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Linking Economic and Energy Modelling with Environmental Assessment

when Modelling the On-Farm Implementation of Anaerobic Digestion

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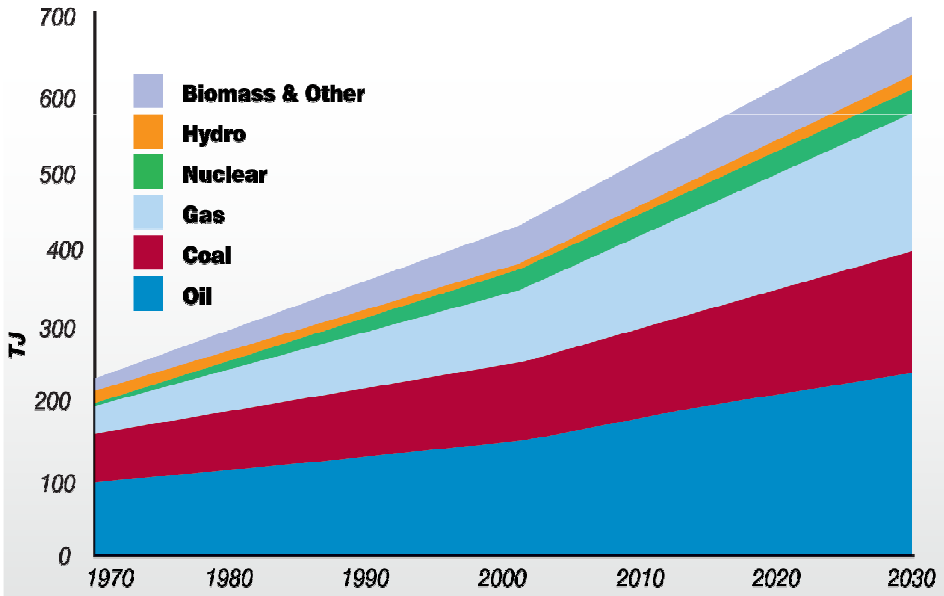
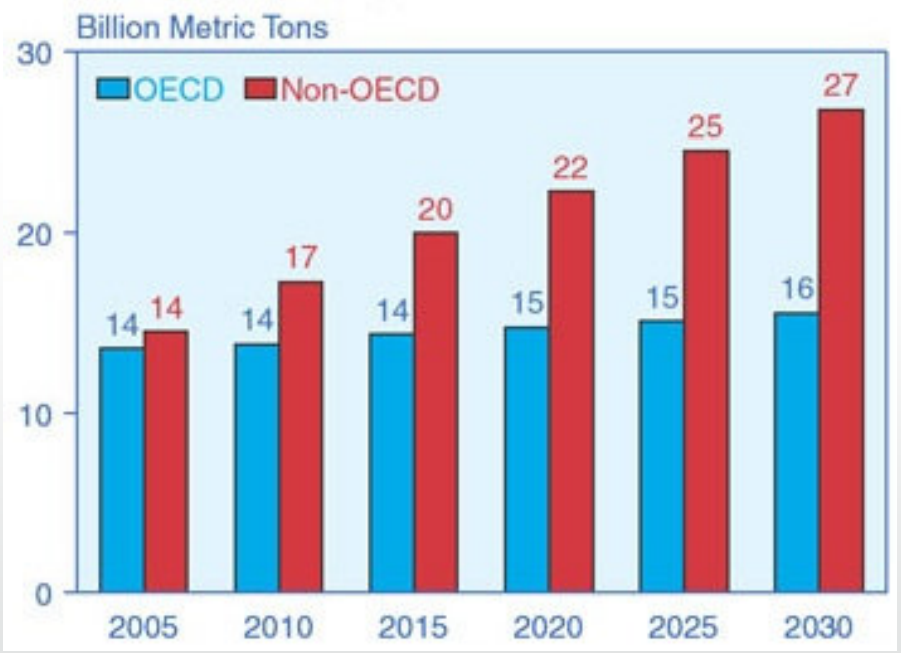
Why introduce AD onto farms?

