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WATER-ENERGY-CARBON NEXUS IN WATER RECLAMATION, REUSE, AND WASTEWATER TREATMENT:

3. Greenhouse Gas Emissions and Carbon Footprint

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Research at the Water-Energy Nexus

GLOBAL PERSPECTIVE

U.S. 2005 GHG EMISSIONS (I)

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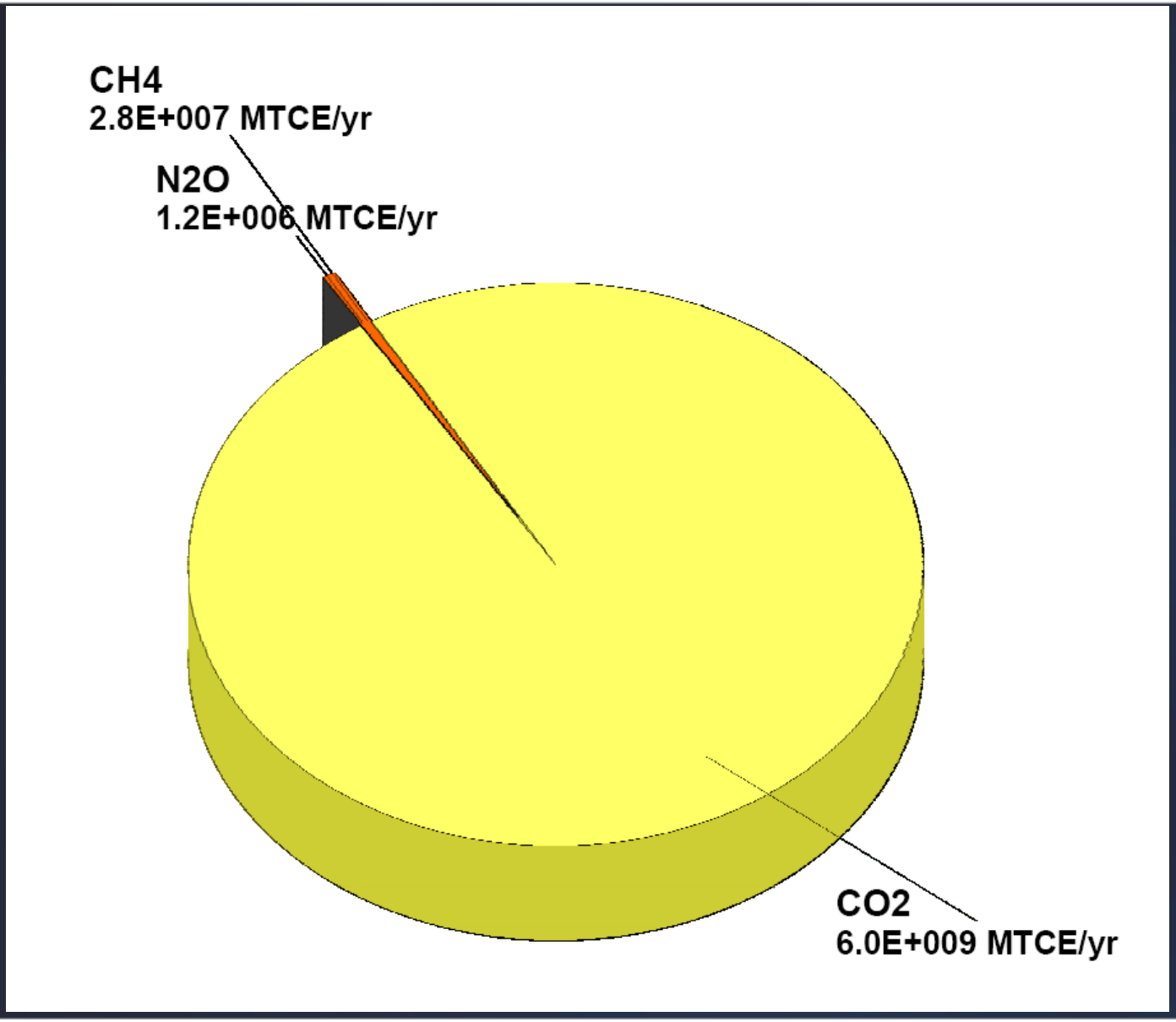
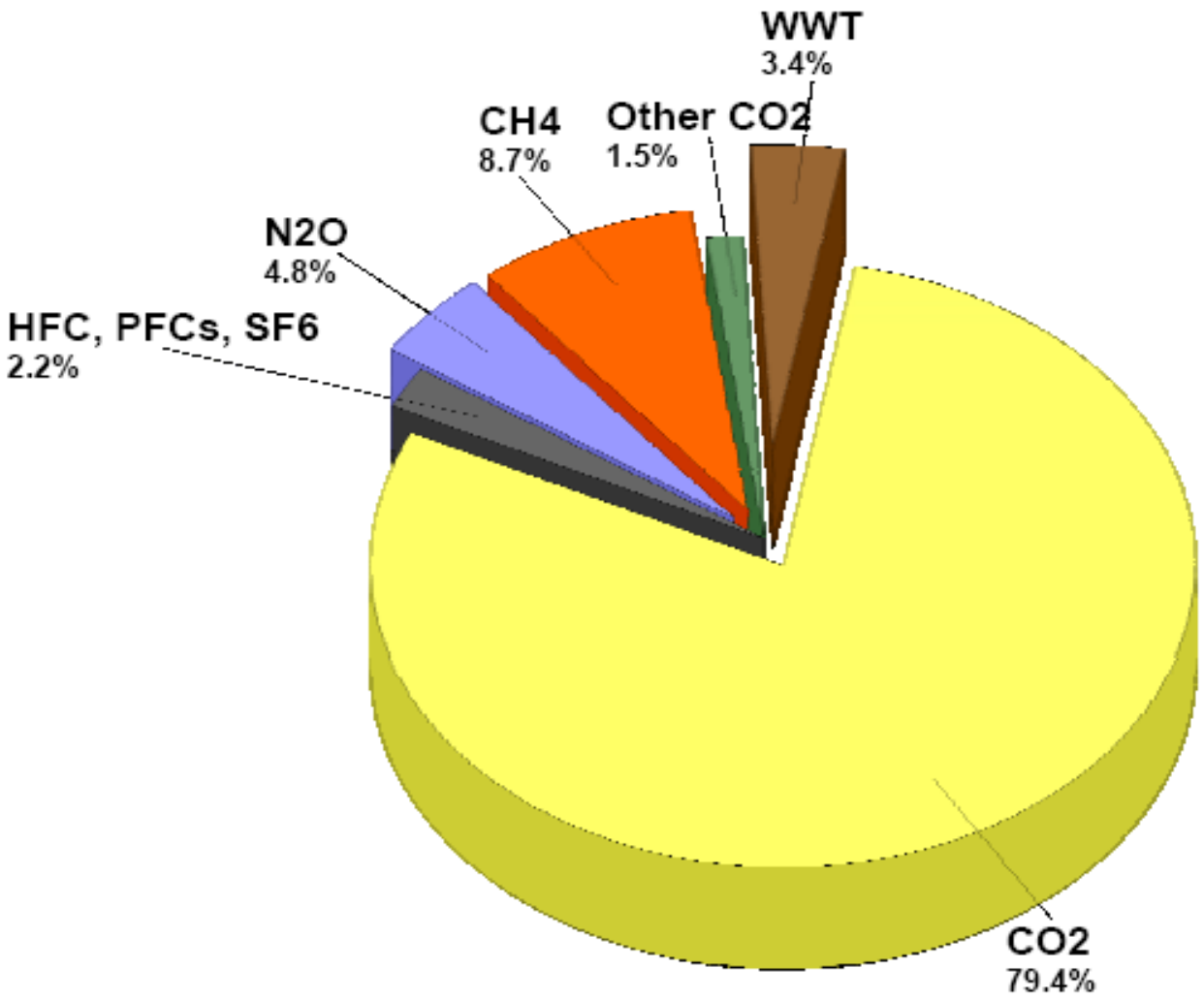


