U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

AMMTO & IEDO JOINT PEER REVIEW

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# Decarbonizing the Water-Energy Nexus


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*This presentation does not contain any proprietary, confidential, or otherwise restricted information*

# Background: IEDO Water-Energy Nexus R&D

- Two Major Focal Areas:
  - Wet Organic Waste Streams
    - Significant opportunities for direct and indirect emissions reduction
    - Potential to solve pressing community and agricultural waste disposal issues
      - Increases probability of adoption
    - Specific Congressional Direction for Water Resource Recovery Facilities - ~$20M/year
- "Fit-for-purpose" Water Supplies
  - Meeting the water needs of the future while minimizing energy consumption
  - Diverse array of uses from a variety of non-traditional sources
  - Goal is "Pipe Parity" – competitive with available fresh water sources
    - Future will be increasingly availability constrained in many parts of the country
  - National Alliance for Water Innovation (NAWI) - ~$25M/year Desalination Hub

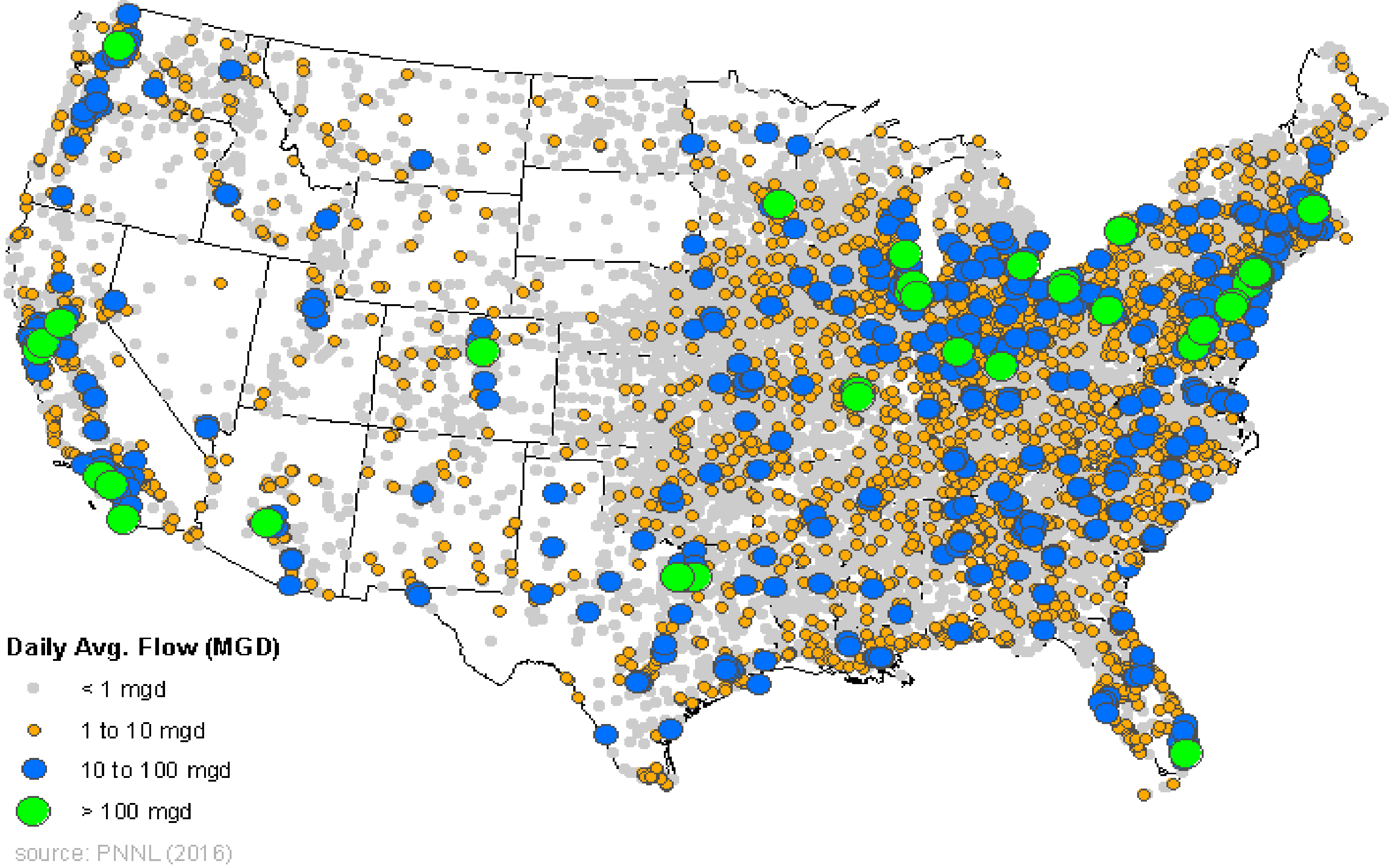
# Wet Organic Waste Resources

| | Annual Resource Generation | | |
|---|---|---|---|
| Feedstocks | Estimated Annual Resources | Inherent Energy Content (Trillion Btu) | Fuel Equivalent (MM GGE)[1] |
| **Wet Feedstocks** | 77.17 MM Dry Tons | 1,078.6 | 9,290.8 |
| Wastewater Residuals | 14.82 | 237.6 | 2,046.6 |
| Animal Waste | 41.00 | 547.1 | 4,713.0 |
| Food Waste[2] | 15.30 | 79.6 | 685.3 |
| Fats, Oils, and Greases | 6.05 | 214.3 | 1,845.9 |
| **Gaseous Feedstocks** | | 733.6 | 6,319.8 |
| Biogas[3] | 420 BCF | 430.5 | 3,708.6 |
| $CO_2$ Streams | 3,142 MM Tons | - | - |
| Associated Natural Gas | 289 BCF | 303.1 | 2,611.2 |
| **Other Waste Feedstocks** | | 526.1 | 4,531.6 |
| Glycerol | 0.6 MM Tons | 8.7 | 75.1 |
| Black Liquor | 44 MM Tons | 517.4 | 4,456.5 |
| DDGS[4] | 44 MM Tons | n/a | n/a |
| **Total** | | **2,338.3** | **20,142.2** |

