Urban Water Security Research Alliance

ENERGY AND GREENHOUSE FOOTPRINTS OF WASTEWATER TREATMENT PLANTS IN SOUTH-EAST QUEENSLAND

David de Haas & Paul Lant

LCA project

17 or 18 August 2009

Queensland Government

CSIRO

Griffith UNIVERSITY

The University Of Queensland AUSTRALIA

Contents

Introduction

Why calculate WWTP greenhouse gas?

- Use ~ 5 to 10 W/EP (~500 to 1000 kWh/ML) electricity
- Can be a significant part of local government total GHG footprint (~40 to 50%)
- *Potential* emissions up to:

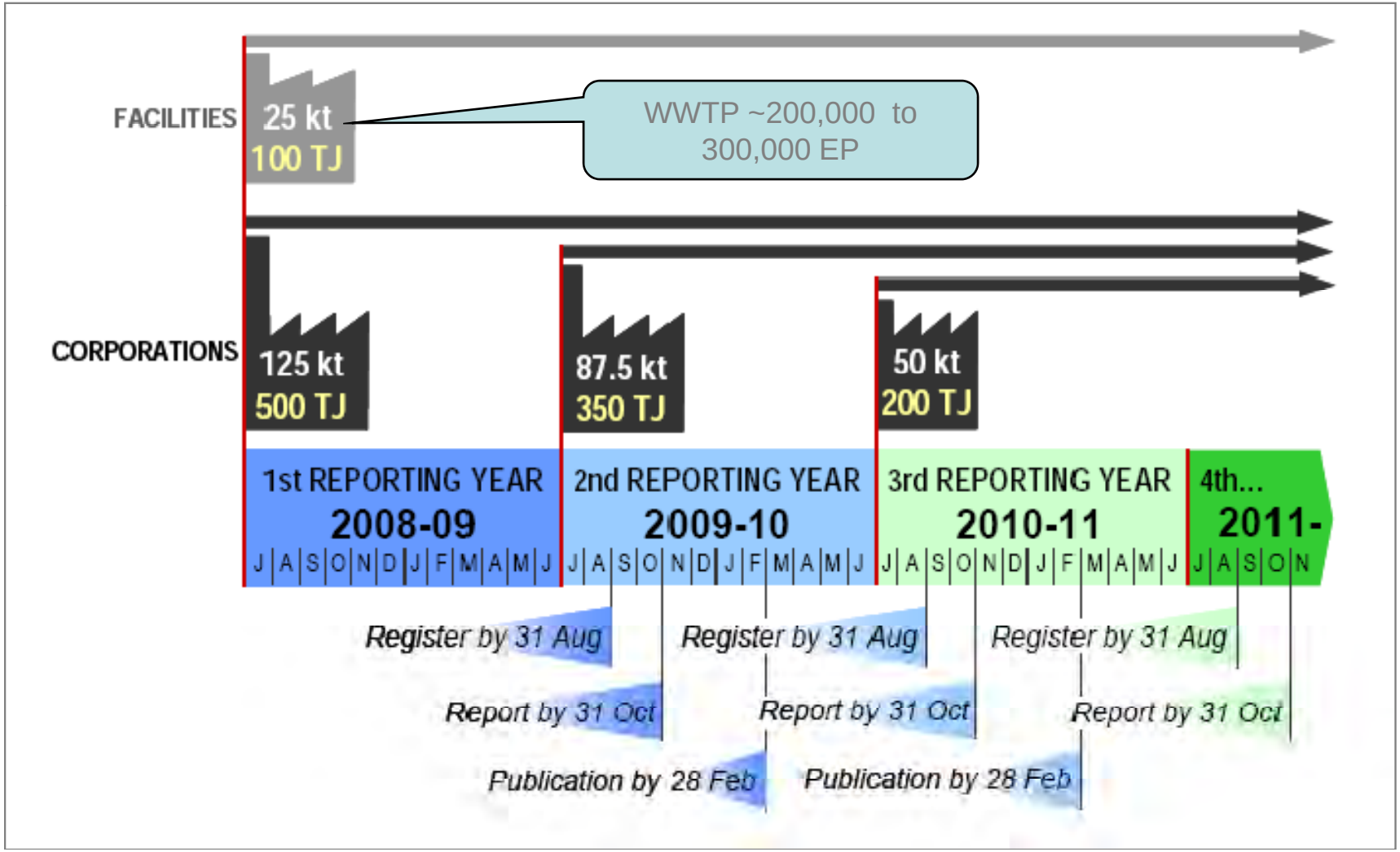
  ~0.8 kg CO_2-e per day per EP as methane

  ~0.3 kg CO_2-e per day per EP as nitrous oxide

  ?? kg CO_2-e per day per EP as carbon dioxide (non-biogenic)

- **NGERS (2007)** – Australian Federal govt. requires reporting (effective July 2008) when exceeding certain thresholds