U.S. 2005 GHG EMISSIONS (II)



Greenhouse Gases

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- Carbon Dioxide (CO_2)
  - Both from biogenic (i.e., short-lived C) and anthropogenic (i.e., long-lived C) sources
  - Not subject to treatment
- Methane (CH_4)
  - 25 times more potent than CO_2
  - Both from biogenic (i.e., short-lived C) and anthropogenic (i.e., long-lived C) sources
  - Easy to treat, if captured (i.e., combustion)
- Nitrous Oxide (N_2O)
  - 298 times more potent than CO_2
  - Formed in both Nitrification and DN
  - Measurement challenges
  - Difficult to treat

MODELING CARBON FLOWS

Treatment train selected

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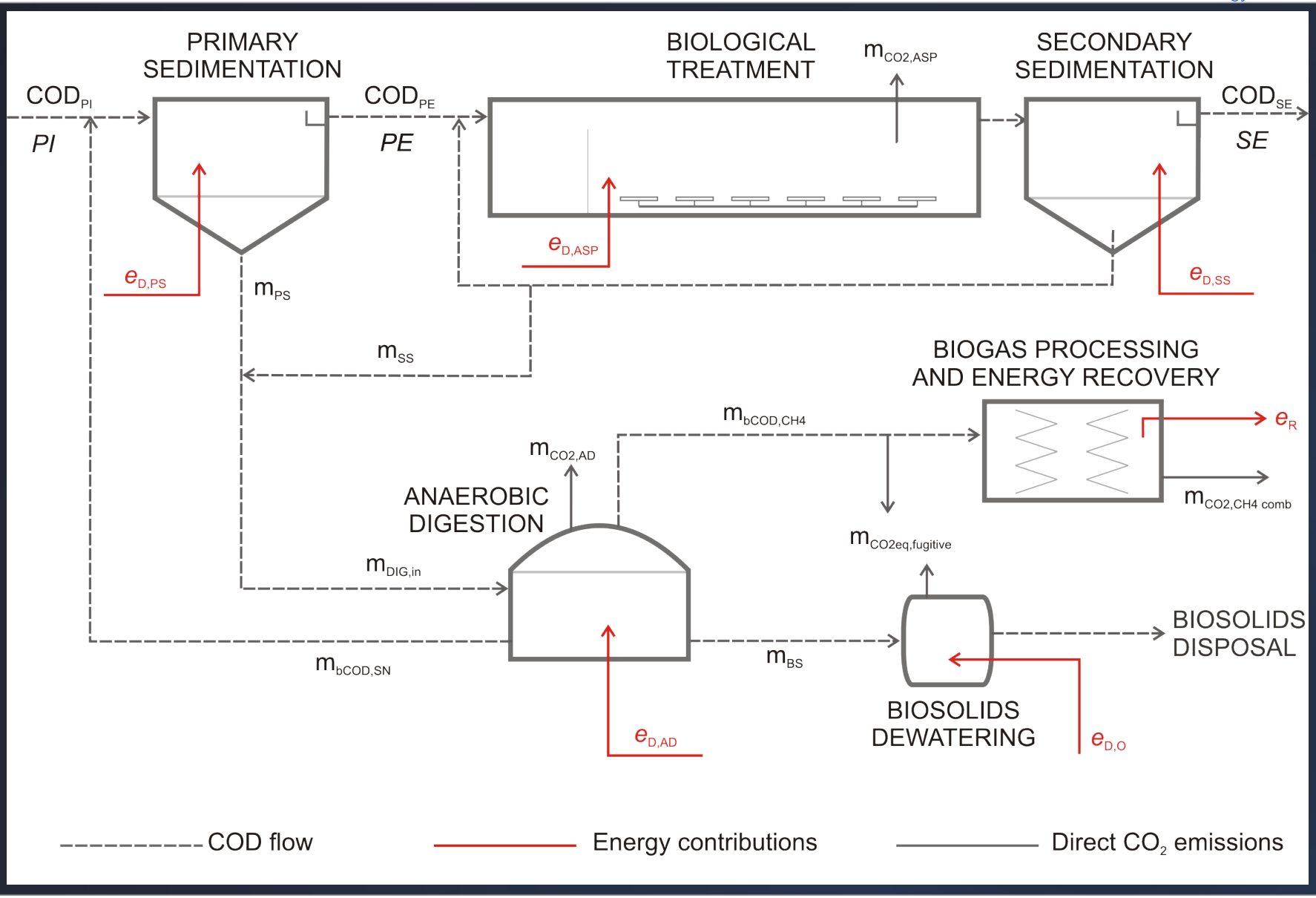

Model structure (I)