World Energy Demand



Source: OECD/IEA World Energy Outlook 2004

World Energy-Related CO_2 Emissions



Source: Energy Information Administration

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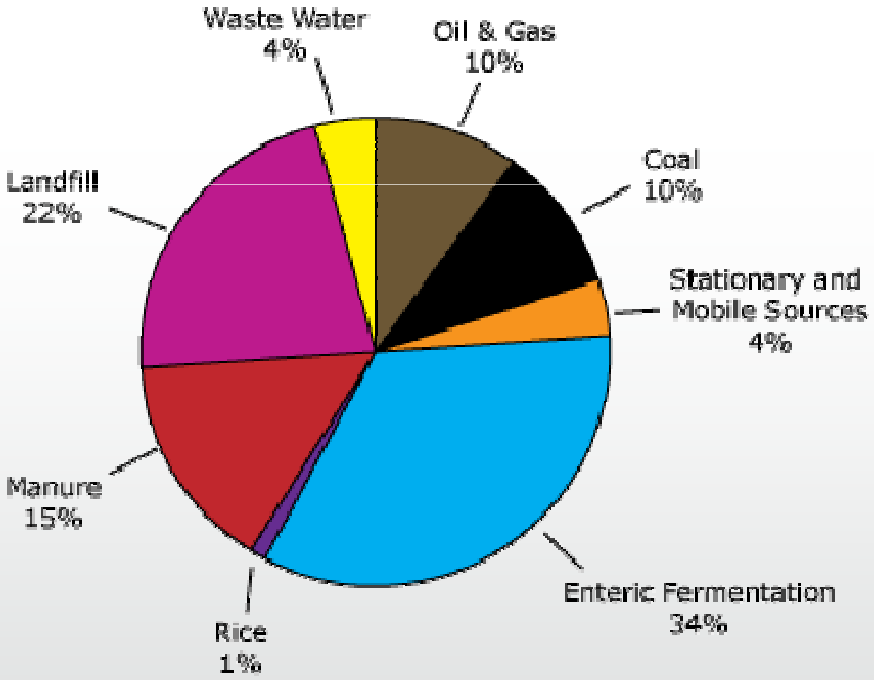
Why introduce AD onto farms?

European Union's Estimated Anthropogenic Methane Emissions by Source, 2005
Total = 448.49 $MMTCO_2E$



Source: 2006 USEPA Report: Global Anthropogenic Non-CO2 Greenhouse Gas Emissions:1990-2020

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Why introduce AD onto farms?

- Production of renewable energy
- Reducing GHG emissions from agriculture
- Farm income diversification
- Recycling of nutrients in organic wastes
- Non-food use of agricultural products to reduce over-supply

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The implementation of AD on a farm may have effects on
Farm economy
The environment
Sustainability of common energy supply

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What are these effects?

It depends…

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Economic effects of AD

may depend on:

- Investment costs
- Technical details of the biogas plant (good planning?)
- Cost of feedstock material and methane yield
- Gate fee for waste material?
- Energy prices
- Financial support
- …