NGERS Thresholds



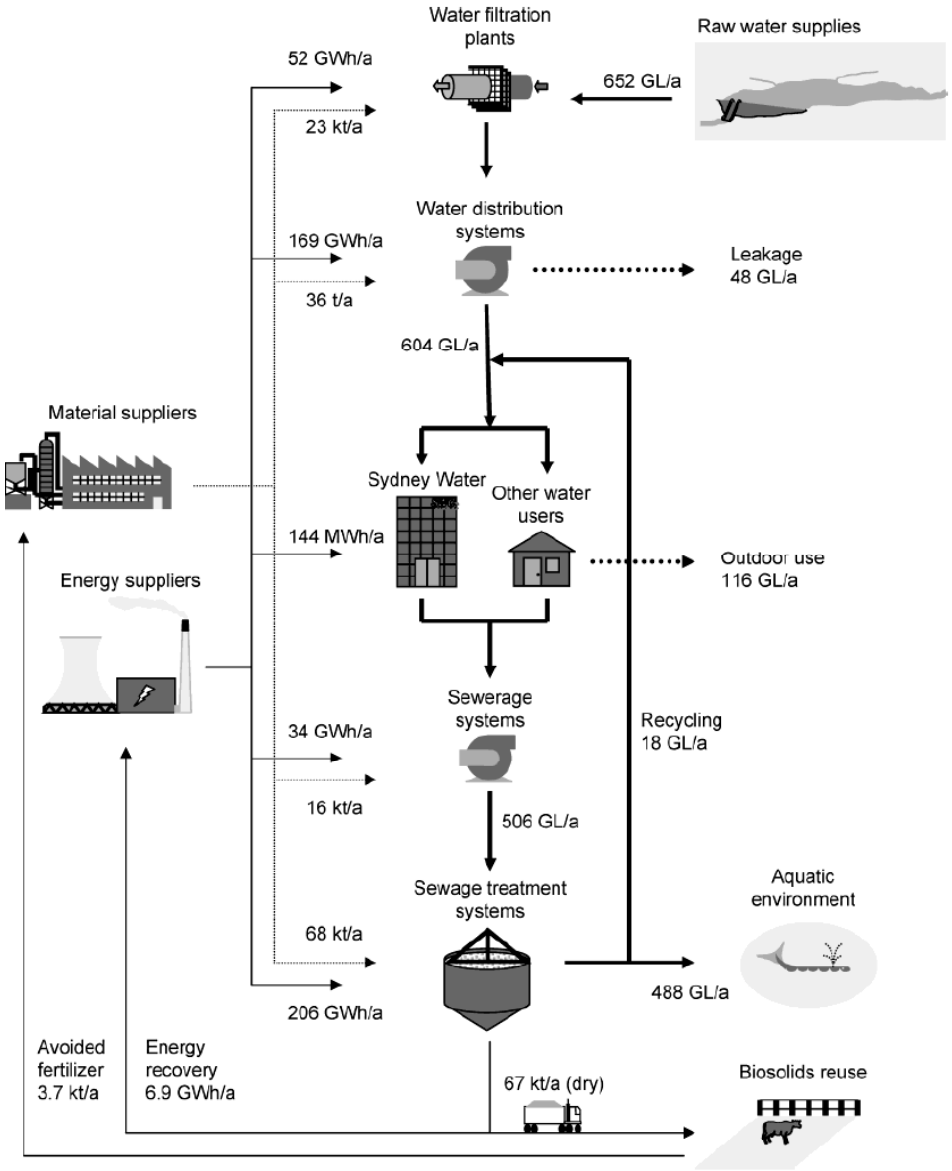
Life Cycle Assessment

- Research alliance objective : LCA model of SEQLD water grid
  - Dams
  - Water Treatment & Distribution
  - Wastewater Collection
  - Wastewater Treatment & Disposal (effluent & biosolids)
  - Water recycling/ Advanced treatment
  - Desalination
- Use LCA as a tool to inform decision makers
  - Energy/ greenhouse & secure water supply
  - Environmental impacts / burden

Previous LCA studies

- WWTP impacts dominated by operational inputs & outputs (power, chemicals, biosolids etc.)
- Embodied energy (construction/ demolition) relatively minor
- Examples : Lundie *et al.* 2004 for Sydney

Lundie et al.(2004) – Sydney Water



Lundie et al.(2004) – Sydney Water

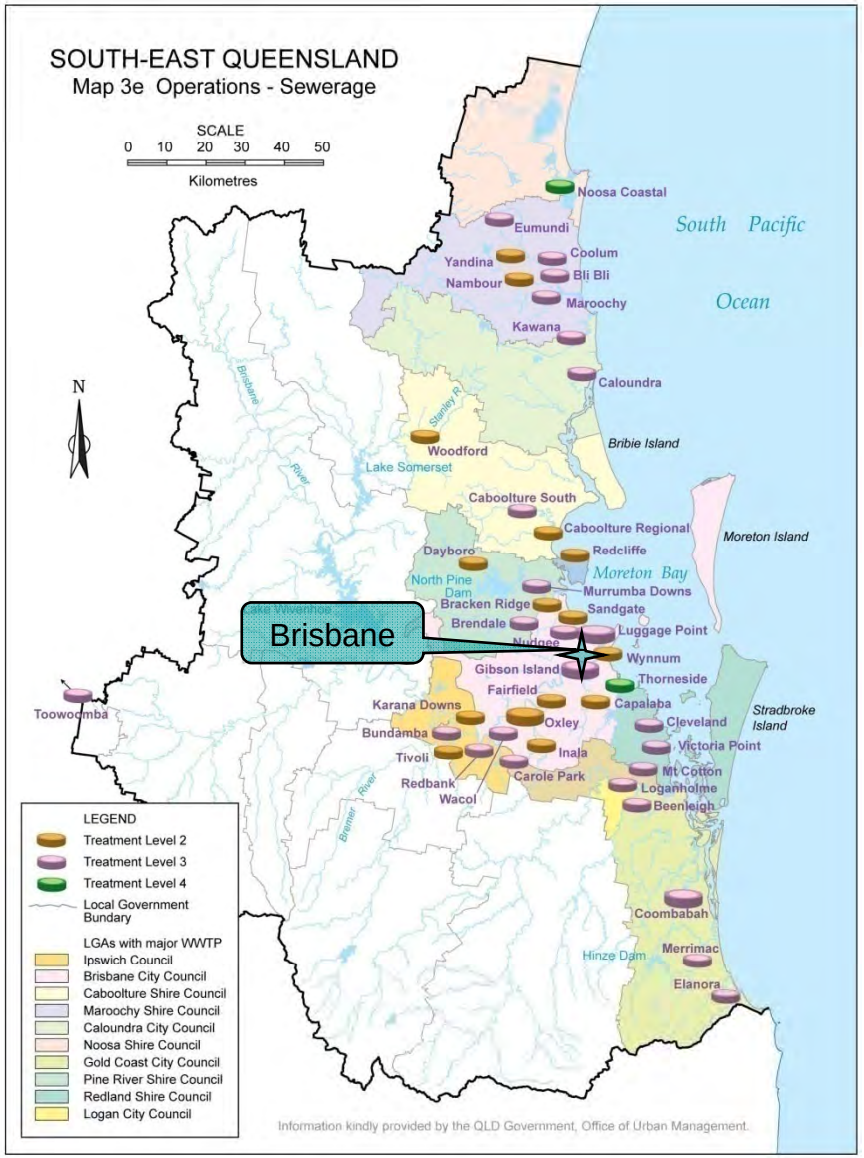
TABLE 5. Comparison of Scenarios against the Base Case for Each Environmental Indicator and Impact Category

	total energy (%)	water usage (%)	climate change (%)	eutrophication potential (%)	photochemical oxidant formation potential (%)	human toxicity potential (%)	freshwater aquatic ecotoxicity potential (%)	marine aquatic ecotoxicity potential (%)	terrestrial ecotoxicity potential (%)
desalination	27	0	23	1	5	1	0	1	3
demand management	−4	−6	−4	−6	−6	−6	−6	−6	−6
energy efficiency	−13	0	−11	−1	−6	−1	0	0	−2
energy generation	−8	0	−7	0	−1	0	0	0	−1
energy recovery from 50% biosolids	−4	0	−2	0	−2	−9	−29	0	−39
population +7%	3	7	4	7	6	7	7	7	7
population +16%	8	16	10	16	15	16	16	16	15
population −7%	−4	−6	−5	−6	−6	−6	−6	−6	−6
population −16%	−8	−12	−8	−12	−11	−12	−12	−12	−11
secondary upgrade of major coastal STPs	23	0	21	−8	16	2	2	0	51
secondary & tertiary upgrade of major coastal STPs	26	0	23	−10	17	2	3	0	60

Methodology

Inventory data - WWTPs

- South-East Queensland
- Approx. total 40 no. WWTPs
- Surveyed 35 no. WWTPs
- Beaudesert, Esk, Laidley, Gatton, Kilcoy etc. not included in study area



Two types of WWTP

TYPE 1

- Primary sedimentation
- BNR activated sludge
- Anaerobic co-digestion of (primary + waste activated sludges)
- Biogas collection → *some* with on-site co-generation (electrical power & heat)
- *Most* with chemical supplementation for nutrient removal (N&P)

TYPE 2

- Extended aeration BNR activated sludge
- Some with aerobic digestion of waste activaeted sludge
- No biogas/ collection
- No co-generation
- *Many* with chemical supplementation for nutrient removal (N&P)