https://www.energy.gov/eere/bioenergy/downloads/biofuels-and-bioproducts-wet-and-gaseous-waste-streams-challenges-and

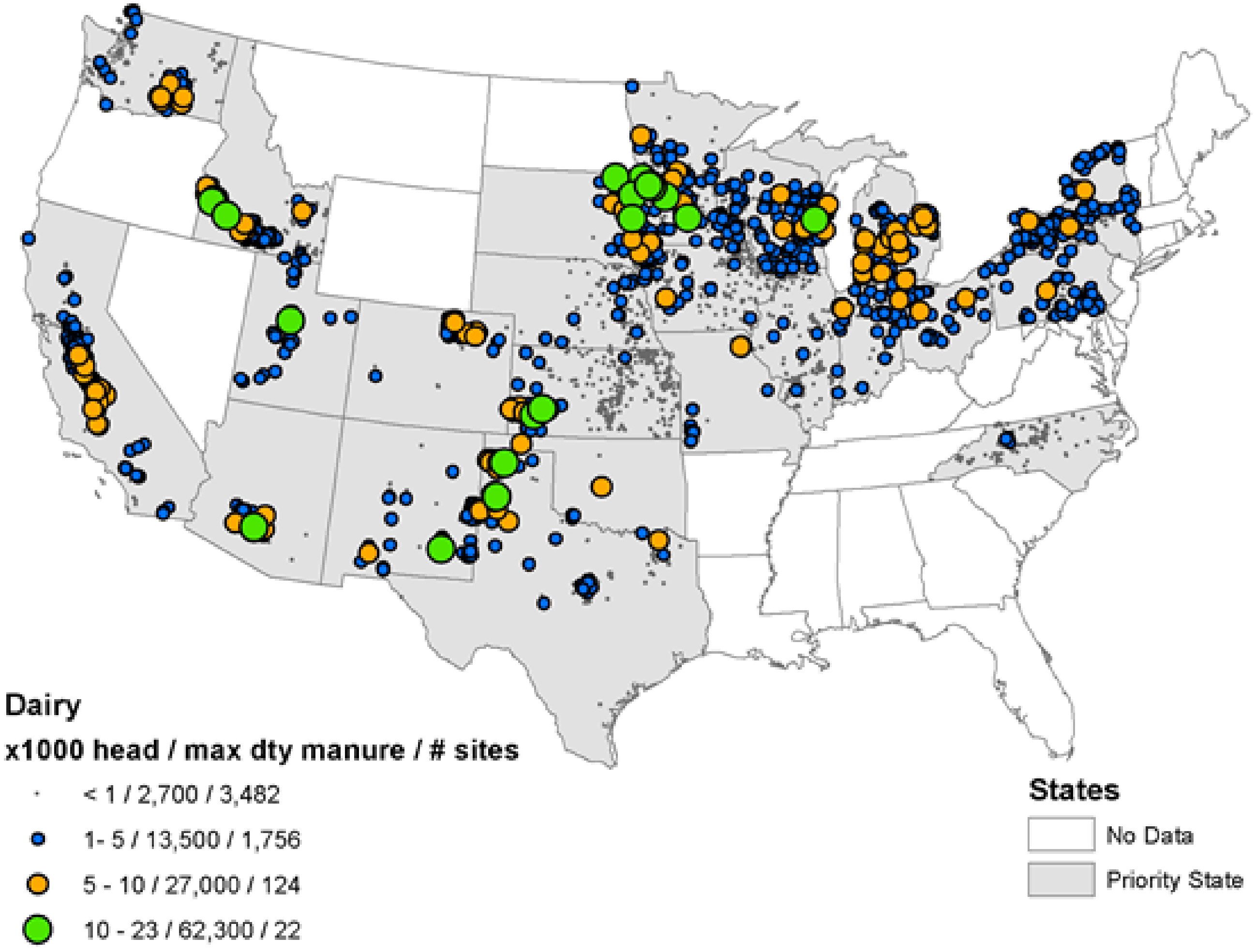
2017 BETO report on energy potential from wet and gaseous waste streams