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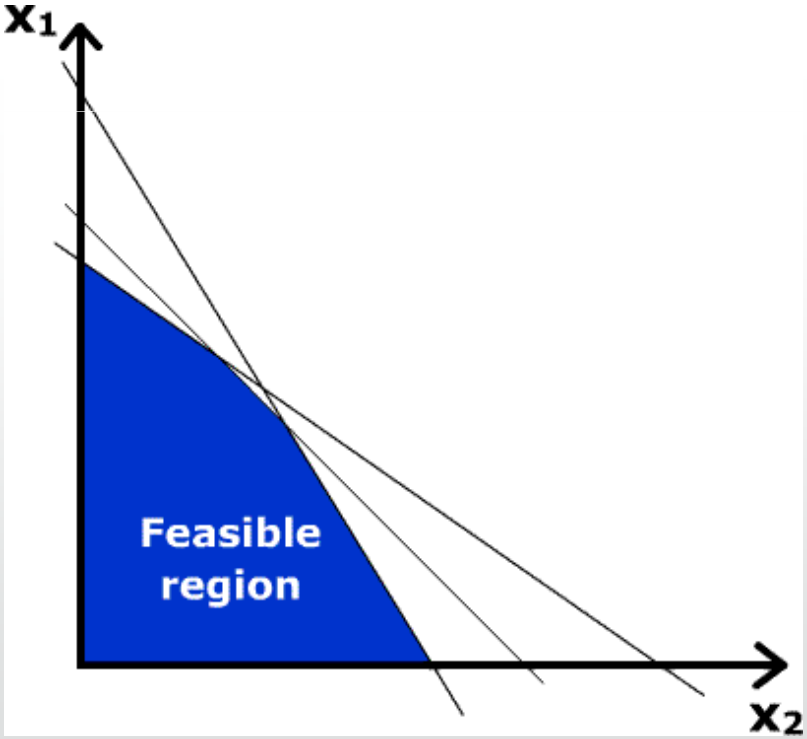
Modelling the Economic effects of AD

Optimising the farm Net Margin under given circumstances!

Linear programming (LP)



(Source: Wikipedia)

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Environmental effects of AD

Effects which <u>can</u> be modelled	**Effects which <u>cannot</u> be modelled**