WWTPs surveyed – size summary

TYPE OF PLANT & DESCRIPTION	No. of plants surveyed of this Type	% of TOTAL ADWF treated for WWTP in survey	% of Effluent TOTAL N LOAD (50%ILE) for WWTP surveyed	Approximate % of effluent TOTAL P LOAD (50%ILE) for WWTP surveyed	Current ADWF (ML/d)			Indicative EP from ADWF, assuming 200 L/EP.d		
					Min	Max	Average	Min	Max	Average
Type 1 – No Cogen	3	8%	7%	5%	5.7	24.1	13.3	29,000	121,000	66,000
Type 1 – Cogen	3	38%	44%	60%	15.1	123.7	63.6	76,000	619,000	318,000
Type 2 - Small	5	0.3%	0.6%	0.4%	0.075	0.46	0.30	400	2,300	1,500
Type 2 - Medium	17	19%	20%	8%	1.5	9.8	5.5	8,000	49,000	28,000
Type 2 - Large:	7	35%	28%	27%	10.4	54.0	24.8	52,000	270,000	124,000
TOTAL no. of plants surveyed	35	100%	100%	100%	0.1	123.7	14.4	400	619,000	71,000

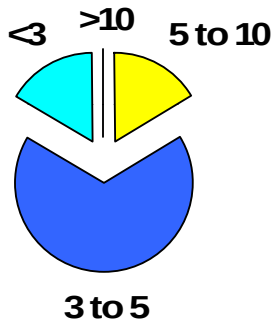
Two biggest plants – no advanced P removal

Effluent N & P

Type 1

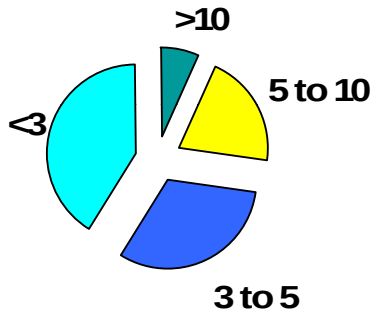
Proportion of plants in survey

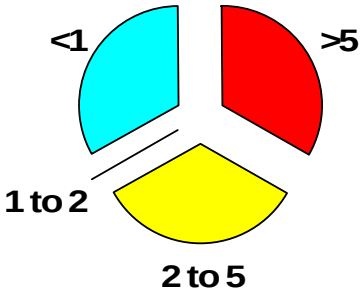
Type 2



Total N

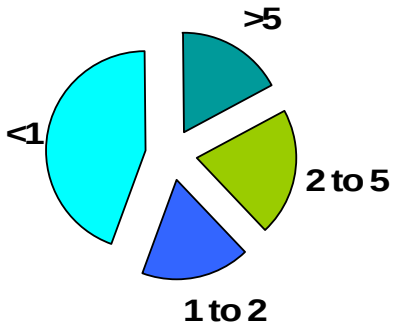
mgN/L





Total P

mgP/L



Data collected

- **Flow** (dry weather average)
- **Influent** COD (or BOD), TKN and TP concentrations
- **Effluent** Total N and Total P concentrations
- **Power** consumption & Power generated (on site) from biogas (if any)
- **Chemicals** consumption
- **Biosolids**
- **Screenings & grit**
- **Biogas** produced (if any) & methane content (if measured)
- **Flow of sludge** stream(s) treated through anaerobic digestion
- **Method of effluent disposal** (ocean, estuary, river, wetlands or irrigation)
- Approx. % effluent volume disposed to **effluent reuse** (e.g. irrigation)

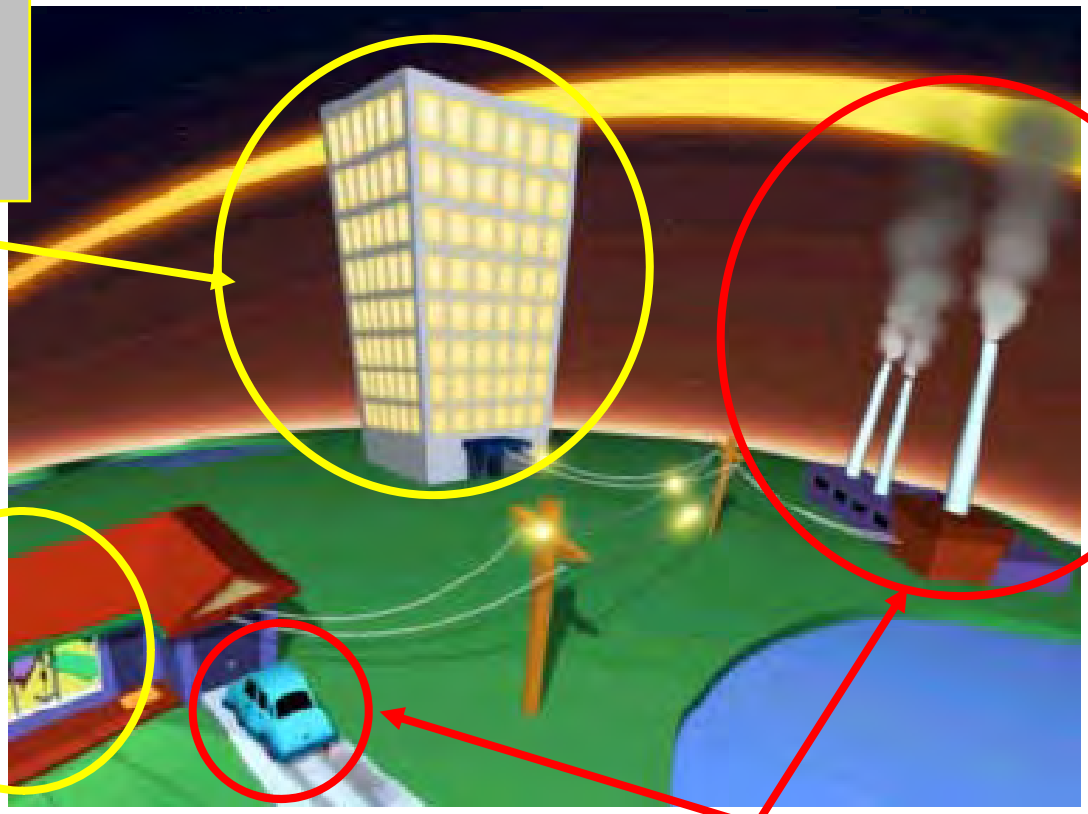
GHG calculations

For WWTPs

- Former AGO workbook methodology inadequate (WSAA, 2007)
- IPCC ‘Tier 3’ or NGERS (2008) Technical Guidelines ‘higher order’
- First principles (mass balance approach)
- WWTP functional areas (C & N in/out)
- Fugitive emissions
  - ✓ Raw sewage dissolved CH_4
  - ✓ Denitrification N_2O
  - ✓ Anaerobic digestion CH_4 (not combusted)
  - ✓ Biosolids CH_4
  - ✓ Effluent N_2O (receiving water/ environment)
- Non-biogenic carbon (CO_2)
- Biosolids carbon sequestration (?)
- ALL SCOPES: 1, 2 & 3 included

