

# Economic viability of farm-based co-digestion of pig manure and food waste

28th March 2017

C. Dennehy, P.G. Lawlor, G.E. Gardiner, Y. Jiang, L. Shalloo, and X. Zhan



NUI Galway  
OÉ Gaillimh



# Agenda

- Specific aims of research
- Methodology
- Typical plant costs
- Current viability of mono-digestion
- Current viability of co-digestion
- Stochastic modelling
- Conclusions



# On Farm Anaerobic Digestion-Barriers Thus Far

- Heat generated needs to be used onsite – demand?
  - Pig farms
- REFIT Ireland 15c kWh vs ROCs in N. Ireland 28c
- Complex planning process



# Manure and Food Waste Co-digestion

Food Waste

Pig Manure

**Stable digestion at high operating rates**  
**Increased volumetric methane yields**  
**€€€€€€€€**

- Additional revenue stream for farmers in the form of gate fees
- Reduce GHG emissions from agriculture
- Increase renewable energy provision
- Non-landfill management route for food residues



NUI Galway  
OÉ Gaillimh

# N.B.

- ABP regulations do not permit on-farm co-digestion of food waste
- Adjacent, separate facility required.
- Higher digester construction and site civil costs



# Rationale

- On-farm co-digestion plants in Ireland not common
- Need to analyse why, and how would they become profitable
- Focusing on a single co-substrate; Food waste (FW)



# Aims

- The objectives of this study were
  - Identify and quantify the key revenue streams, capital, (CAPEX) and operational (OPEX) costs associated with mono- and co-digestion.
  - Assess the current financial viability of co-digestion (PM and FW) and mono-digestion plants using a deterministic model
  - Present a methodology which can assess the sensitivity of overall profitability of co-digestion plants to changes in key revenue streams and operational expenses using stochastic modelling.



# Methodology

- 6 scenario's to be analysed

Scenario No.	Farm Size (sows)	Digester tank size (m <sup>3</sup> )	CHP Size (MWe)	Substrates
1m	521	1,500	0.05	Manure only
2m	2607	7,500	0.26	
3m	5214	15,000	0.52	



# Revenues

- Biogas utilization via combined heat and power unit (CHP)
  - Heat used on-farm to displace the use of oil boiler
  - Electricity to grid via REFIT
    - € 0.15/kWh for plants with  $< 0.5$  MWe, € 0.13/kWh  $> 0.5$  MWe
- FW co-digestion drives methane yields and generates gate fees
  - limited in scenario c1 due to digester size; need to maintain feedstock solids concentration below 15-20%; **3000 t/year**
  - c2, c3; the average amount FW treated by AD plants in Ireland (**8500 t/year**; derived from EPA figures)



# Financial Metrics

- Return on Investment
- Net Present Value (NPV)
  - Accounts for the payback of CAPEX, cash flow based on OPEX & revenue, and the future value of current capital and cash flow (the discount rate)
- Internal Rate of Return
  - Profit made while accounting for reduction in value of the capital invested in the project during project lifetime