•Clear causality •Relatively simple •Data available	•Very complex •Causality uncertain •Data not available

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Assessing environmental effects of AD

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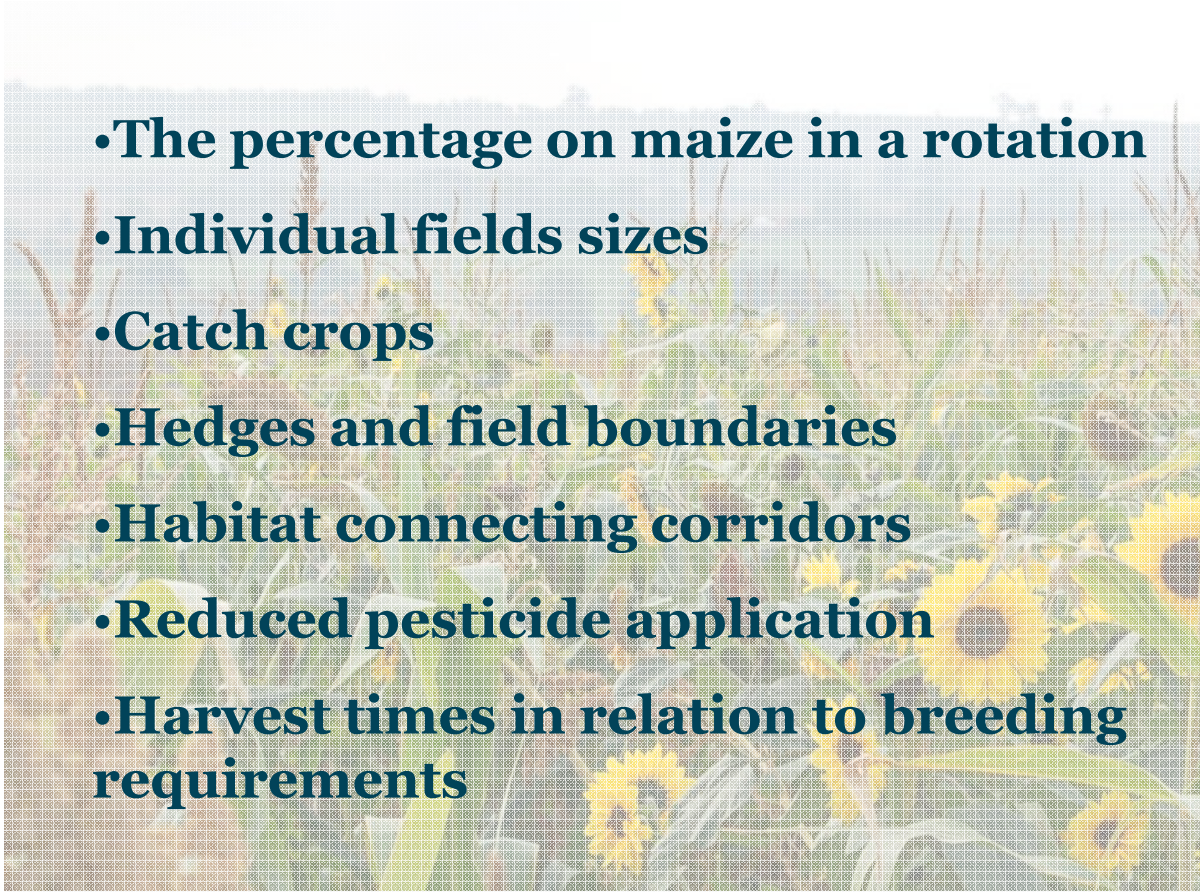
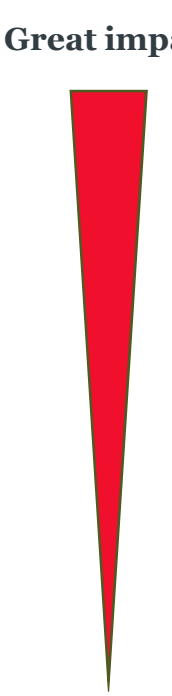
Assessing environmental effects of AD