Scopes 1, 2 & 3

Scope 2: Indirect
Emissions from electicity consumed but generated elsewhere



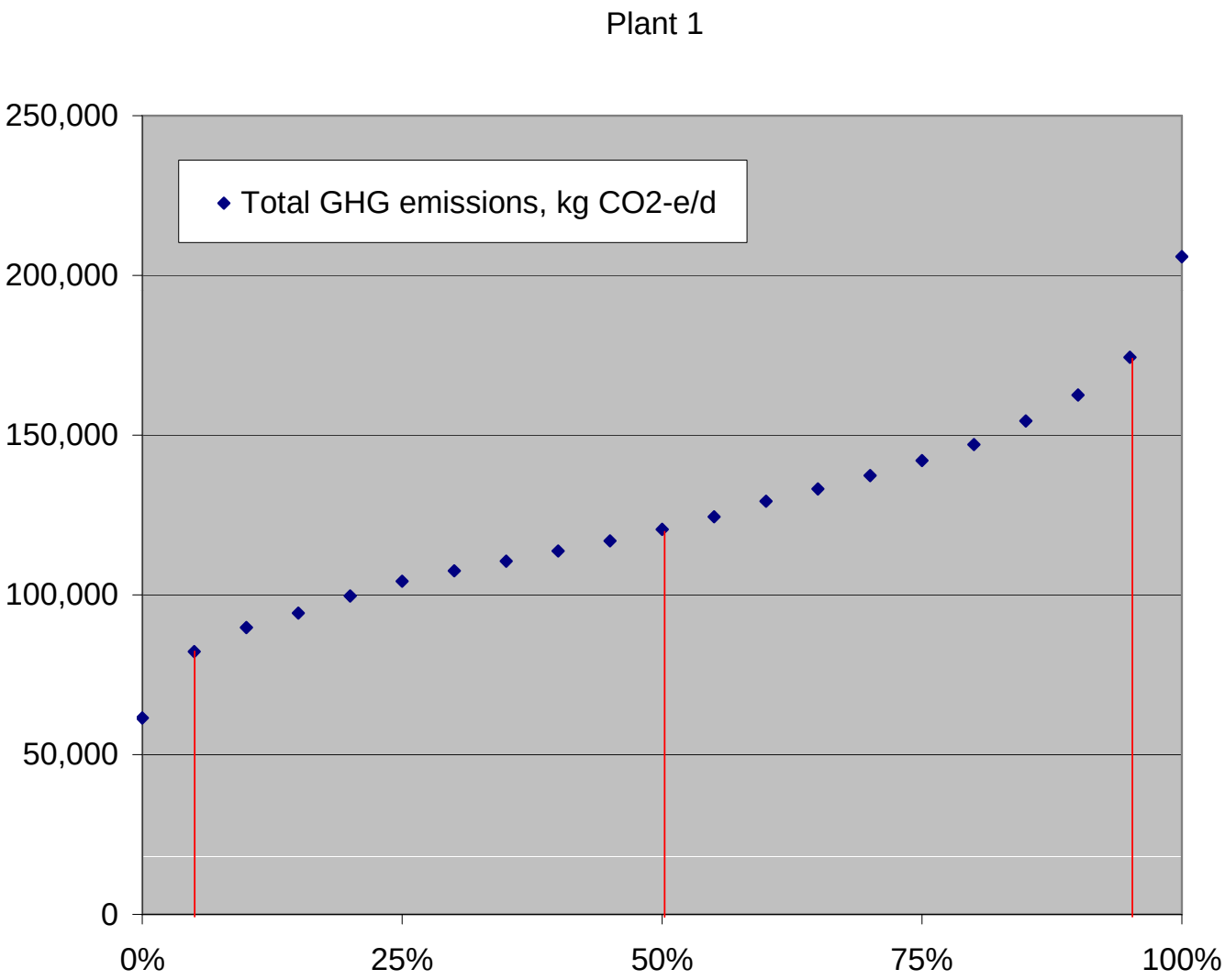
Scope 3
Other indirect emissions resulting from business but emission sources are not owned e.g. from supply chain of consumables or transport of goods purchased

Scope 1: Direct
Emissions from fossil fuels or other sources under direct control (e.g. own production process or vehicle fleet).

Emission factors

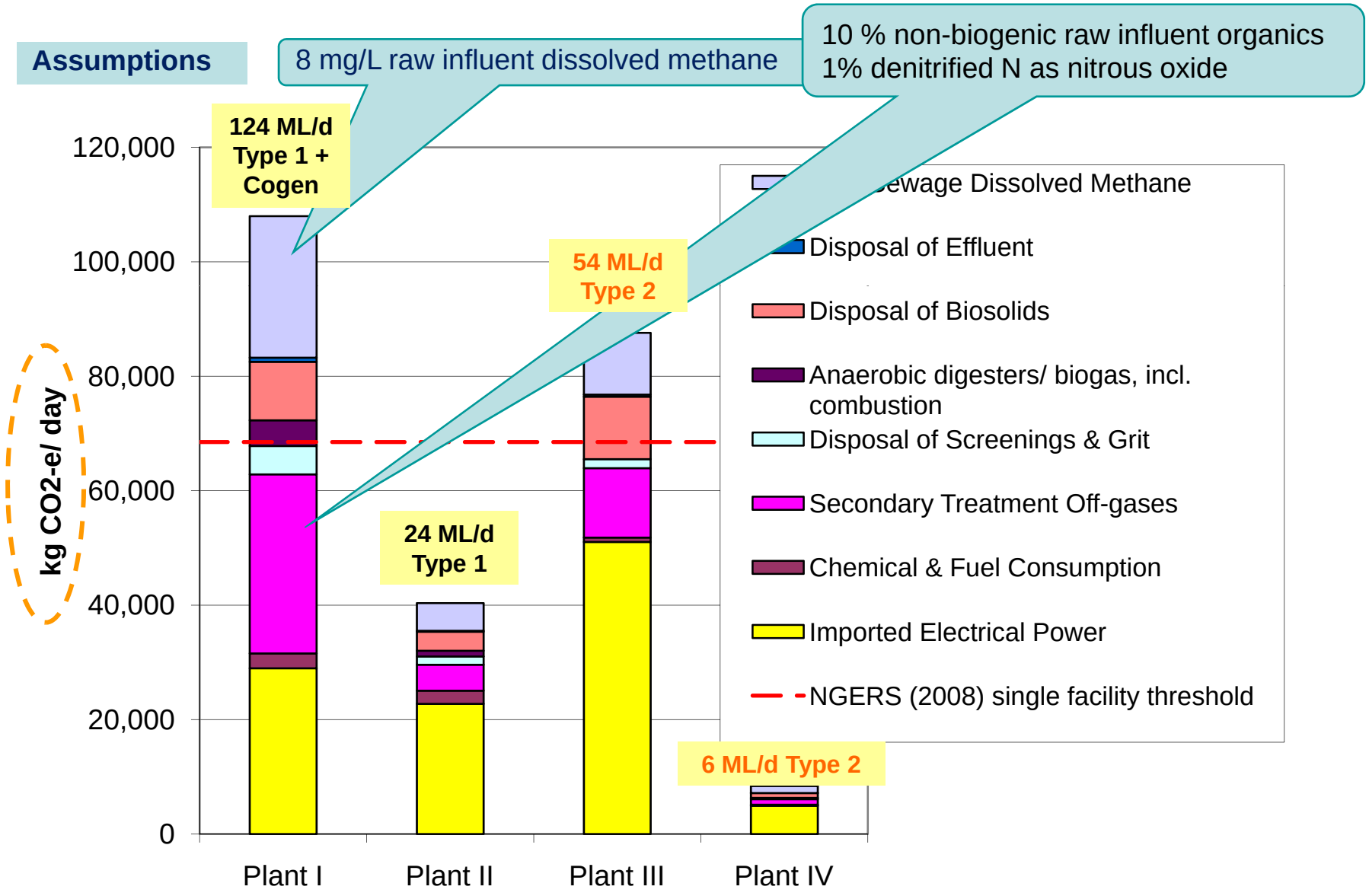
- Sources
  - ✓ NGERS (2008) Technical Guidelines (e.g. power, fuels)
  - ✓ Simapro® LCA software databases (e.g. chemicals)
  - ✓ Literature survey (WSAA, 2007) (fugitive emissions)
  - ✓ Other: literature or estimates (e.g. non-biogenic carbon)
- Major uncertainties
  - ✗ Fugitive emissions factors
    - ➢ DN process off-gas N_2O : ~500-fold range
    - ➢ Biosolids disposal N_2O or CH_4 : ~5 to 100-fold range
    - ➢ Effluent N_2O : ~up to 1000-fold range
  - ✗ Non-biogenic organic carbon in wastewater (1% to 50%??)
  - ✗ Carbon sequestration in biosolids disposed (5 to 25%??)