# Wet Organic Wastes: Water Resource Recovery Facilities



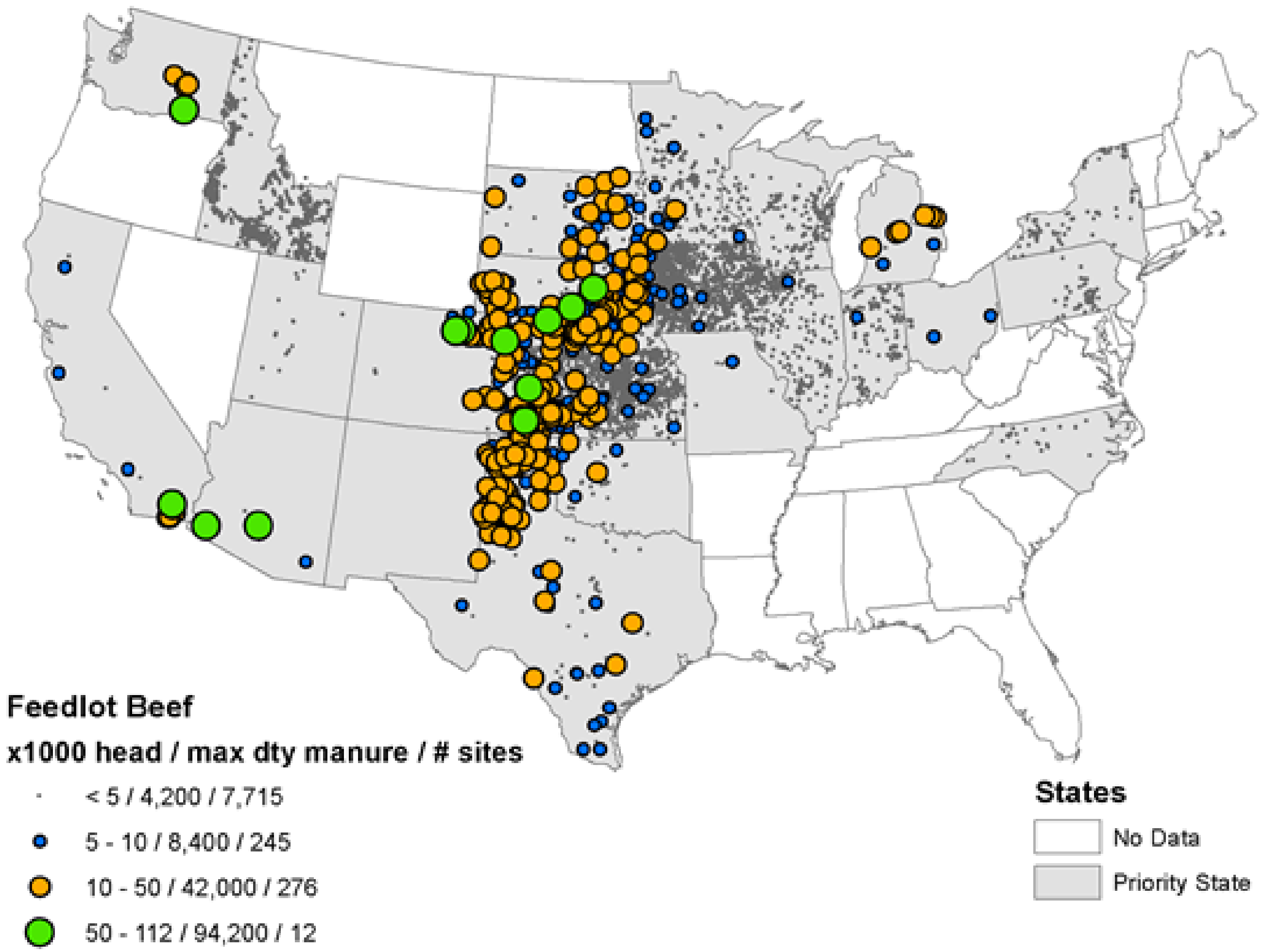

**Spatial distribution and influent range of 14,581 U.S. EPA CWNS 2012 catalogued treatment plants**

# Wet Organic Wastes: Dairy Manure



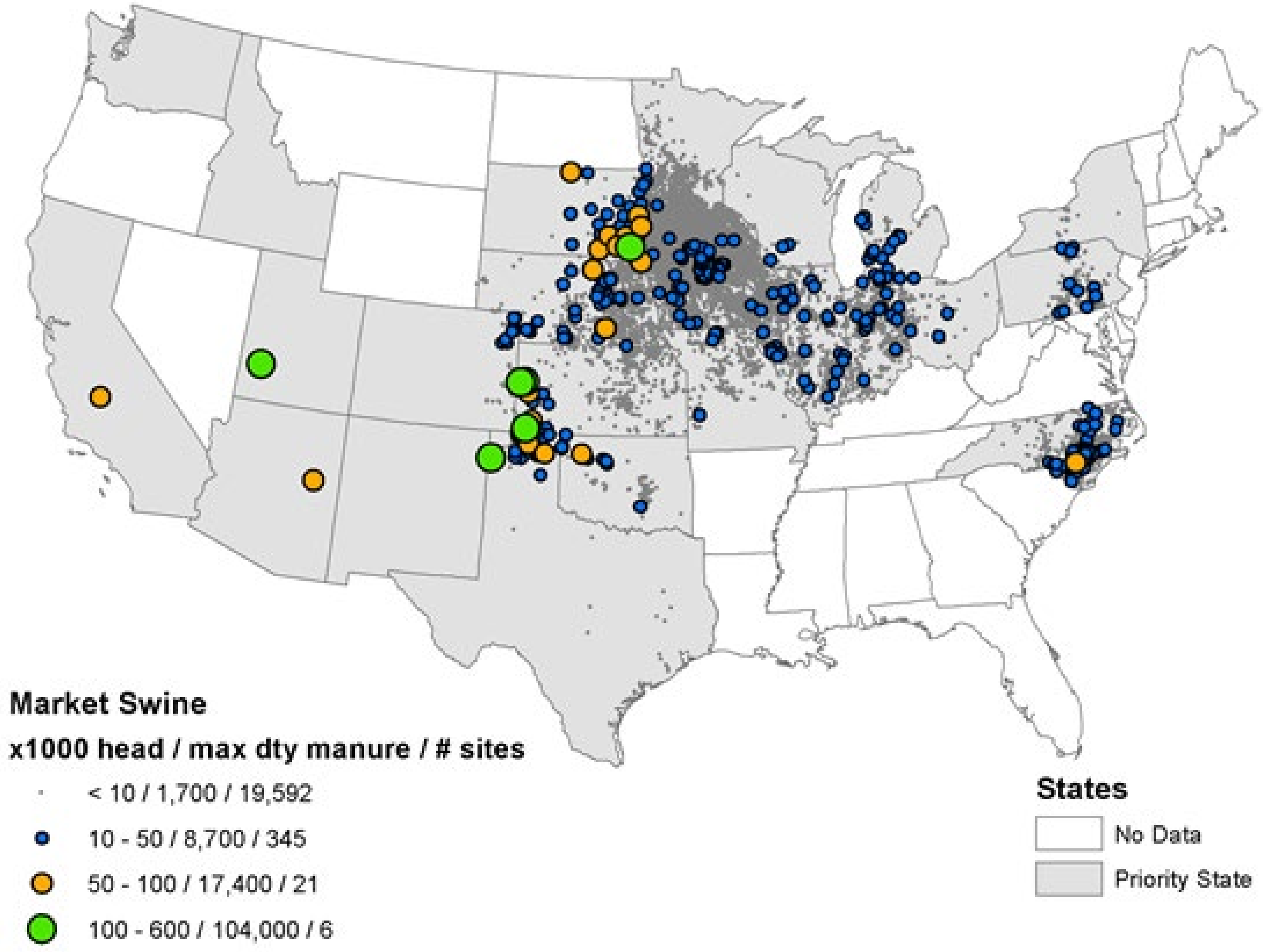

Recoverable Manure for Dairy Cows

# Wet Organic Wastes: Feedlot Beef




Recoverable Manure for Fed Beef Cattle

# Wet Organic Wastes: Swine




Recoverable Manure from Market Swine

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# WRRFs and Wet Organic Wastes – Decarbonizing the Present

# GHG Emissions from Water Resource Recovery Facilities (WRRFs)

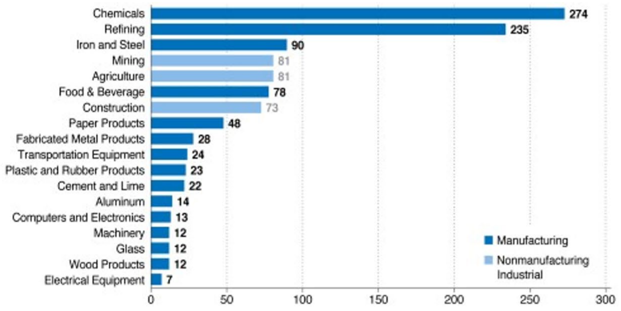
- EPA GHG inventory estimates total WRRF emissions as ~44 MMT $CO_{2e}$; 18.3 MMT from $CH_4$ and 23.5 MMT for $N_2O$. These estimates are widely considered to be low by a factor of 2x or more on a life-cycle basis, as they do not include the indirect emissions from electricity generation, sludge transport, or landfill methane.

- If the actual figure including indirect emissions is 70-100 MT, then WRRF emissions are comparable to direct emissions rom Food & Beverage and Iron & Steel
- An existing AOP is analyzing WRRF emissions in depth, including by process

https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-te

**Aligned Focus: Top Five Carbon-Intense Subsectors (*1,154 MMT)**

Strategy initially focusses on 63% of Manufacturing Emissions with fuels and process emissions, but does not include construction, mining, and agriculture (non-mfg. industrial subsectors)