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- Based on ASM-family
- VSS is described in COD terms
- pCOD/VSS is a user input or a range of fractions are prospected
- Sludge sent to stabilization:

$$\dot{m}_{pCOD,\,dig} = \left(pCOD/VSS\right)_{PS} \cdot \dot{m}_{VSS,\,PS} + \left(pCOD/VSS\right)_{PS} \cdot \dot{m}_{VSS,\,SS}$$

- $\dot{m}_{pCOD,\,dig}$: COD MASS FLOW TO DIGESTER
- $\left(pCOD/VSS\right)_{PS}$: COD CONTENT OF PRIMARY VSS
- $\dot{m}_{VSS,\,PS}$: MASS FLOW OF PRIMARY VSS
- $\left(pCOD/VSS\right)_{PS}$: COD CONTENT OF SECONDARY VSS
- $\dot{m}_{VSS,\,SS}$: MASS FLOW OF SECONDARY VSS

Model structure (II): energy footprint

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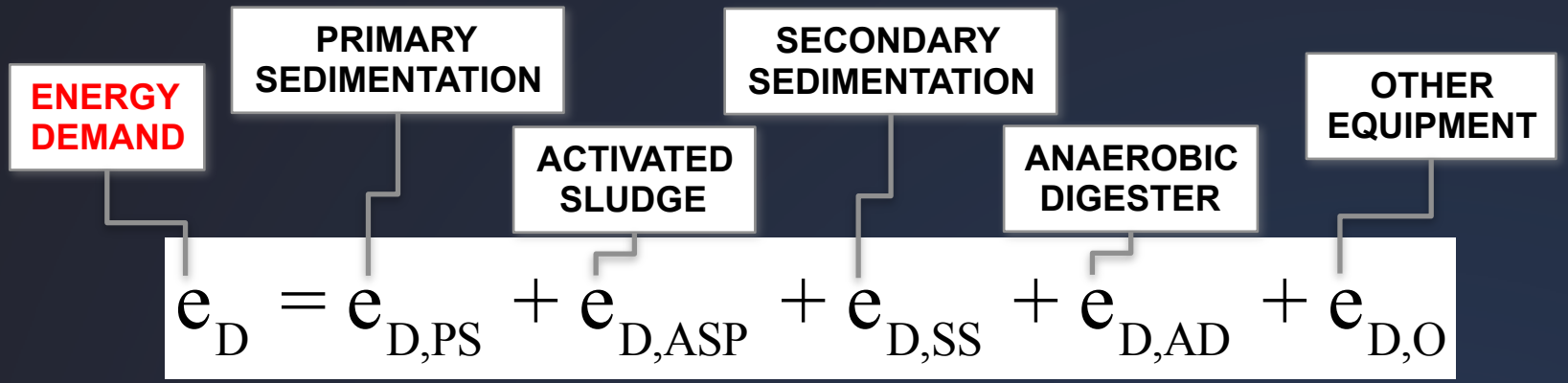
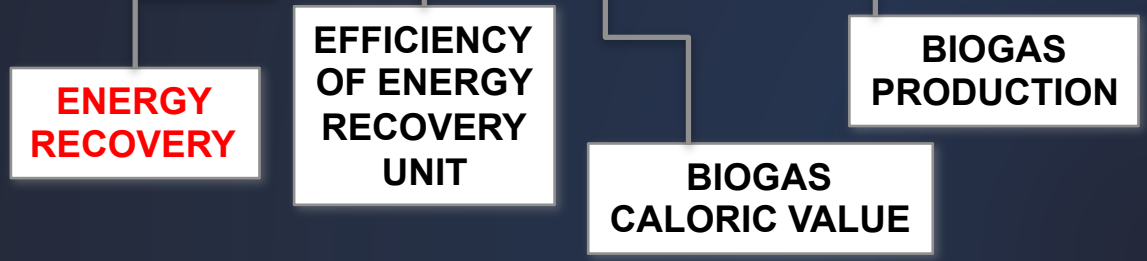


$$e_D = e_{D,PS} + e_{D,ASP} + e_{D,SS} + e_{D,AD} + e_{D,O}$$

$$e_R = \eta_{ER} \cdot h_{BG} \cdot m_{BG}$$



$$eFP = e_D - e_R$$

Model structure (III)

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- Carbon-equivalent footprint (CFP)
  - Only C-based emissions (CO_2, CH_4, power; no N_2O)
  - Assumes fixed power generation portfolio (i.e., constant $kg_{CO2,eq}/kWh$)