# DETERMINISTIC ANALYSIS



NUI Galway  
OÉ Gaillimh

Department of Civil Engineering

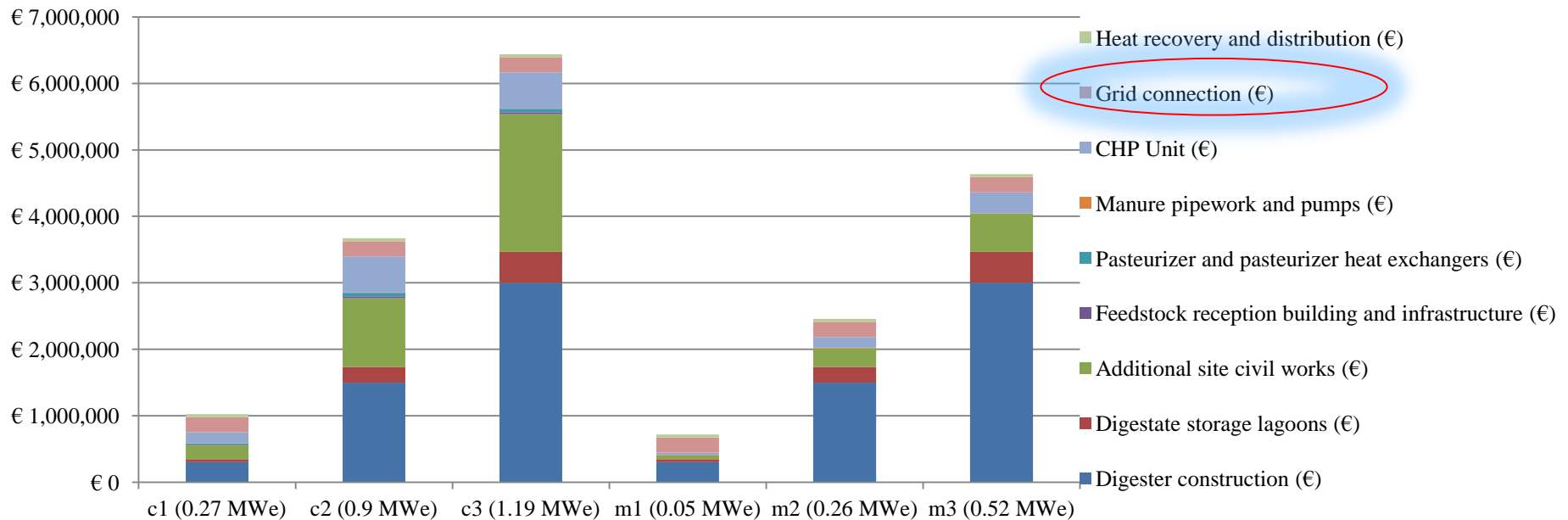
# Deterministic model

- Financial model based on fixed costs for capital expense (CAPEX), operational expense (OPEX) and revenues; static costs for
  - REFIT(€ 0.15/kWh or € 0.13/kWh )
  - Gate Fees (€30 /t)
  - FW availability (**3000 t/a c1, 8,500 t/a c2 and c3**)
  - Digestate disposal costs (€4/t up to 5kt, €7/t thereafter)
- Data for model generated from lab and meso-scale plant operation, and contacting plant operators and designers
- **CAPEX REMAINS HIGHLY VARIABLE!**



