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Developing a sustainable biosolids program through a comprehensive, collaborative approach for Arlington county

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Abstract

Arlington County, Virginia has recently completed a wastewater solids master plan addressing the near- and long- term needs of the County's biosolids program. The planning process included comprehensive evaluation of over 70 technologies. The project team included representatives from engineering, operations, maintenance, and management from the County; a consultant team of national and local experts; a technical expert advisory committee from consultants, utilities, and academia; and community stakeholders. There were multiple project team workshops and regular presentations to stakeholders, feedback from which was incorporated into the planning process. Ultimately, there was a detailed evaluation of four process options – lime-stabilization (the current process), mesophilic anaerobic digestion, thermal hydrolysis pre-treatment leading to anaerobic digestion, and anaerobic digestion with thermal drying. The four options were evaluated against nineteen criteria representing economic, operating, environmental, and social issues of the 'quadruple bottom line.' The County has now developed a more sustainable biosolids program plan that includes the development of anaerobic digestion with thermal hydrolysis pre-treatment to produce a commercially viable biosolids product. The process will also produce biogas for use as fuel. The collaborative approach, which included evaluating numerous options and engaging with many stakeholders, contributed to the project's success and has provided a resilient roadmap towards a more sustainable biosolids program.

Key words: anaerobic digestion, biogas, biosolids, master planning, sustainable, thermal hydrolysis

INTRODUCTION

Arlington County, Virginia, is a densely populated, suburban county near Washington, D.C. It has more than 220,000 residents and houses many national landmarks – including the Pentagon and the Arlington National Cemetery. Wastewater is treated at the Arlington County Water Pollution Control Plant (WPCP). The service area for the latter includes a mix of residential, institutional, and commercial customers, and covers the majority of Arlington County as well as some areas outside its boundaries.

The WPCP – Figure 1 – is a 151 ML/day (40 mgd) wastewater treatment plant on South Glebe Road, in the County's southeast. It discharges treated wastewater into Four Mile Run, a stream that is part of the Potomac River sub-basin in the Chesapeake Bay watershed. Primary and waste activated solids are thickened, dewatered, and stabilized by adding lime to the dewatered cake before being hauled off-site. In 2015, approximately 27,000 tonnes (wet) of lime-stabilized biosolids were taken for beneficial use as a Class B biosolids in bulk land application. The lime-stabilization process was constructed in the mid-1990s and requires significant operations and maintenance attention due to its age and condition. To address concerns with the sustainability of the current process and plan for the future, Arlington County began developing a Solids Master Plan in 2014. Several goals were identified at the outset, including:

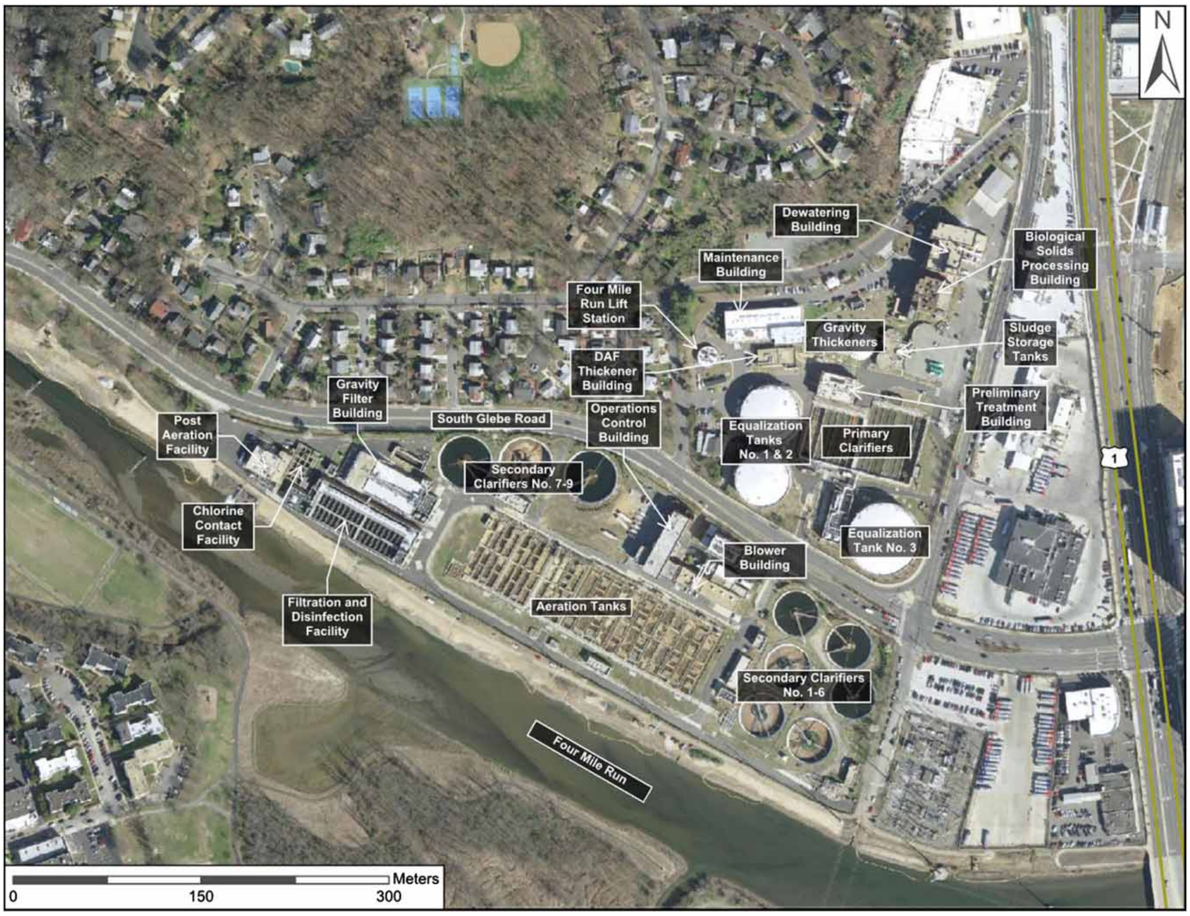

Figure 1 | Aerial image of Arlington county WPCP.

- Replacing failing and end-of-life equipment
- Mitigating the risk of potential future regulatory changes to the current practice of recycling Class B biosolids through application to agricultural land
- Reducing the energy and greenhouse gas footprints of the WPCP
- Achieving additional County-wide sustainability goals
- Developing a solids management strategy that offers long-term reliability
- Establishing an implementation plan compatible with County Capital Improvements Program funding

COLLABORATIVE APPROACH

To get the best advice and input in developing the plan, the county selected a consultant team consisting of CDM Smith, Rosegate Construction Solutions, LA Stone, LLC., and Environmental Financial Group, Inc. to lead the project. This was supported by a technical advisory committee (TAC) comprising senior experts in the field, and including representatives from academia, consultants, and utilities, in order to obtain a broad range of perspectives on the technologies and their process impacts. The Water Research Foundation, Virginia Tech, as well as communications and biosolids market specialists were also involved. This project team interacted through a series of workshops with a County team including engineering, operations and maintenance staff from the

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WPCP; Department of Environmental Services (DES) finance, energy, and communications staff; and DES leadership representatives.

The project team recognized the project's impacts on WPCP's customers and neighbors in the community. A communication plan was developed early and community outreach was conducted throughout the project. The outreach was intended to ensure early, frequent and two-way communication with key stakeholders and residents throughout the project. The communication plan and outreach facilitated information exchange, enabling the team to inform stakeholders of the plan's progress and recommendations. The County also received valuable stakeholder feedback while hosting a series of community meetings over a two-year period. At meetings, stakeholders were told about progress on the project and the County received input from the stakeholder group at key decision points. Meeting summaries and presentations, including a question/answer log, were posted to a publicly available project website.

Stakeholder input included participation in developing the evaluation criteria weightings used in analyzing the alternatives. Stakeholder participation in developing the plan reflected increased emphasis on social and environmental impacts of the project, the importance of exploring regional solutions, and the need for evaluation of potential emissions from the technologies recommended.

MASTER PLAN DEVELOPMENT

The master plan was developed through a comprehensive decision-making framework, which included developing the criteria and associated performance measures used in the planning process ahead at the project outset plus an initial screening of technologies to select those most appropriate.