Uncertainty analysis



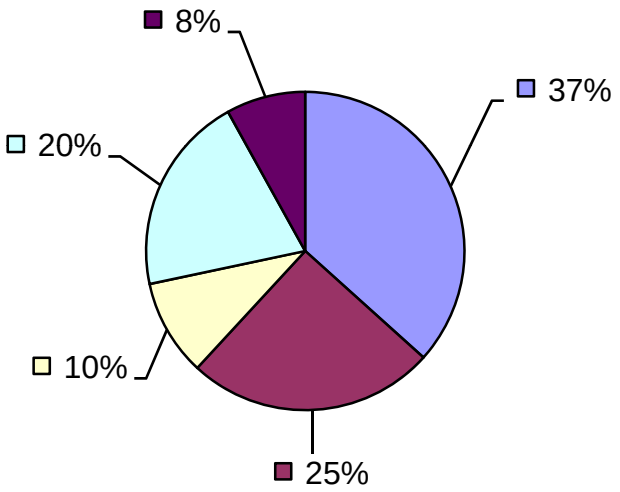
Results

GHG emissions results



Emissions by Scope – Type 1

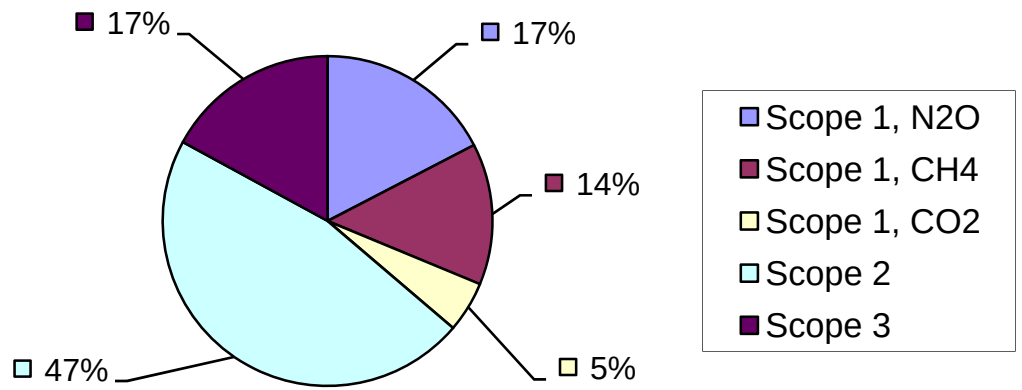
Plant I: Type 1 (with biogas + **cogen**.)



125 tonnes/d CO_2-e

124 ML/d ADWF

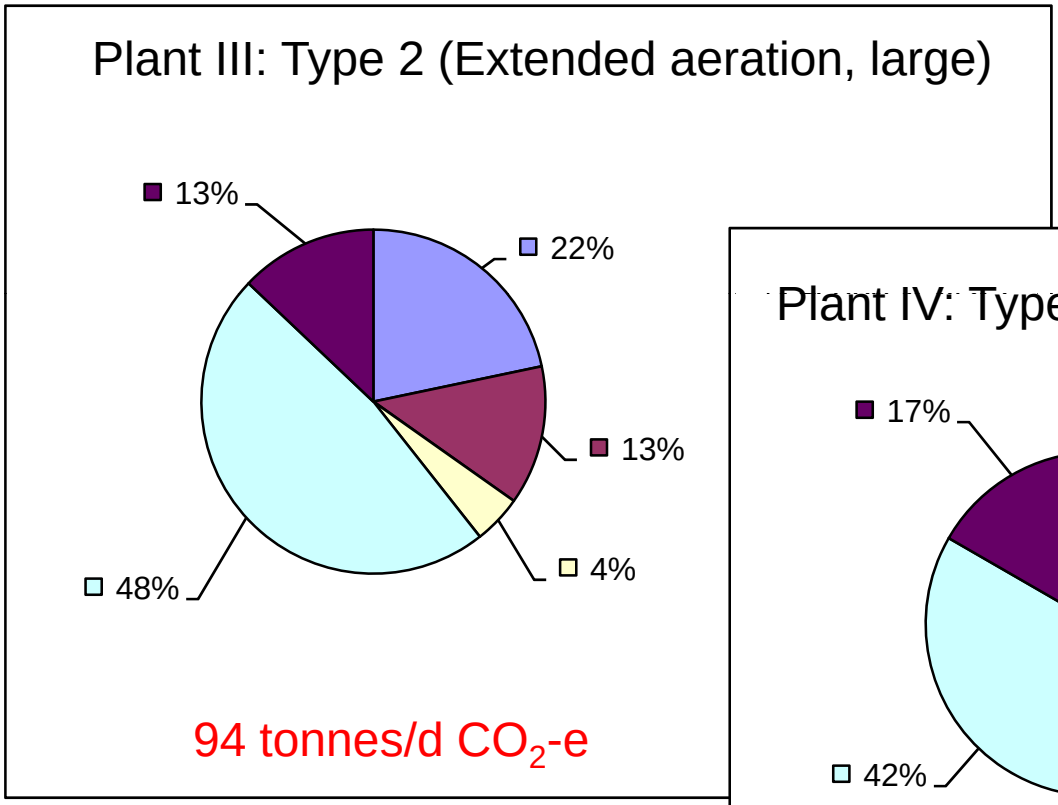
Plant II: Type 1 (with biogas but ***no cogen***.)