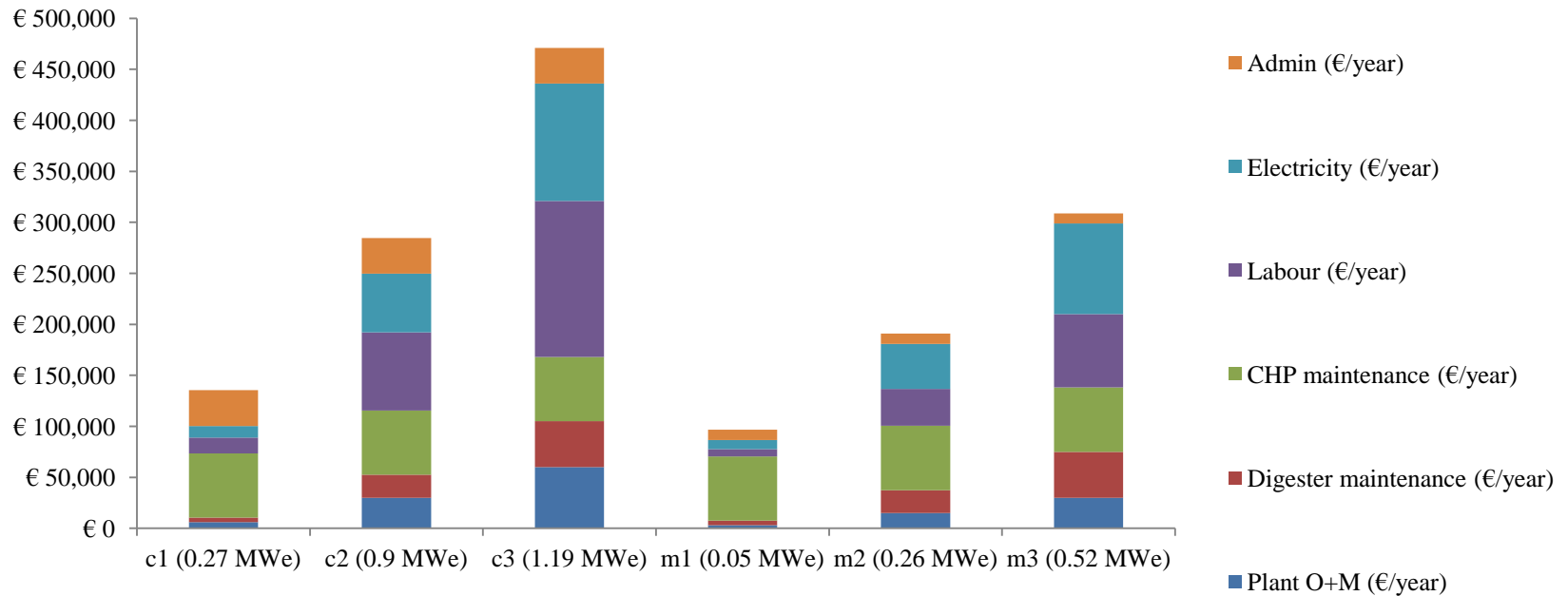
# Plant costs-CAPEX

- Ex. Development, engineering, contingency