Energy-related $CO_2$ emissions breakdown by industrial sector in 2020, million MT $CO_2$

| Manufacturing Subsector | Total Emissions MMT (2020) |
|---|---|
| Chemicals | 274 |
| Petroleum Refining | 235 |
| Iron and Steel | 90 |
| Food and Beverage | 78 |
| Cement and Lime | 52* |
| **Subtotal for Top 5** | **729 (63%)** |

*Cement includes 30 MMT non-energy process emissions. Iron and steel includes process emissions.

Specific opportunities identified in "Industrial Decarbonization Roadmap" with private-sector input.

# Overarching Water Resource Recovery Facility (WRRF) management concerns

- WRRFs have two main objectives:
  - Meeting their discharge permits
    - Individual managers are subject to legal liability if they do not
  - To the degree feasible, minimizing rate increases
- As a result, the industry is extremely risk-averse
- The adoption of new technologies is entirely driven by their ability to meet the key objectives
  - WRRF management will require substantial proof (i.e. de-risking) in order to move forward with any new adoption.
- One of the key current challenges for the second objective is sludge disposal, in part due to increasing restrictions on landfill disposal and land applications, which increases costs.
- In order to facilitate adoption, IEDO wastewater solicitations should focus on solving problems relevant to WRRFs which simultaneously achieve decarbonization objectives.