Effects of AD on biodiversity - the example maize





Evaluation of a specific farming situation
3
5
1
3
3
2
1

Energy effects of AD

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- Renewable
  - Non-fossil fuel based
  - Biomass based fuels
- Sustainable
  - Can produce the same or more energy each year
  - Without harm to the environment

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Energy balance

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- What is meant by an energy balance?
  = *Energy out - Energy in*
  Energy out / Energy in

- Parasitic inputs
  - Direct energy
  - Indirect energy

- Beneficial outputs

- System boundaries

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Crop based AD - energy flows and sources of emissions

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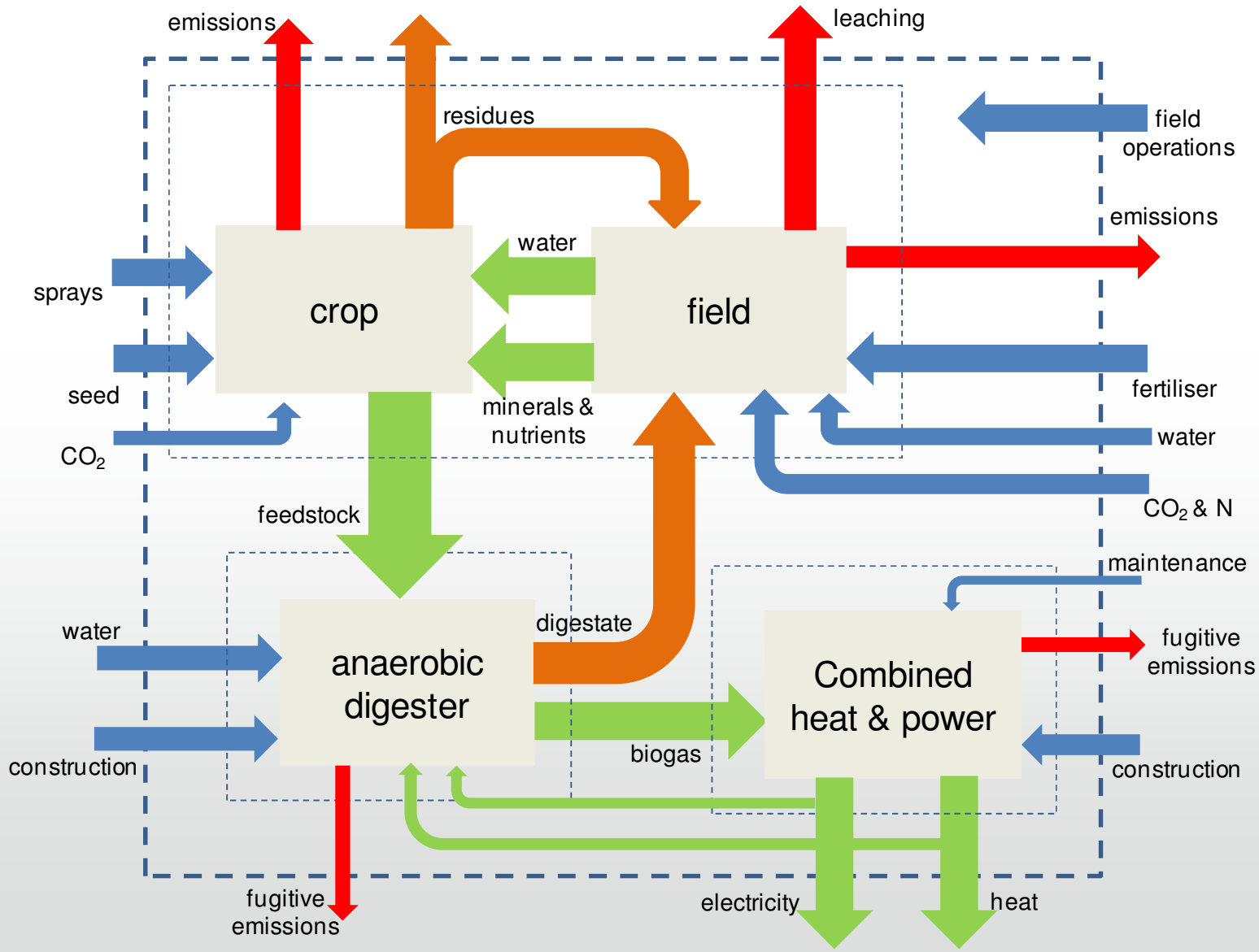

Biomass based energy balance

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crop production (direct & indirect)	7,429	GJ/yr
crop transport	274	GJ/yr
digester embodied energy	2,109	GJ/yr
digestate disposal	430	GJ/yr
energy into system	**10.9**	**TJ/yr**
methane produced	1.94	10^6 m^3
Electricity generated	20.8	TJ/yr
Heat generated	34.7	TJ/yr
parasitic electricity required	0.7	TJ/yr
parasitic heat required	4.1	TJ/yr
electrical energy out of system	20.1 (5597)	TJ/yr (MWh/yr)
heat energy out of system	30.6 (8501)	TJ/yr (MWh/yr)
Energy balance ($E_{out} - E_{in}$)	**39.9**	**TJ/yr**
Energy ratio (E_{out}/E_{in})	**4.7**	

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For a full assessment of the implementation of AD on a farm we need to examine all three aspects:
Economics
Environmental impact
Energy balance

Scenario development

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- Wide range of possible scenarios
  - Type of farm - arable, dairy, mixed
  - Size of farm
  - Proportion of crop material diverted to energy production
  - Organic or inorganic
  - Use of mineral fertilisers as opposed to recycled digestate
  - Import of organic waste from off farm
- Objective of the model
  - Economic, environment, energy