and insurance costs

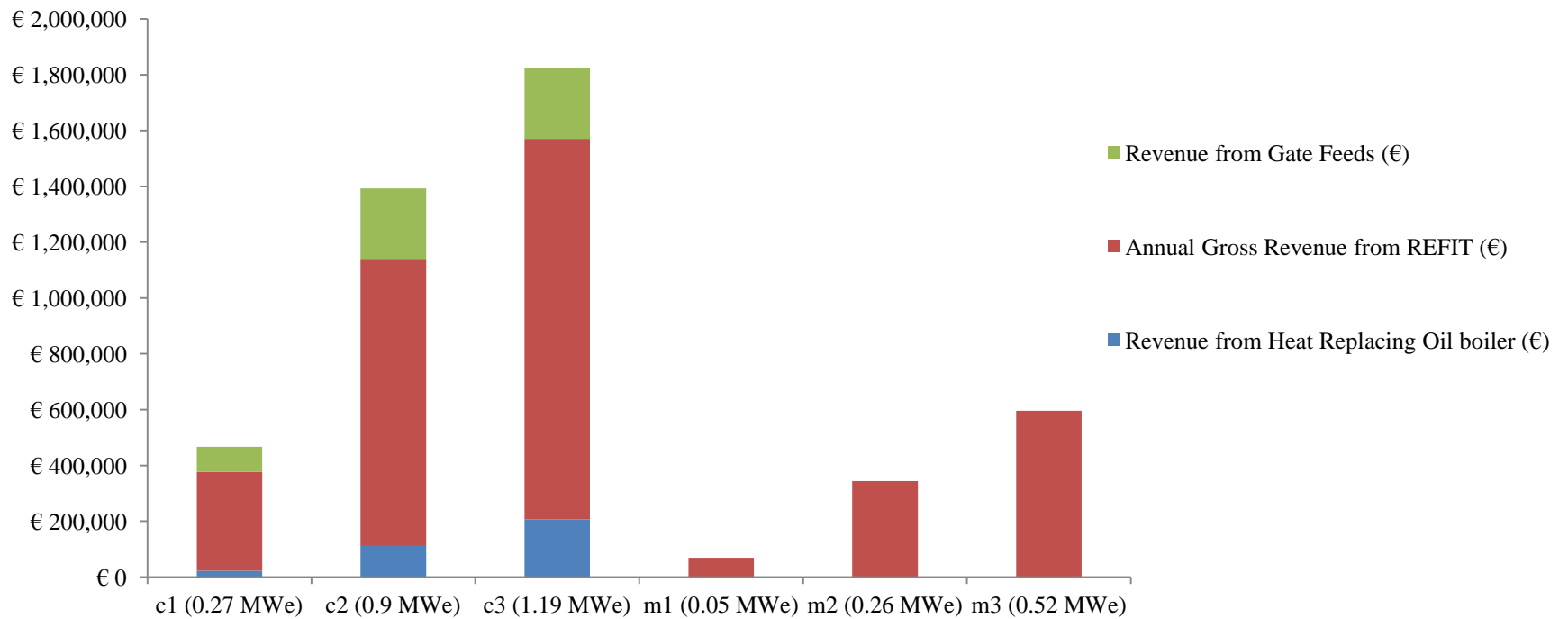


# Plant costs-OPEX