TOTAL $CO_{2,eq}$ EMISSION

DIRECT CO_2 FROM ASP RESPIRATION

DIRECT CO_2 FROM DIGESTER

DIRECT CO_2 FROM BIOGAS COMBUSTION

INDIRECT $CO_{2,eq}$ FROM POWER GENERATION

$CO_{2,eq}$ CREDIT OFFSET FROM ENERGY RECOVERY

DIRECT $CO_{2,eq}$ FROM FUGITIVE BIOGAS

$$m_{CO_2eq} = m_{CO_2,ASP} + m_{CO_2,AD} + m_{CO_2,CH_4comb} + m_{CO_2eq,PG} - m_{CO_2eq,offset} + m_{CO_2eq,fugitive}$$

CFP/eFP EFFECTS OF ENHANCED PRIMARIES

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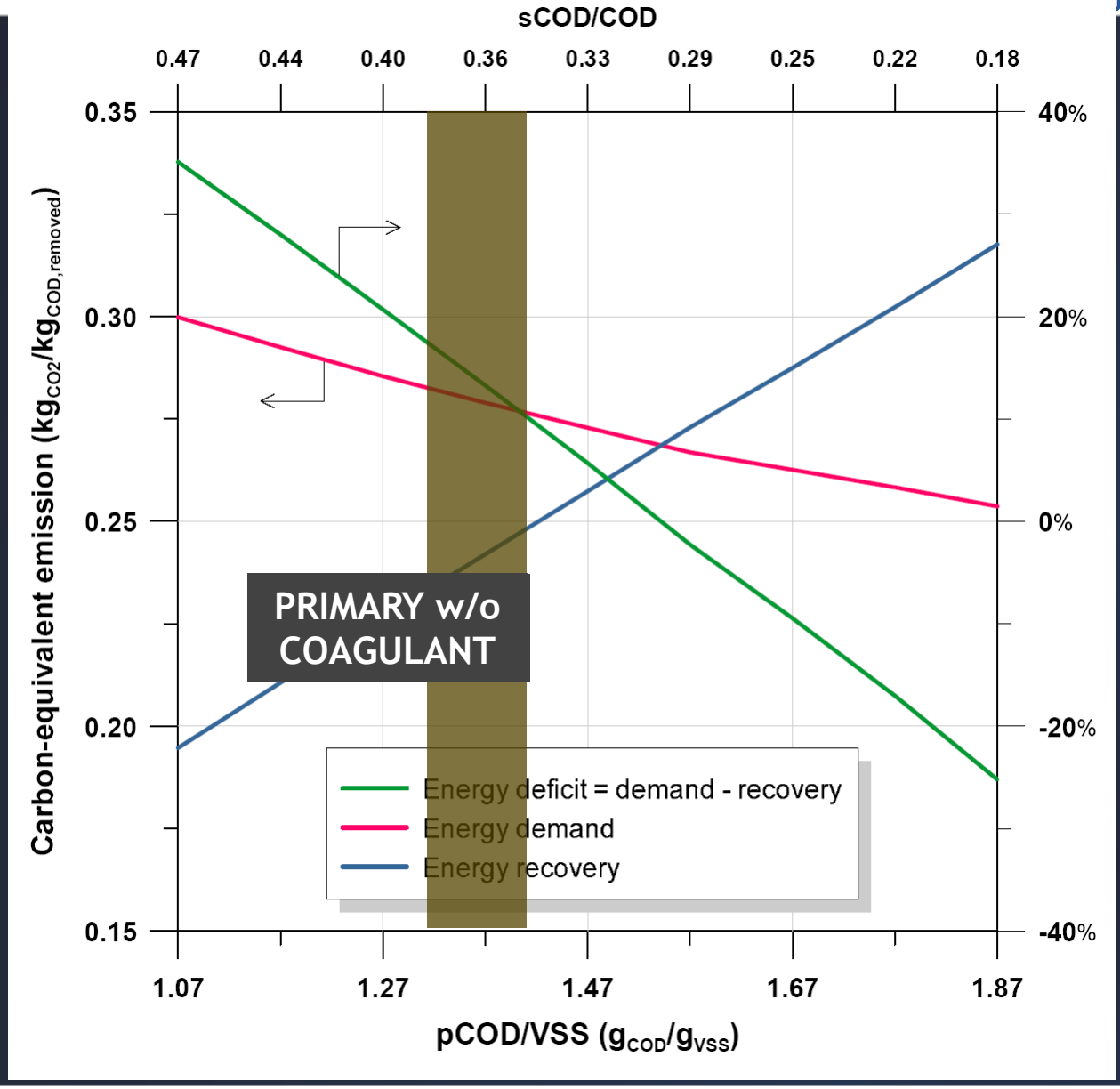