# Two FOAs to Date (Wet Organic Wastes Side)

- **DE-FOA-0002336: Research and Development for Advanced Water Resource Recovery Systems**
  - 16 projects, total of ~$27M, awarded in FY 21
  - Primary focus on energy efficiency (prior to IEDO/AMMTO split)
    - Subset of projects less than perfectly aligned with revised IEDO mission
  - These are the projects that will make oral and poster presentations for this peer review, in addition to NAWI
- **DE-FOA-0002855: Decarbonization of Water Resource Recovery Facilities (D-WRRF)**
  - FY 23
  - Two topics: Unit processes (50% emissions reduction) and Full treatment trains (25% reduction)
  - Up to $29M available, announcements expected July 2023

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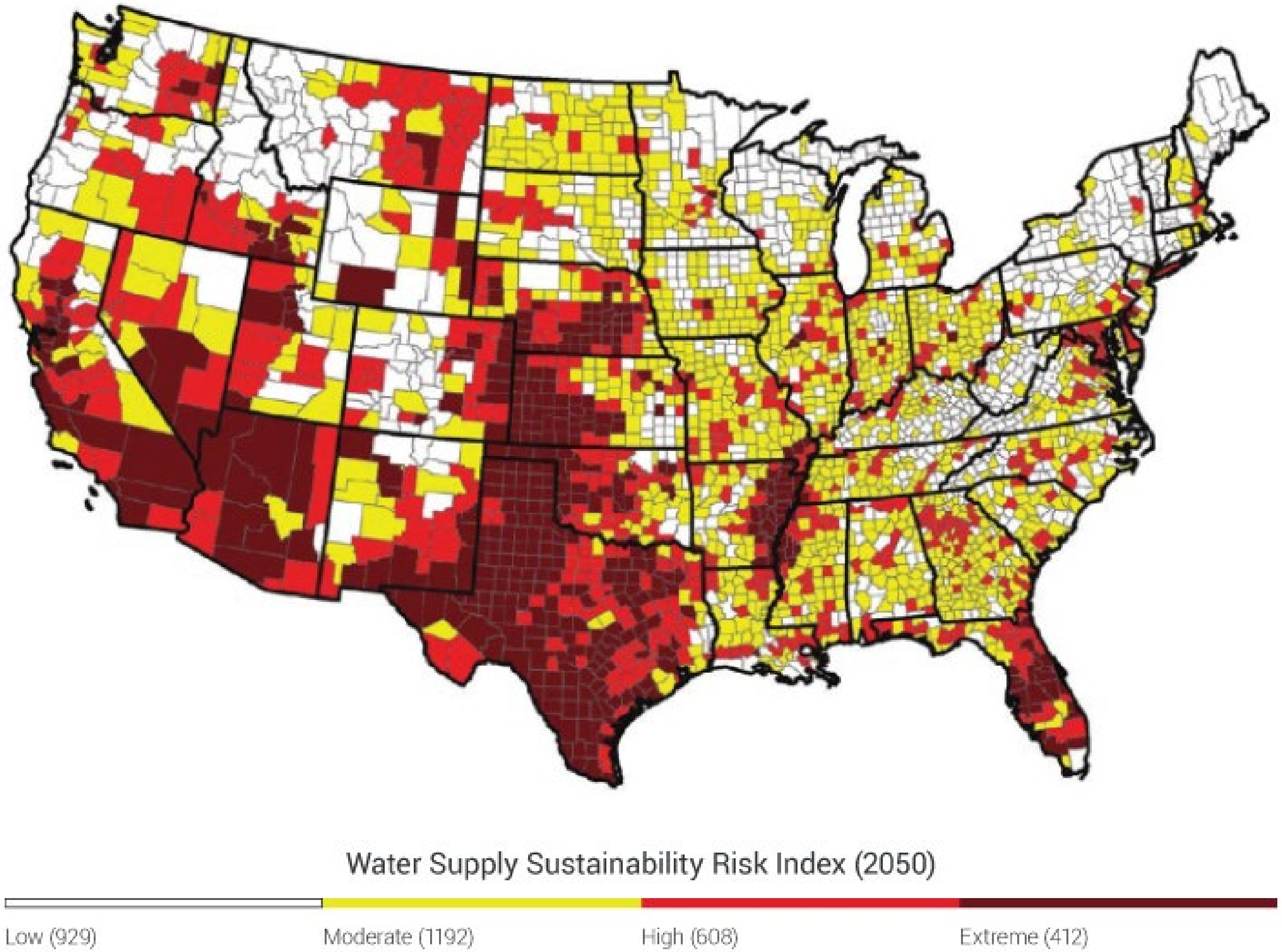
# NAWI within IEDO – Decarbonizing the Future

# Water Availability is increasingly a problem in the U.S.  Now …


https://www.globalchange.gov/browse/multimedia/water-stress-us

# NAWI: Projected Water Stress in the Future …




https://www.globalchange.gov/browse/multimedia/water-stress-us

# Increasing Water Demand = Increasing Energy Demand

- **The inter-dependencies between energy and water are set to intensify in the coming years, as the water needs of the energy sector rise.**
  - Water consumption (as opposed to withdrawal) for energy expected to increase 60% by 2040
  - In 2014, some 4% of global electricity consumption was used to extract, distribute and treat water and wastewater, along with 50 million tonnes of oil equivalent of thermal energy, mostly diesel used for irrigation pumps and gas in desalination plants.
- **Energy requirements for water will also skyrocket**
  - Although desalination and water re-use meet less than 1% of global water needs today, these processes account for almost a quarter of total energy consumption in the water sector.
  - By 2040, they account for 4% of water supply, but 60% of the water sector's energy consumption.
  - Energy consumption in the water sector can be reduced by 15% in 2040 if the economically available energy efficiency and energy recovery potentials in the water sector are exploited.
  - **IEDO wants to do better than this.**