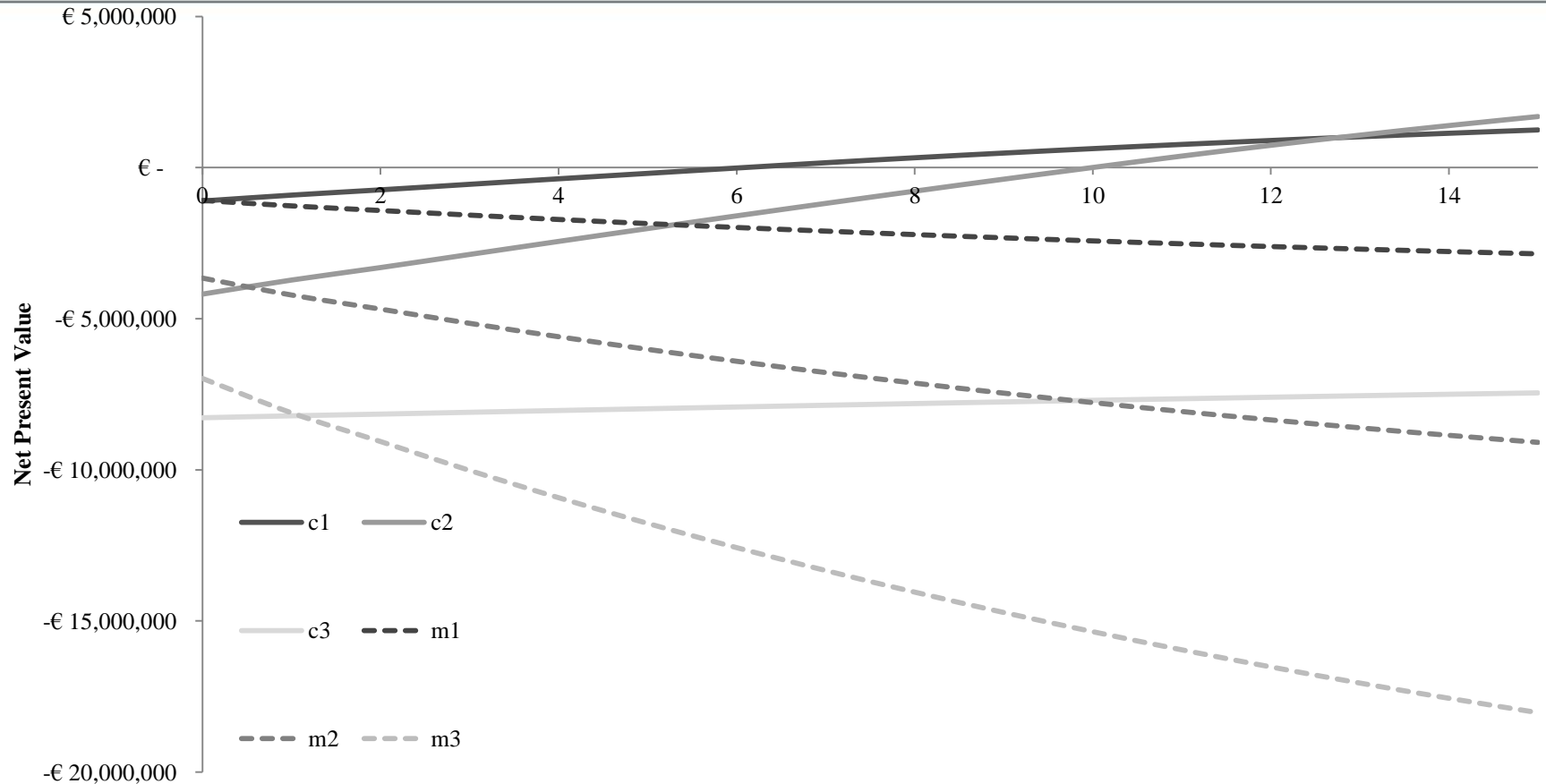
- Ex. Depreciation, interest and insurance