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3 concepts for analysis

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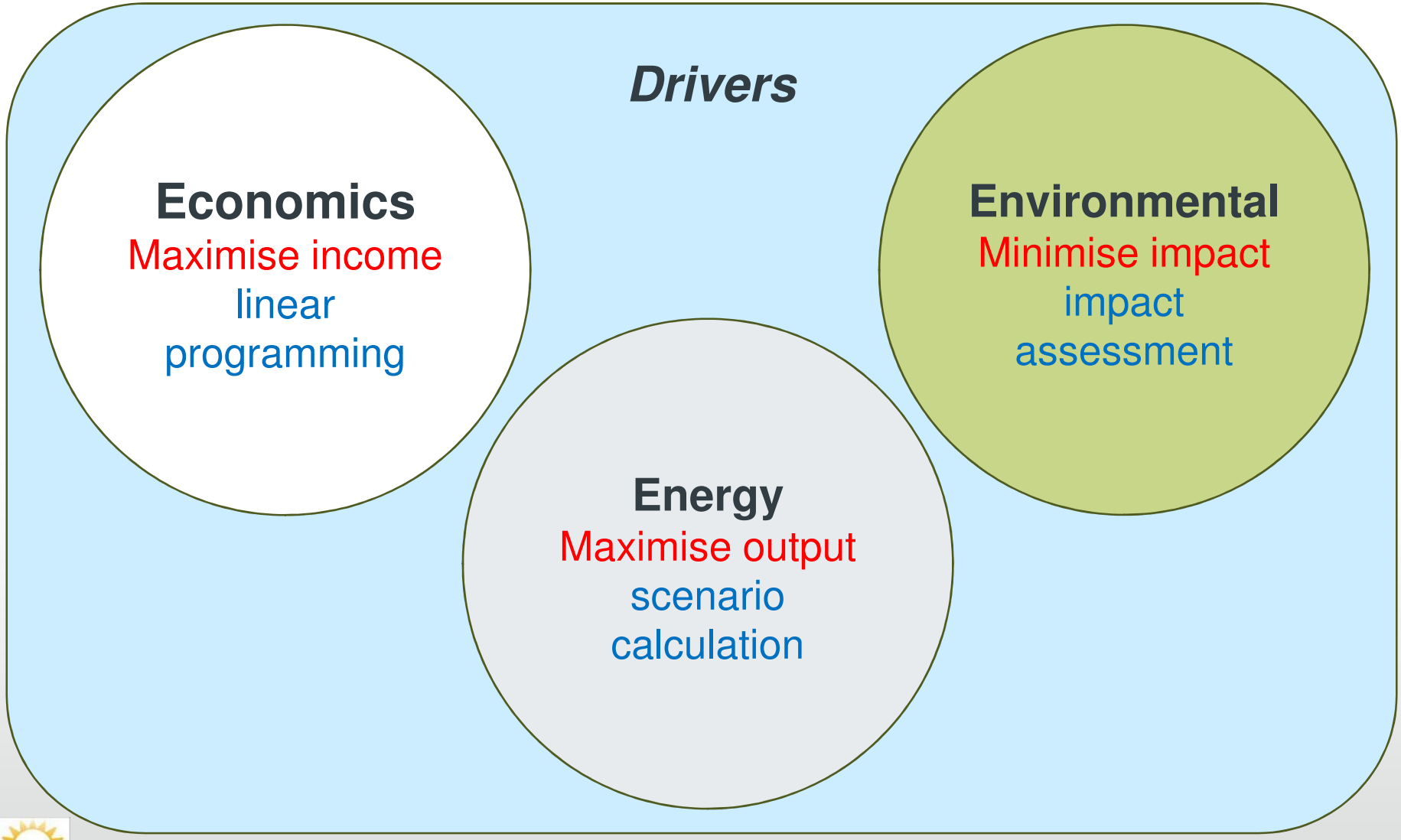

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Conflicting cropping requirements