Source: IEA World Energy Outlook, 2017

# Questions?

## Decarbonizing the Water-Energy Nexus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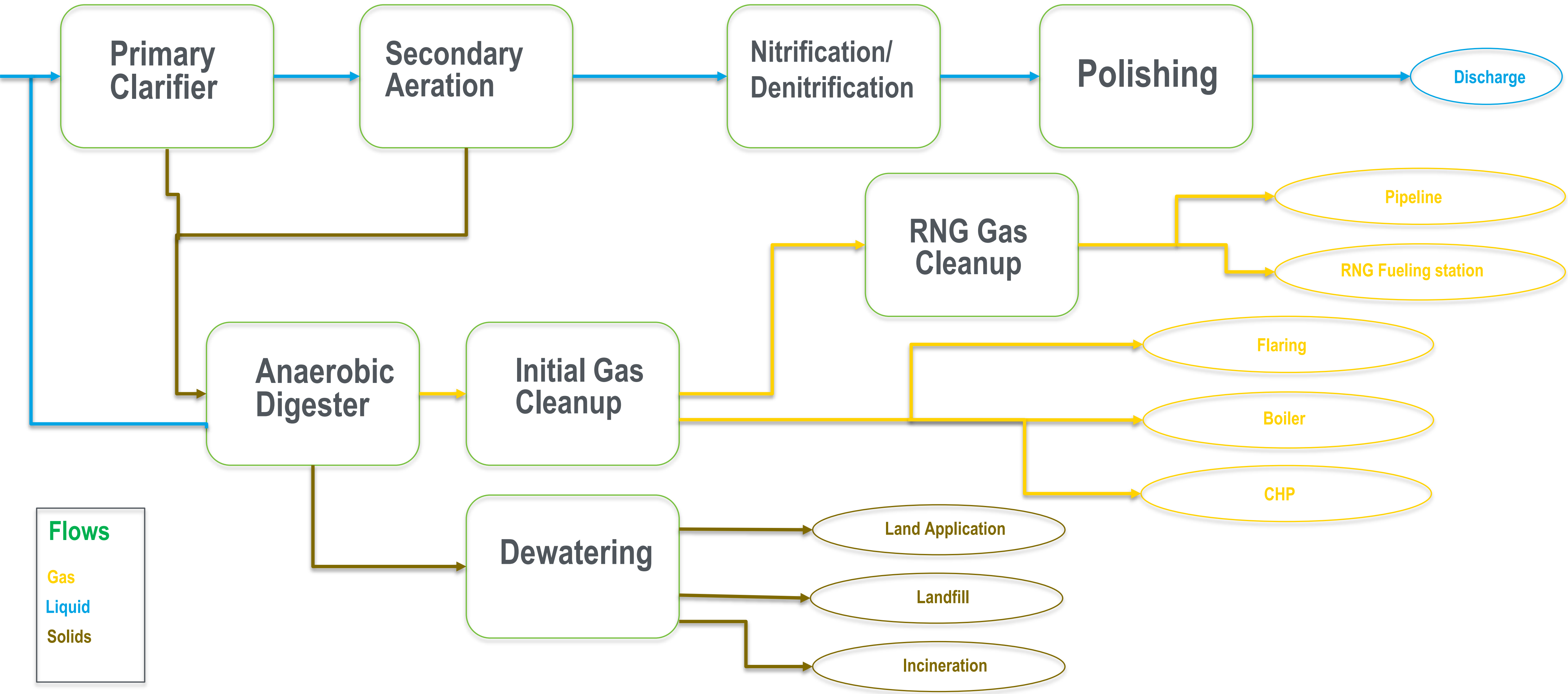
# Backup Slides