# Plant revenues



# Results-baseline scenario (deterministic model)





# Conclusions

- >70% of revenues from co-digestion systems and all of the revenue from mono-digestion generated by REFIT
- Scenarios c1 and c2 viable with RoI's of 126 % and 11 %, Internal Rate of Return (IRRs) of 20 % and 9 %
- Scenario c3, and all mono-digestion scenarios not viable
  - FW availability limits revenue generating potential; high CAPEX and OPEX



# STOCHASTIC MODEL



NUI Galway  
OÉ Gaillimh

Department of Civil Engineering

Variability in market conditions need to be considered

Analysis of project viability must consider these variable costs



# Stochastic model

- Analysis of the effect of possible changes in key inputs was undertaken via Monte Carlo simulation
  - The financial model was run 10,000 times, with the values for the variables changed randomly within Normal distributions
  - Parameters varied from worst case to best case scenario
  - The effect of these changes on 15 year NPV was recorded and analysed.

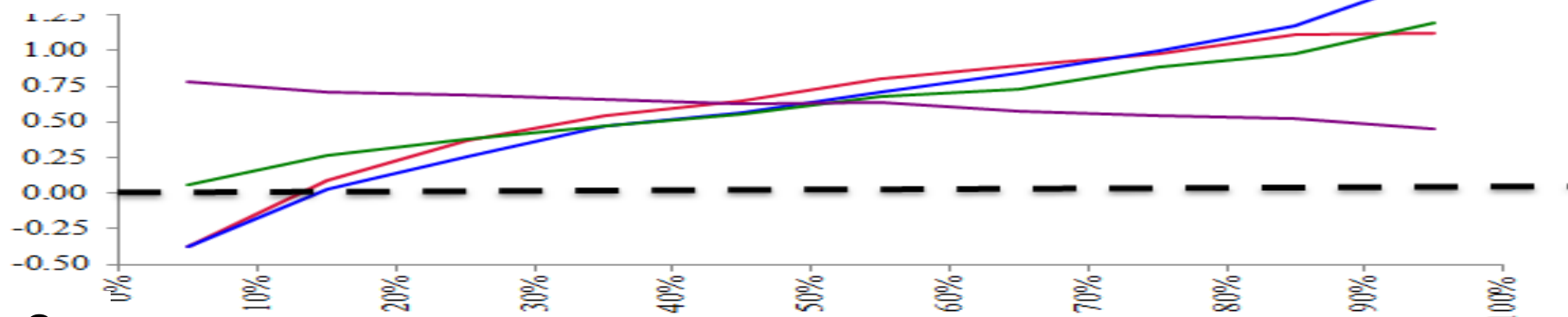


# Variable distributions

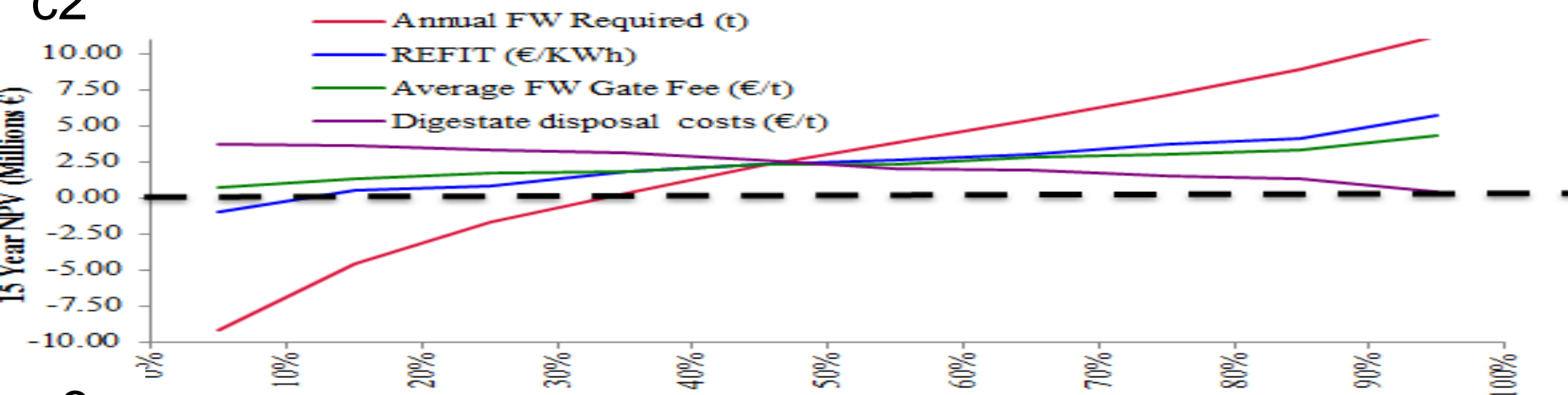
- REFIT (mean €0.15, std. dev. €0.03)
- Gate Fees- (mean €30/t, std. dev. €10/t)
- Base digestate disposal costs- (mean €4/t, std. dev € 1.5/t)
- FW availability
  - c1; mean 3000t, std. dev 500t and truncated at 3000
  - c2; mean 8500t, std. dev. 5000t and truncated at 15000
  - c3; mean 8500t, std. dev. 5000t and truncated at 30000