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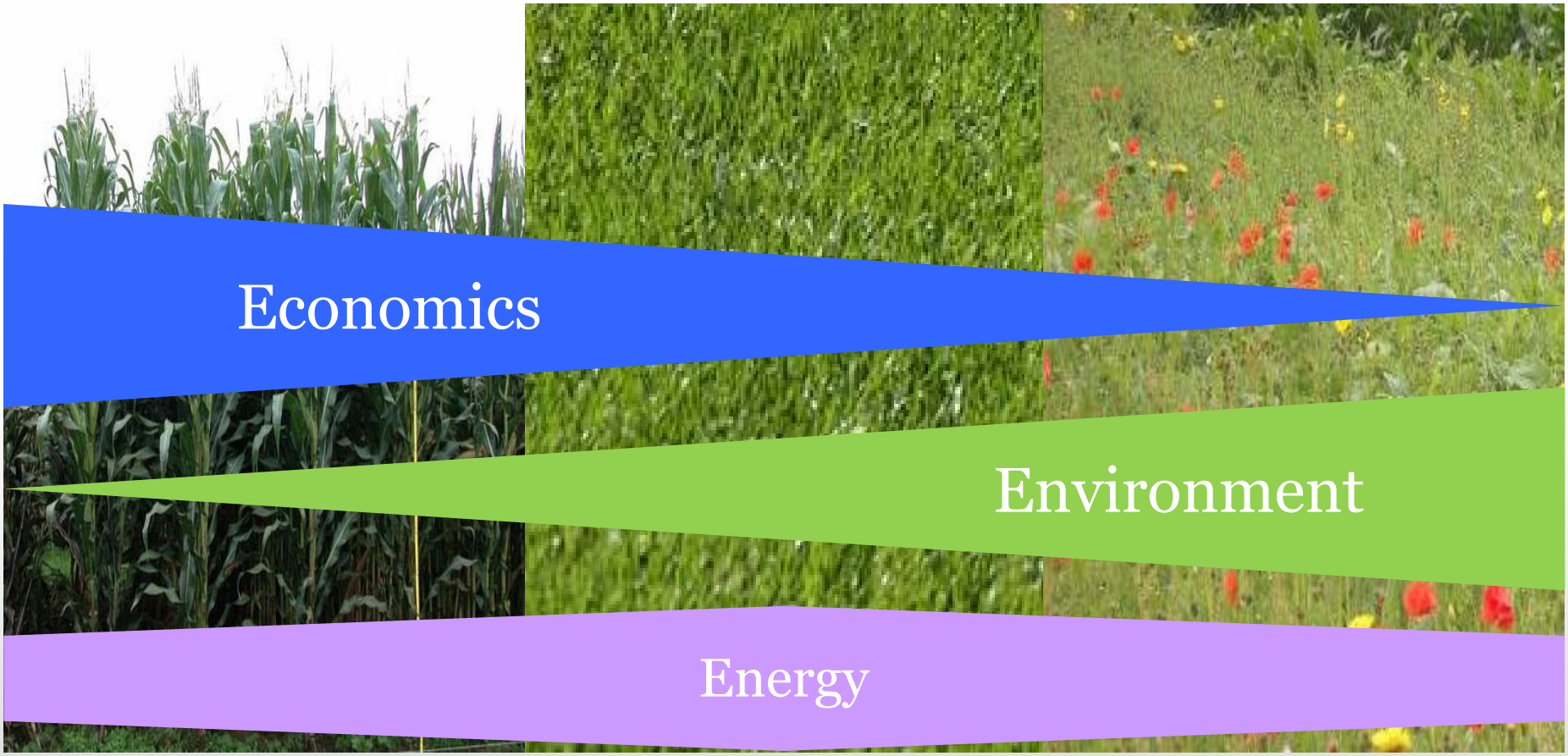
Intensive farming ⟷ Natural growth



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The Modelling Process

- Develop individual assessment models
- Develop interfaces
- Validate models against 'real' farm data and apply to farms identified in the farm survey
- Redefine and enhance models

