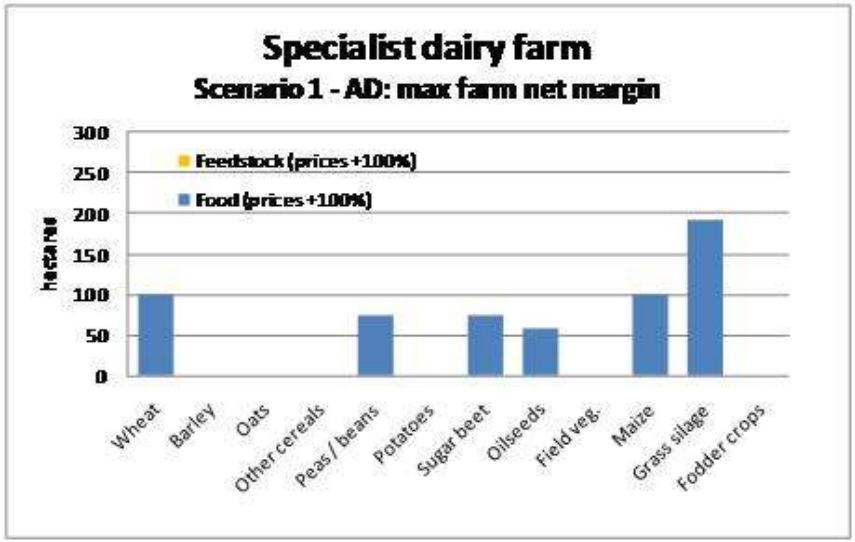

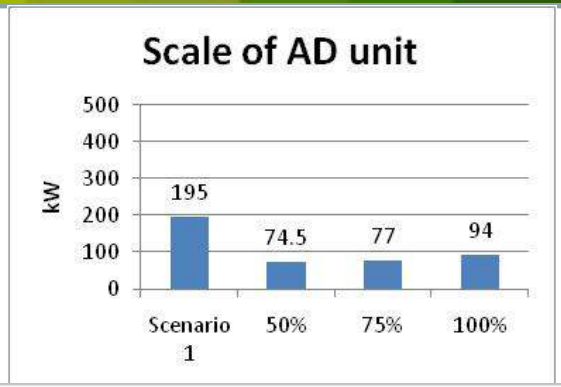

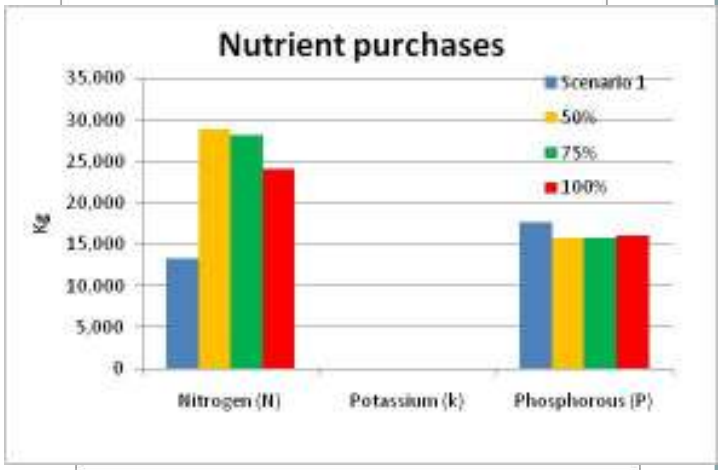

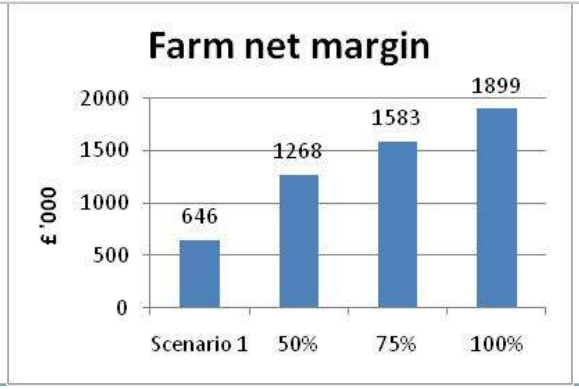

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Scenario 3 – Reduced Feed-in tariff