CFP/eFP EFFECTS OF ENHANCED PRIMARIES

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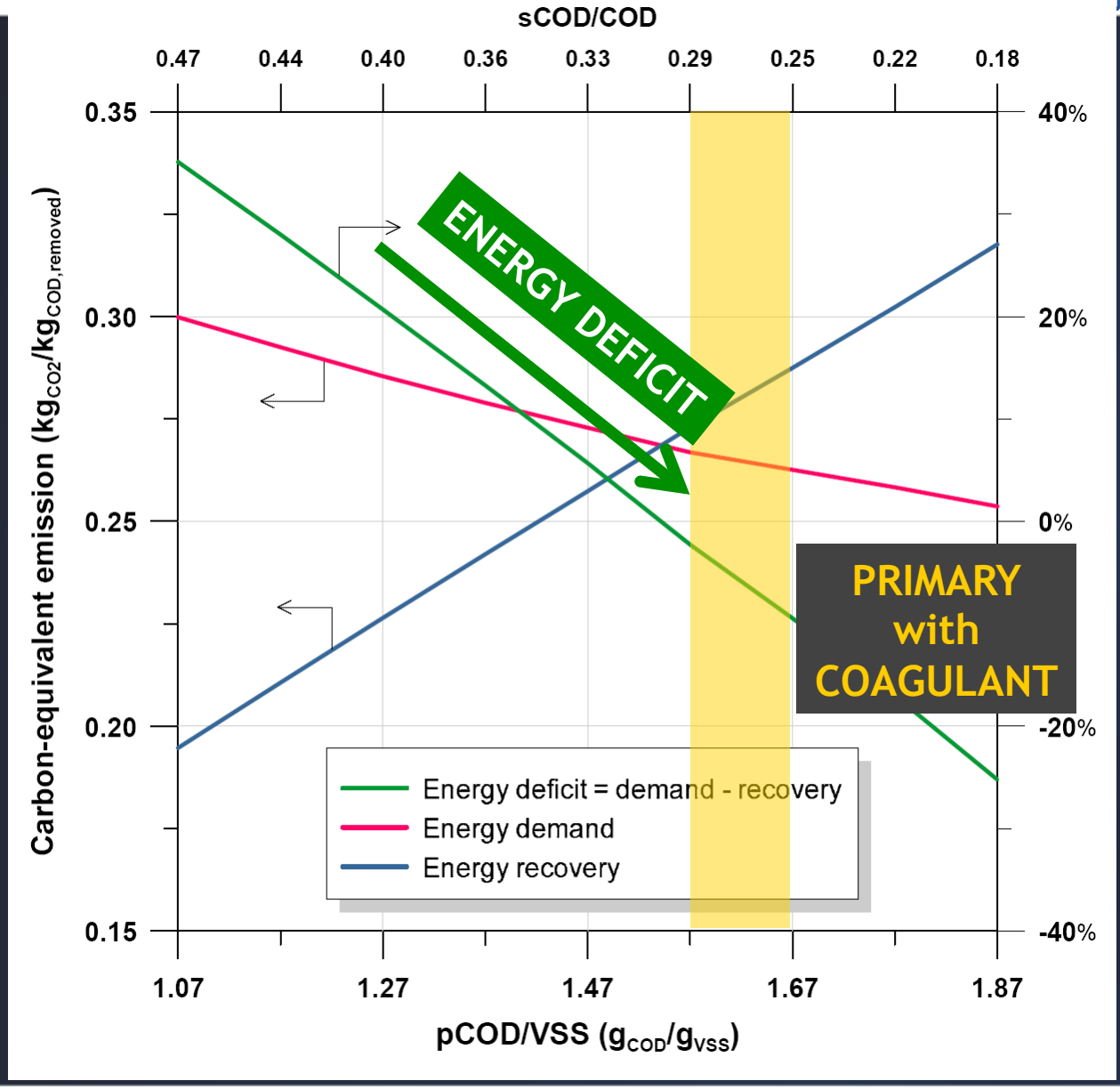