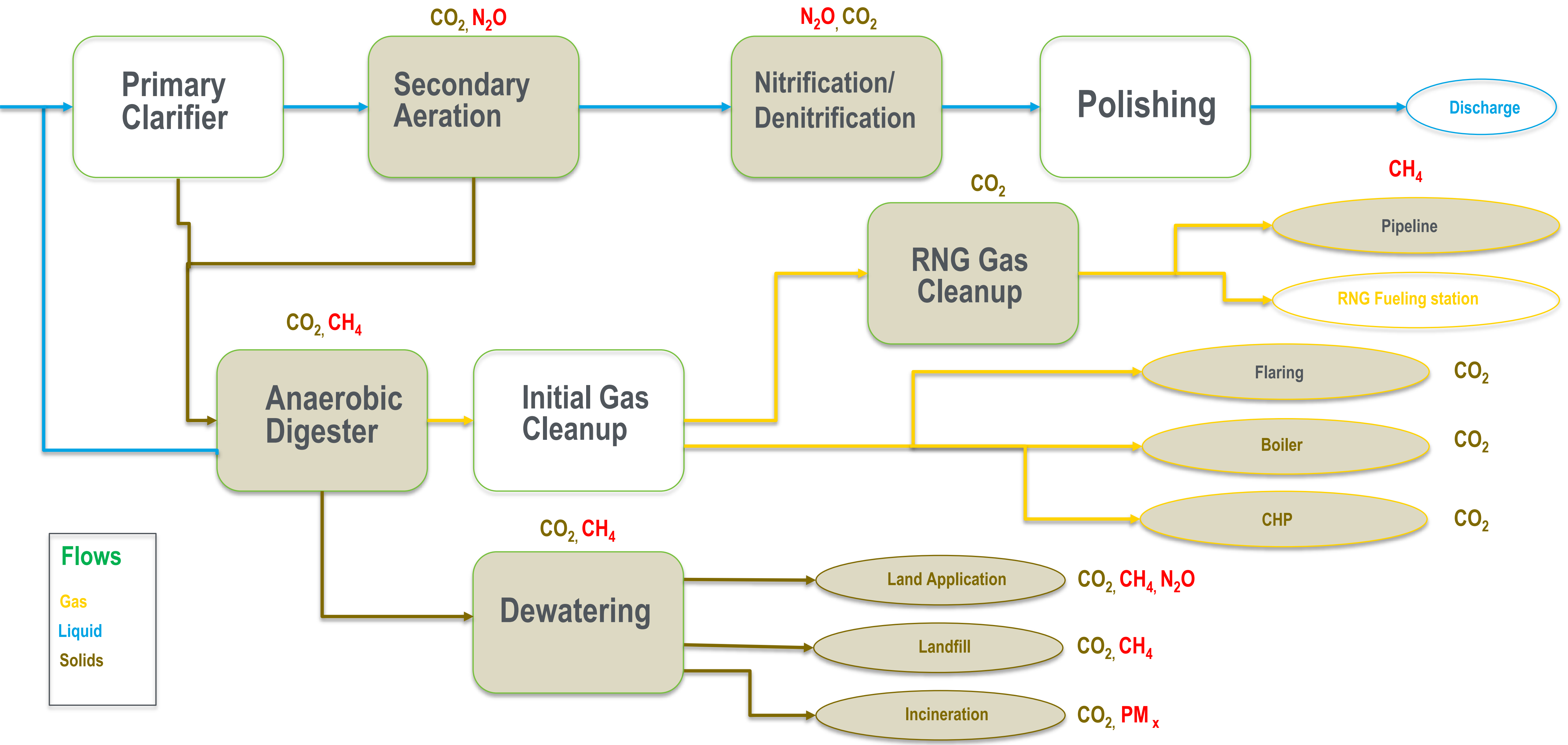
# FY 22 Congressional Appropriations

In addition, the recommendation provides $20,000,000 for research and development on technologies to achieve energy efficiency of water and wastewater treatment plants, including the deployment of alternative energy sources, as appropriate.

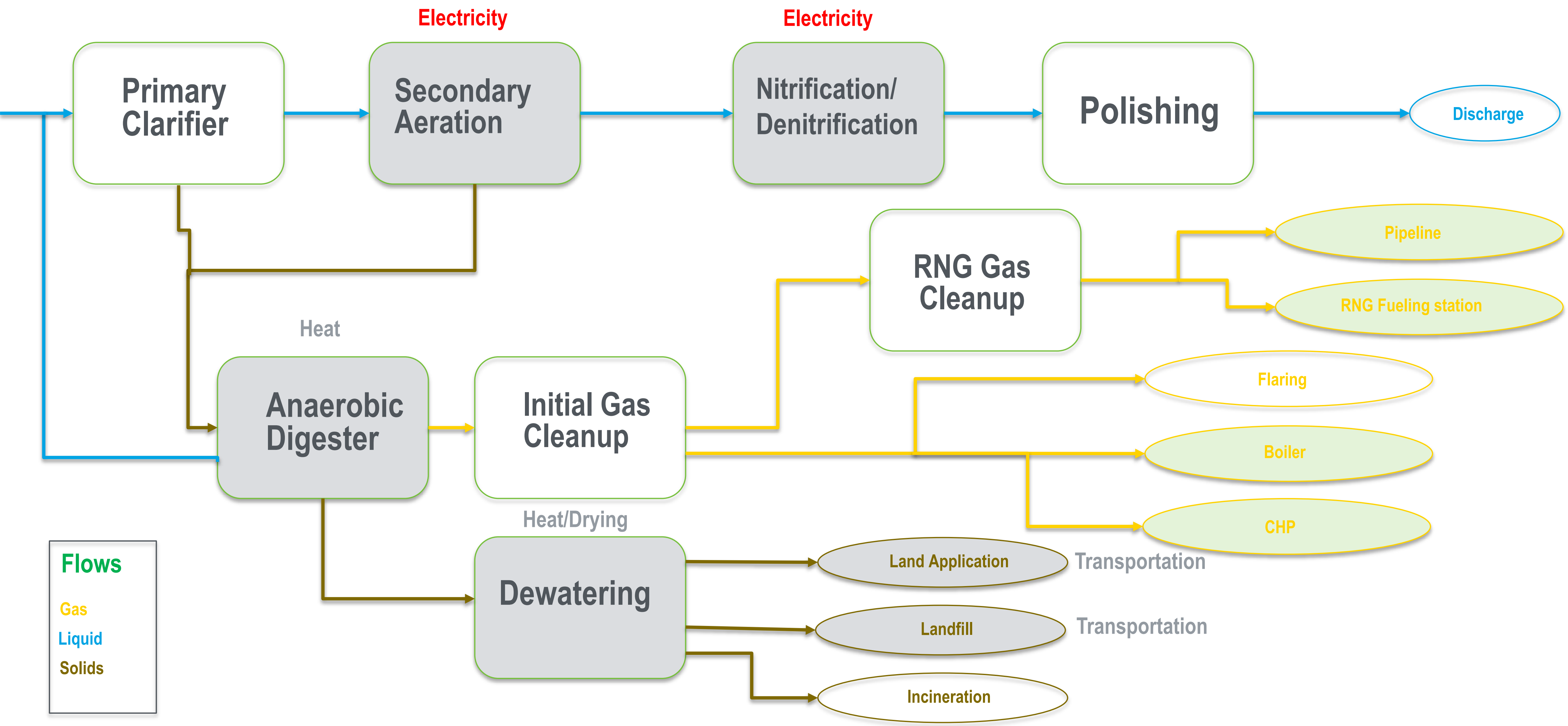
# WRRF Process Flow Overview (simplified)