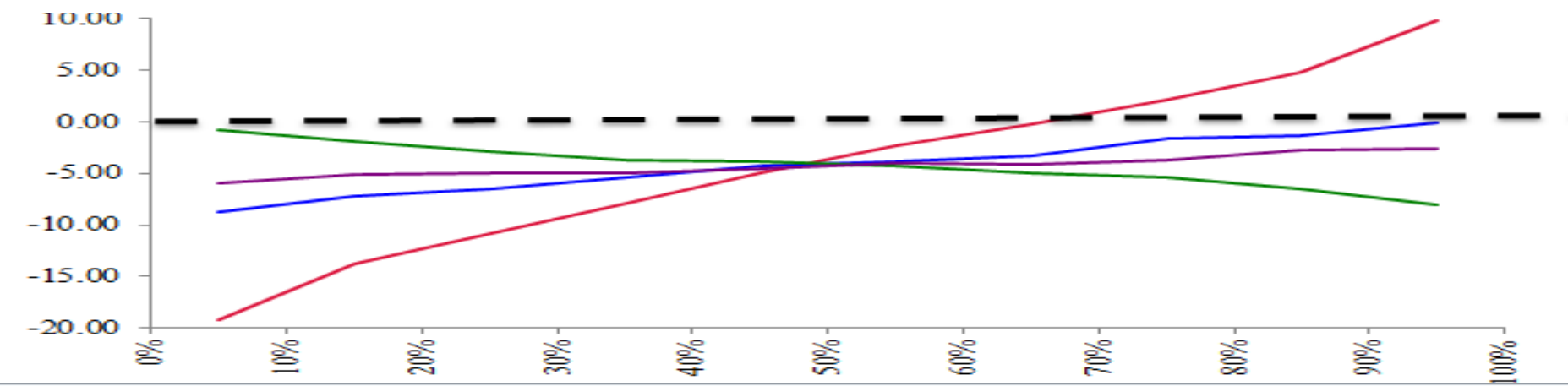
c1

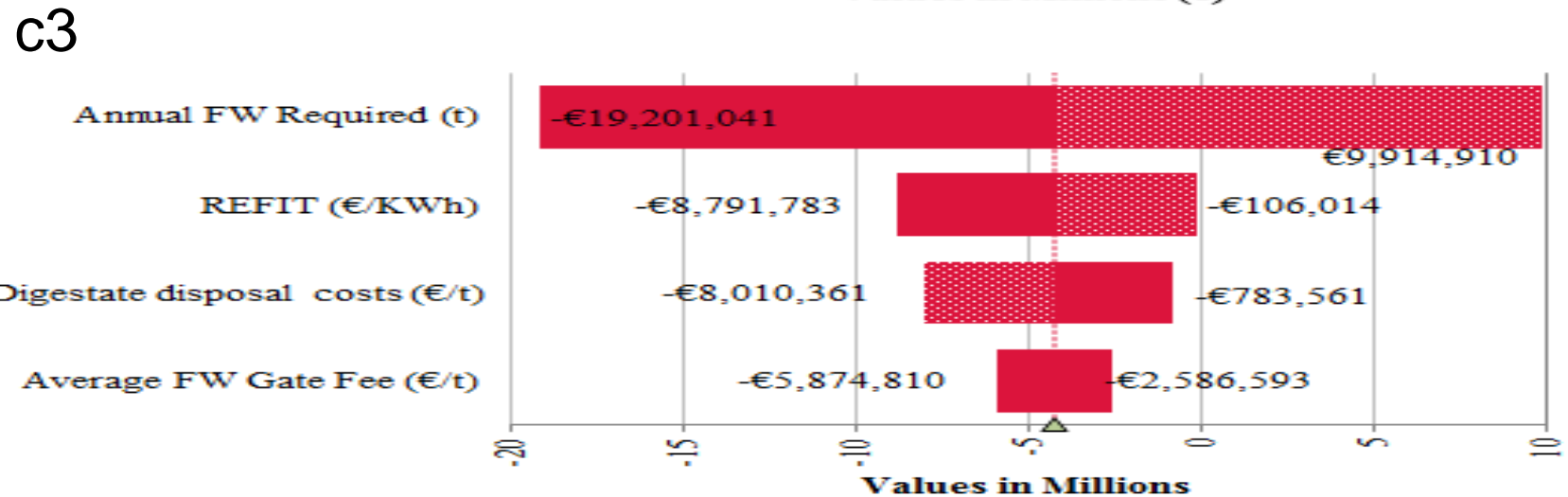
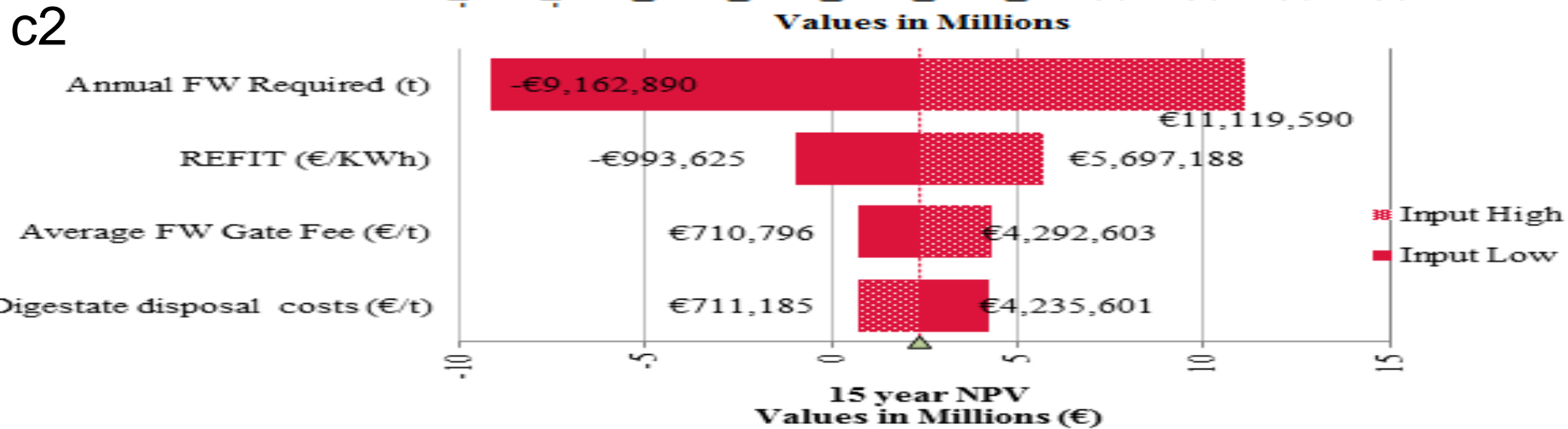
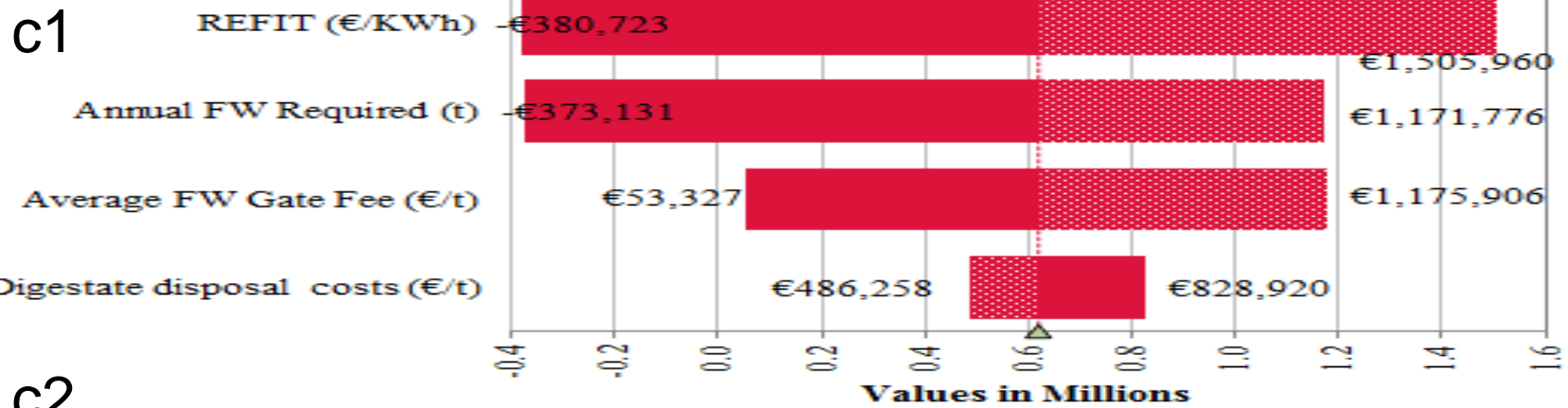


c2



c3





# Stochastic modelling conclusions

- Scenario c1 least impacted by changes in all parameters
- Scenario c2 and c3 highly sensitive to changes in FW availability
- Due to higher CAPEX and OPEX and the limited FW supply, scenario c3 remains unviable
  - unless large volumes of FW can be secured (which case significant profits can be realised)
- FW availability limits scale of on-farm PM and FW co-digestion
  - Working with local food processing facilities and waste management companies?
  - Alternative feedstocks



# Conclusions

- Mono-digestion of PM not financially viable
- Farm of 521 sows co-digesting 3000t of FW per annum financially viable.
- Farm of 2,607 sows co-digesting 8,500 t of FW per annum was found to be financially viable, but strongly affected by market conditions
- FW availability limits the scale of on-farm biogas plants treating FW exclusively



# Thank You

Conor Dennehy- [c.dennehy2@nuigalway.ie](mailto:c.dennehy2@nuigalway.ie)

## ACKNOWLEDGEMENTS

Funding for this Research was provided by Science Foundation Ireland (Ref: 12/IP/1519)



NUI Galway  
OÉ Gaillimh