Case Study:
The cost of inefficient primaries

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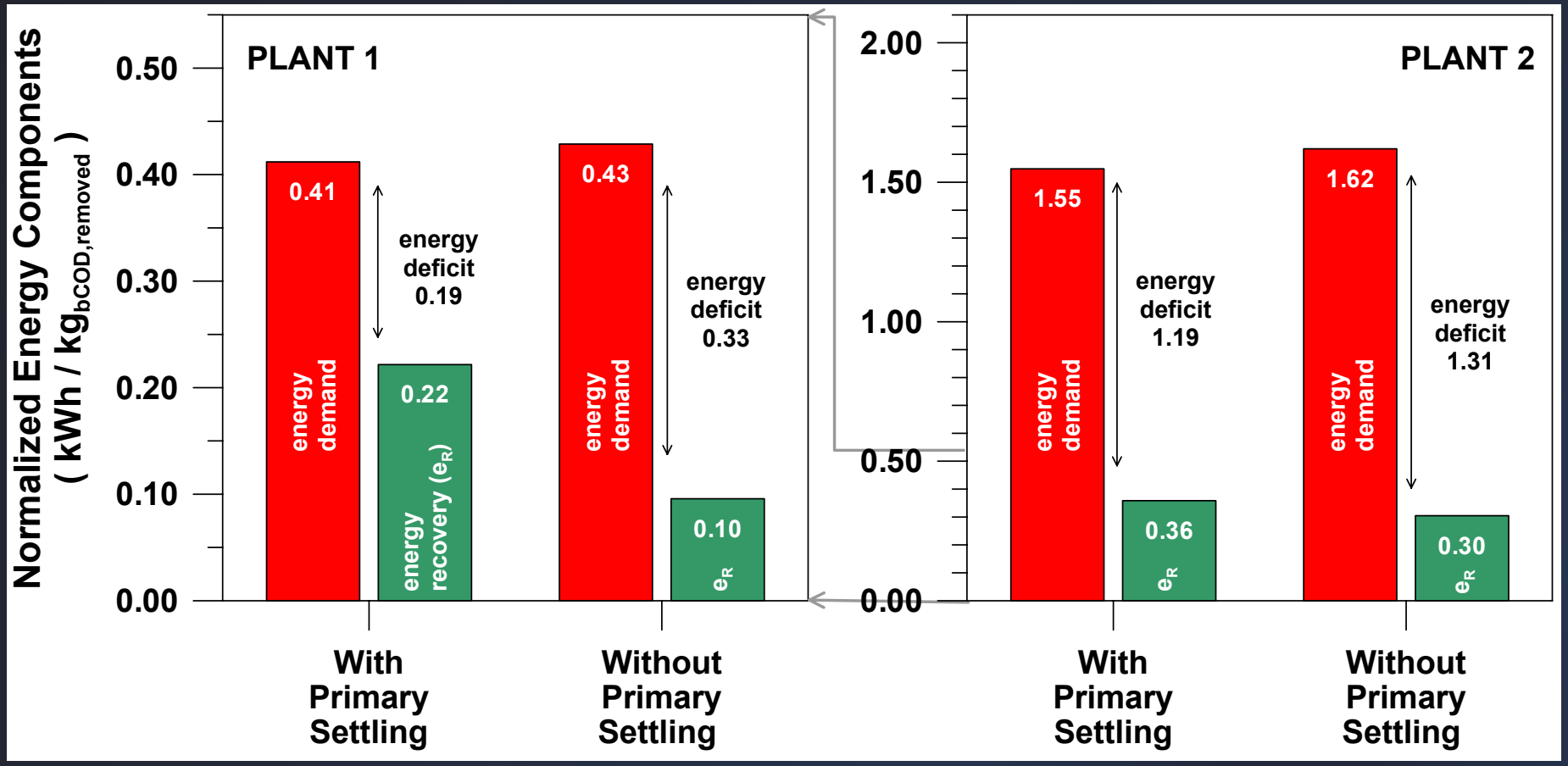
Gori et al (2013) Wat. Sci. Technol.