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3 way interactions

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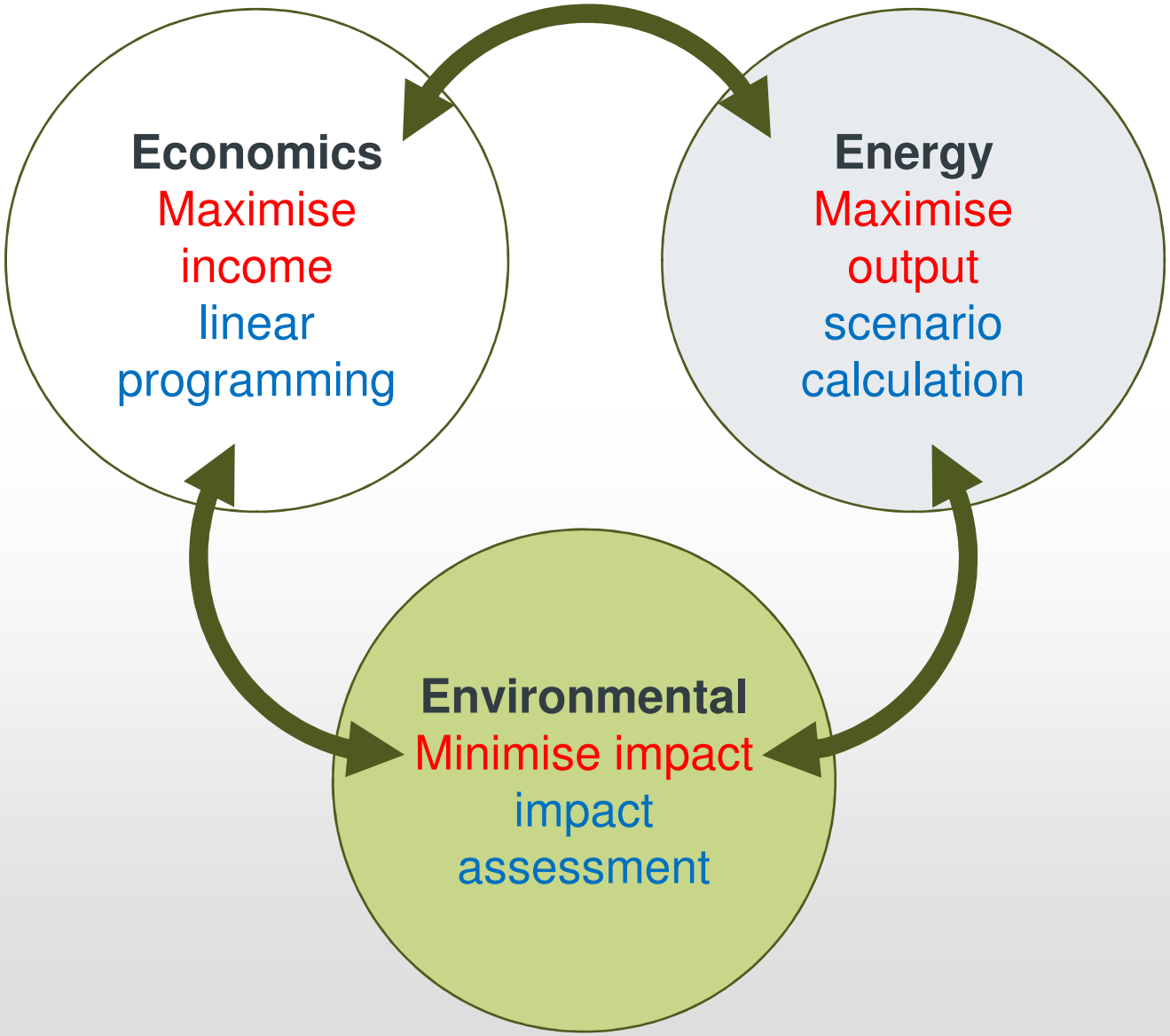

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Conclusion

- For a full evaluation need to consider economic, environmental and energy aspects
- Difficult to derive a single 'complete' model
- The three assessment methods can be linked, the outputs from one assessment used as inputs for another.

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Funded under the RELU project:

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

More information can be found at:

http://www.AD4RD.soton.ac.uk

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