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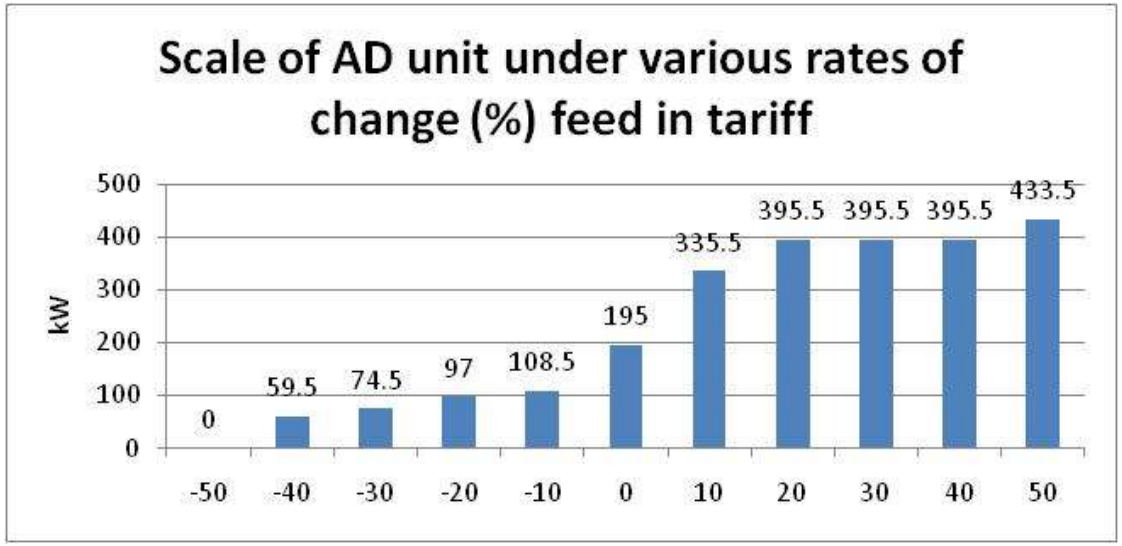

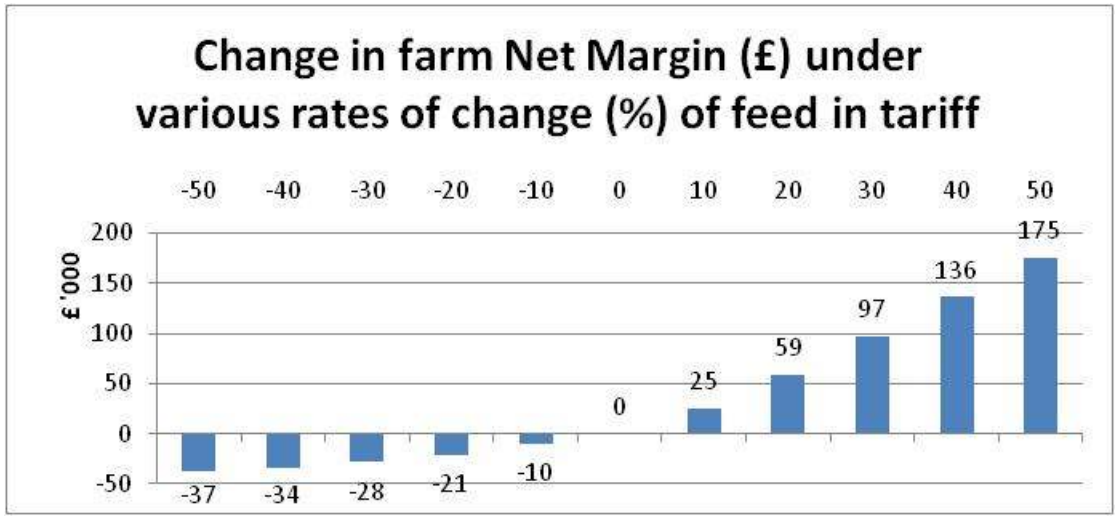

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