The cost being inefficient is directly reflected in an energy deficit.
Treatment plants pose as potential energy and water factories,
i.e. Taking "Waste" out of "WasteWater" [Grant et al (2012) Science]

Case Study:
The cost of inefficient primaries

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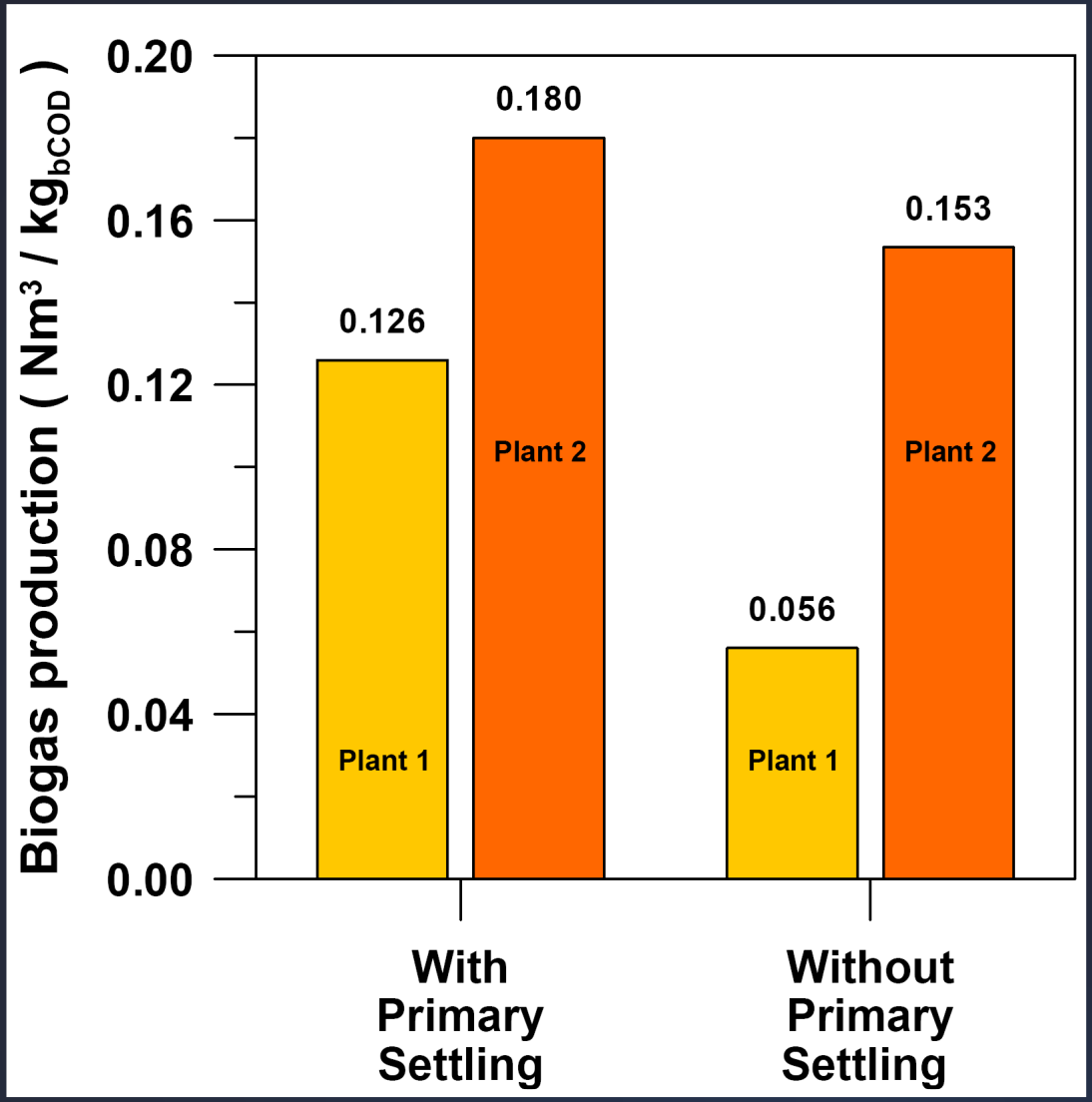
Biogas production with and without primary settling Gori et al (2013) Wat. Sci. Technol.



CONCLUSIONS

In sum

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- Carbon Footprint Modeling: COD and VSS are different!
- The value of good primary treatment
- Enrichment of sludge (e.g., with FOG) may pass the energy turning point
- A site-specific model is always better than an estimate

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