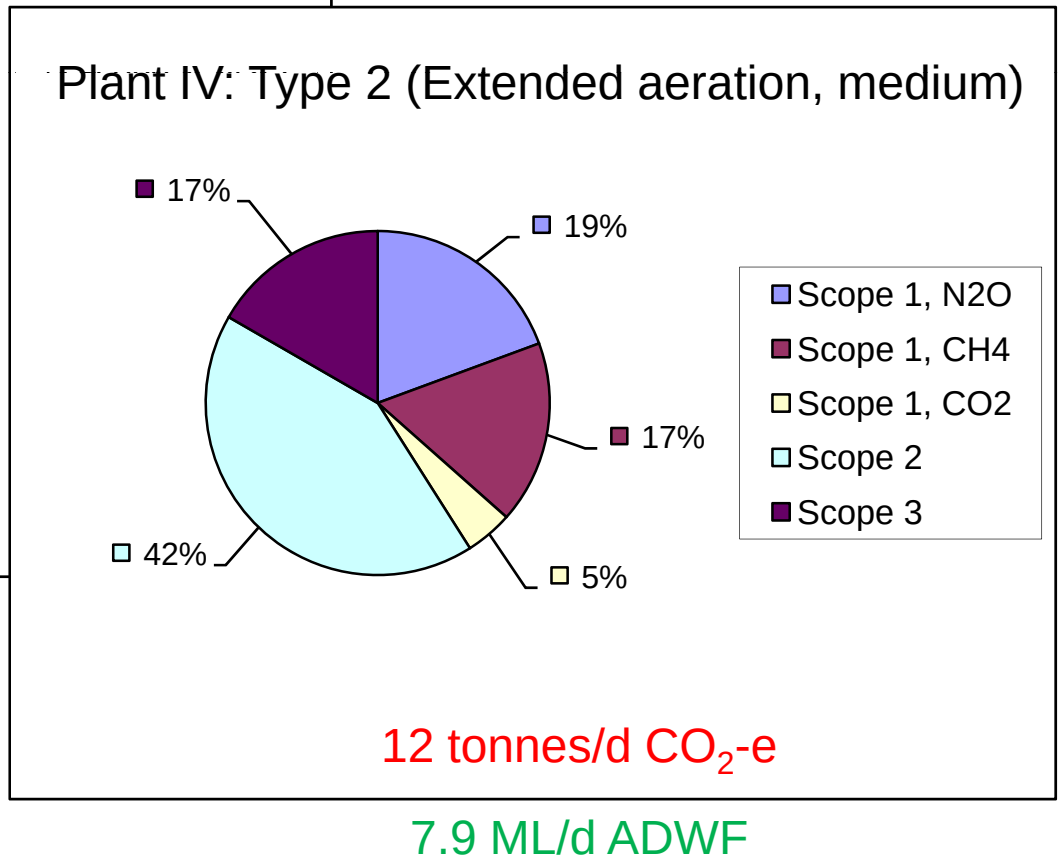


43 tonnes/d CO_2-e

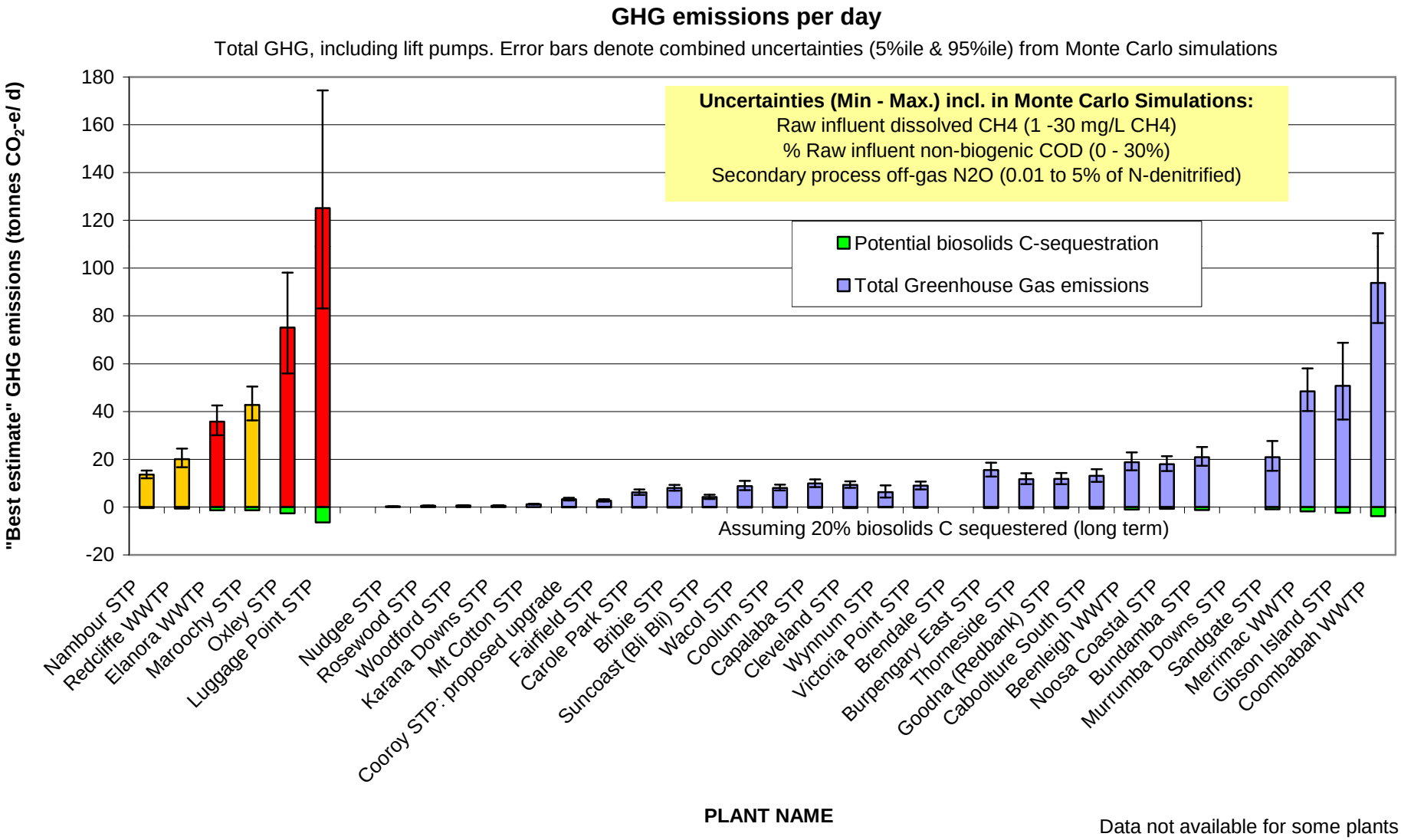
24 ML/d ADWF

Emissions by Scope – Type 2



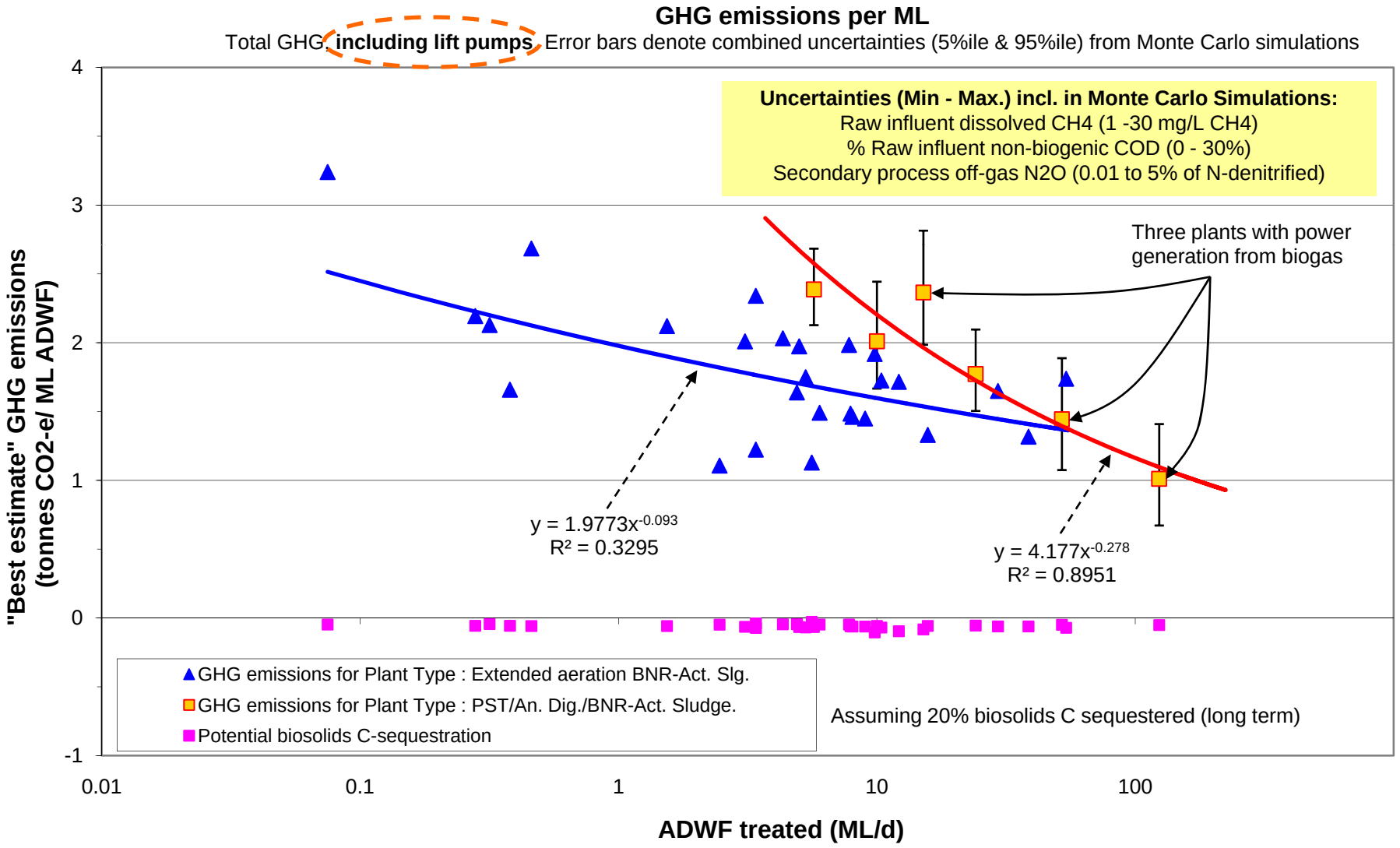


Snapshot of GHG from SE QLD WWTPs

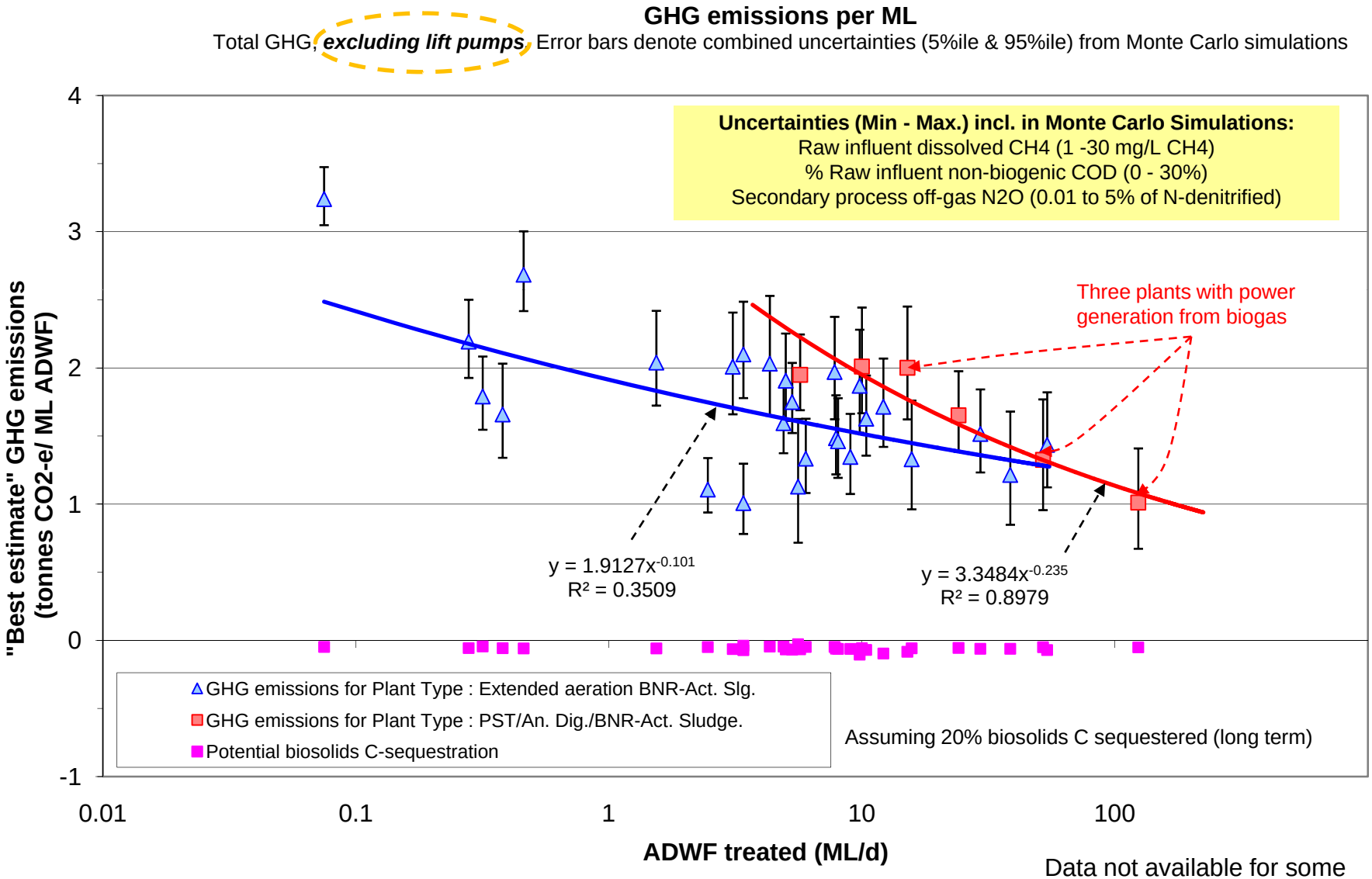


Data not available for some plants

GHG emissions per ML

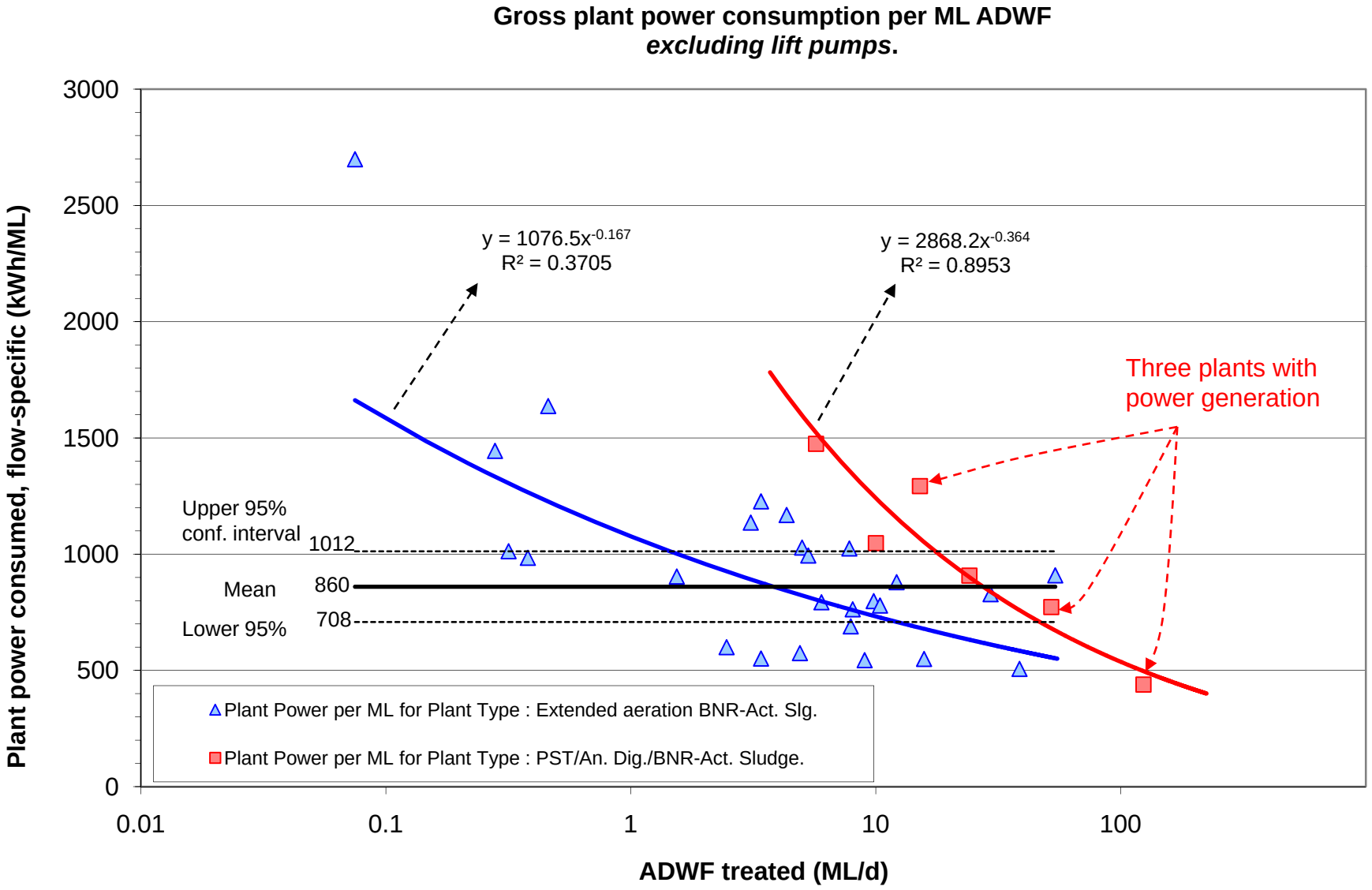


GHG emissions per ML