# WRRFs: Direct GHG Emissions



# WRRFs: Energy usage (indirect GHG emissions)



# Recent WRRF emphasis on net-positive treatment facilities

- CHP especially valuable where it can replace high retail electricity costs
  - WRRFs have substantial electricity requirements (mostly aeration), especially those with N removal
  - Also have needs for heat for mesophilic (37ºC) and thermophilic (55ºC) digesters, facility building heating
  - Economic viability depends on scale and local electricity prices
  - Co-digestion of food wastes and fats, oils, and greases gaining increasing traction
  - SB 1383 in California requires 50% diversion of organic wastes (including municipal sludge) from landfills by 2020, 75% by 2023. Similar regulations are increasingly applied in other states.
  - 10-20 WRRFs nationwide have achieved net-positive, others are approaching
- AMO should target overall net energy usage, not just efficiency

## Options for GHG Reduction (1)

- Replace secondary aeration entirely in the WRRF treatment train
  - Generally single largest electricity user in a WRRF
  - Anaerobic Membrane Bioreactors (AnMBRs) are one possibility, others likely exist
    - Key challenges with AnMBRs are minimizing costs of avoiding membrane fouling, significantly lowering dissolved methane, and recovering ammonia
    - Both AMO and BETO have some projects in this area, really a better fit for AMO, as WRRF focus is not on biofuels production
- Alternative forms of N removal (reduce or eliminate aeration requirements)
  - When present, second largest electricity consumer
  - Multiple ways to do this, some in piloting in real world, but no mainstream applications yet
  - Also opportunities for N recovery in various forms
  - Eliminate substantial additions of methanol

## Direct Emissions Reduction Opportunities (2)

- Significant reduction of sludge volumes
  - In addition to reducing GHG emissions, sludge/biosolids disposal is often one of the biggest operating costs for WRRFs
    - Landfill costs tend to be highest in the Northeast and the West Coast
    - Even prior to SB 1383, several jurisdictions in the LA region are forced to truck their sludge to Arizona, at a high cost in both dollars (~$200/ton) and GHG emissions
  - Starting in the West, landfills are increasingly no longer an option for WRRFs due to landfill diversion legislation such as SB 1383 in California
  - Additionally, states are beginning to place strict restrictions on land application of sludge/biosolids due to contaminants of emerging concern, such as per- and polyfluoroakyl substances (PFAS) – Maine has recently banned land application. This represents a huge cost liability for WRRFs, which reducing the amount of sludge generated would reduce.
  - Sludge/biosolids reduction would help to solve current pressing problems for WRRFs, which would increase the likelihood of adoption of novel technologies

## WRRF Offset Opportunities beyond CHP

- RNG – Combination of RFS and California LCFS provides strong incentives
  - Combined credits are worth roughly 10x the value of the methane (2021)
  - Actual molecules do not need to flow to California, simply need a purchase contract and pipeline connection
  - Converting $CO_2$ in biogas to $CH_4$ via biological, electrochemical, or other means is a decarbonization opportunity (displacing additional fossil natural gas)
    - Would need close coordination with BETO to avoid duplication
- Replacing fossil-based liquid fuels and products (e.g. plastic, chemicals) with replacements from sludge is also a candidate
  - Again, collaboration with BETO would be a must, but they would welcome same
- Resource recovery (primarily N and P) is another possibility
  - Big decarbonization payoff would be in replacing Haber-Bosch based N fertilizers
  - Lots of active work in the sector, but hasn't really started to pay off yet

# FOA Proposal Sketch (1)

- Primary Metric: 25% GHG reduction vs. baseline
  - Applicants required to define and justify baseline based on which parts of the WRRF treatment train they are proposing to replace. Validating this could be a focal point of SOPO negotiations.
  - Optional secondary metric: 25% cost reduction vs. baseline, also requires justification.
  - All applicants must include a WRRF as a significant project co-PI
    - Increases the probability of early adoption
    - Include a strong preference for either WRRFs or relevant engineering firms as the prime
  - Only real wastewater streams are allowed for go/no go criteria and final objectives
    - Synthetic streams allowable in early testing
  - Labs can not be prime, but are allowed as subs
  - Proposals encouraged to target one of the GHG reduction opportunities identified in red on prior three slides