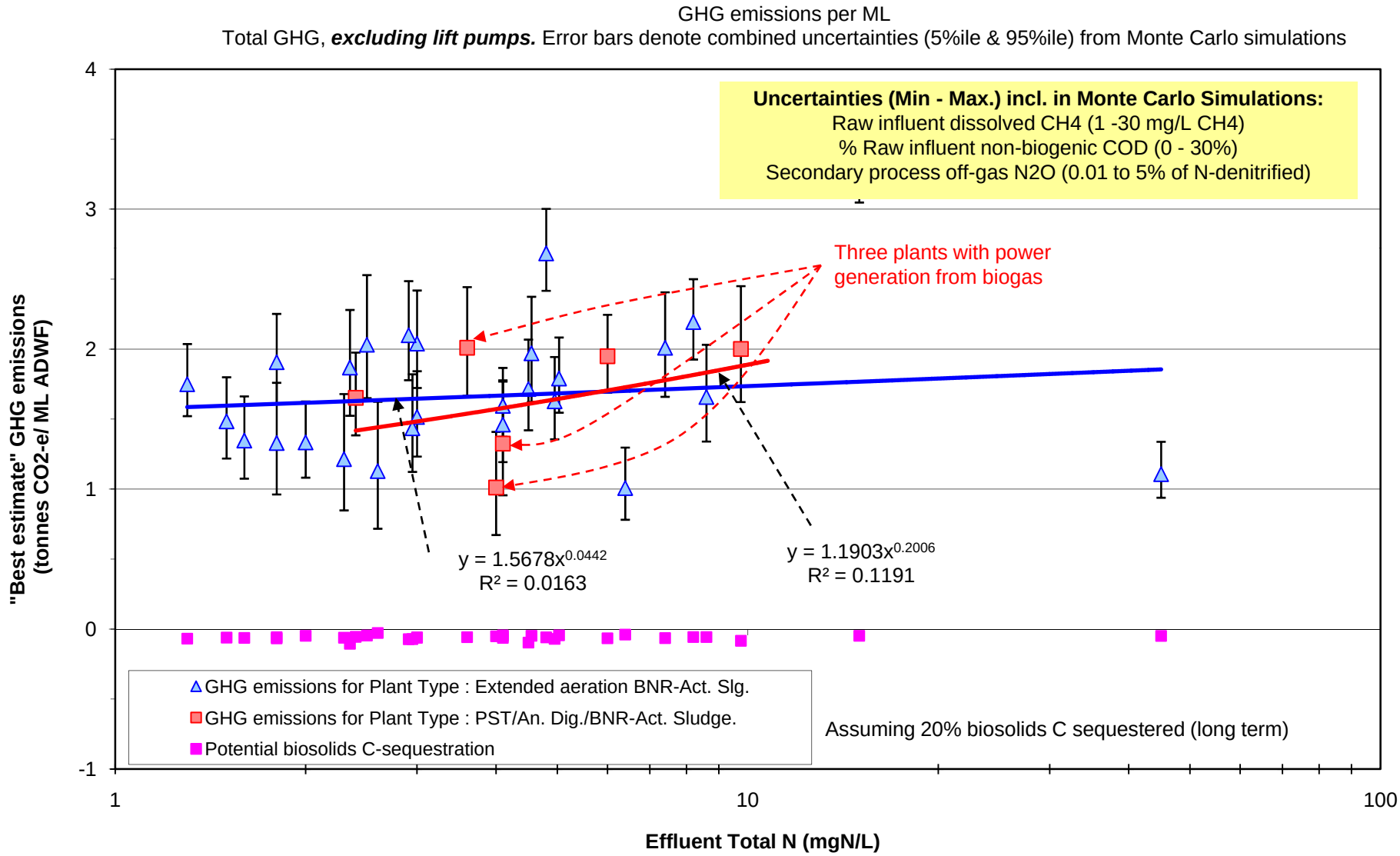


Data not available for some plants

Power consumption per ML



Power consumption vs. N removal



Conclusions

Conclusions

- Useful inventory of operating data from WWTPs in SEQLD
- Uncertainty in emission factors highlighted
  - Fugitive emissions of CH_4 & N_2O
  - Non-biogenic organics in raw sewage
  - Carbon sequestration in biosolids
- Uncertainties appear to influence results in range: ~mean (±20%)
- Typical emissions, flow-specific basis ~1 - 2.5 tonnes CO_2-e /ML
- Economies-of-scale: lower emissions/ML with increasing plant size
- Type 1 plants: lower emissions only with power recovery from anaerobic digestion & biogas
- Trade off with advanced nutrient removal → LCA
- Need to extend study to full SEQ Water Cycle

Thank you

www.urbanwateralliance.org.au