After initial screening, the technologies were assembled into process train sets for evaluation. A preliminary evaluation was completed to select process train options for more detailed evaluation. The latter was completed against a series of criteria and performance measures developed by the project team. The importance of individual criteria were reflected by weighting factors developed using a paired-metric comparison. The criteria, performance measures, and weighting factors were agreed by the team, including representatives from community stakeholder groups, prior to any analysis of options.

The framework also included development of process train options incorporating preferred technologies and evaluation on the basis of anticipated costs (CAPEX = capital expenditures; OPEX = annual operating expenditures; and Life-Cycle = 20-year net present value of CAPEX and OPEX), footprint/site constraints, and alignment with County project goals. Selected process trains from this preliminary evaluation were taken forward for more detailed evaluation and ranking. The detailed evaluation, including ranking, was completed by scoring each option against the criteria developed at the project start.

In summary, the decision-making framework included three primary stages:

- Initial screening of technologies.
- Preliminary evaluation for selection of process train options aligned best with County goals.
- Detailed evaluation, scoring, and ranking of selected options, using an agreed and comprehensive list of criteria.

Technology screening

Table 1 shows the criteria and scoring guidance developed at the project start for screening technology.

As noted, the first planning step was to identify and screening technologies, to select preferred processes and equipment. The initial technology list comprised more than 70 technologies, including

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Table 1 | Criteria and scoring guidance for technology screening

Criterion	Comparative basis	Description	Score
Development status (adapted from Water Research Foundation Technical Development Level)	Research and development status	Early development through bench-scale and pilot testing.	0
	Emerging technology demonstrations or first generation technologies	Demonstration scale through first generation of full-scale facilities in a relevant environment.	0
		Applied at 2–4 full-scale wastewater facilities.	1
	production & implementation	Qualified through testing and implemented at full-scale, but not considered established (conventional).	1
	Conventional	Established and implemented at wastewater treatment facilities for more than 5 years.	2
	Adaptive use	Established technologies modified to produce a new technology or to achieve additional treatment objectives.	1
Typical application scale	Small	Facilities treating less than 5 tonnes per day of dry biosolids.	0
	Medium	Facilities treating 10–100 tonnes per day of dry biosolids.	2
Site requirements (on-site, except where noted)	Large	Requires purchase of adjacent or off-site property to fit technology and ancillary systems adequately.	0
	Moderate	No additional land purchase, but possible demolition or relocation of existing facilities to fit technology and ancillary systems.	1
	Small	Fits easily on existing site, with minimal footprint and demolition or relocation required.	2
	Remote/off-site	Solids processed elsewhere.	2
Relative costs	High	Higher than current stabilization/end use costs.	1
	Moderate	Comparable to or lower than current stabilization/ end use costs.	2
Ability to obtain regulatory permit	Unlikely	History suggests that obtaining a permit could be difficult.	0
	Uncertain	Process is new and/or has varied permitting history.	1
	Easy	Process has been permitted in the past and/or no permitting difficulties are expected.	2

equipment to reduce the volume of material, and processes to stabilize solids, convert them or treat them thermally, and to manage the side-streams generated.

On the basis of the five criteria and scoring guidance, the screening exercise enabled identification of technologies appropriate for the WPCP. The preferred technologies identified are presented in Table 2.

Preliminary evaluation

The preferred technologies were assembled into process trains and evaluated on the basis of anticipated costs (CAPEX, OPEX, and Life-Cycle), footprint/site constraints, and alignment with project goals. Individual technologies, like rotary drum thickeners and centrifuges, were combined with processes such as anaerobic digestion and thermal drying to generate 12 options (Table 3).

Following two project workshops reviewing the initial evaluations, four options were identified for detailed evaluation:

- **1: Lime-stabilization.** This is the current process at WPCP and was the comparison baseline. It produces Class B biosolids and the current equipment would simply be replaced in this scenario.

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Table 2 | Preferred technologies considered for Arlington county solids planning

Processing function	Preferred technologies
Non-digestion stabilization	Composting at off-site location
Digestion stabilization	Auto-thermal thermophilic aerobic digestion (ATAD) Anaerobic digestion (single- and multi- phase)
Digestion pre-treatment	Thermal hydrolysis pre-treatment
Thermal drying	Drum, belt, paddle, disc and tray dryer
Thermal processes	Off-site incineration Off-site organic fertilizer production
Thickening	Gravity, dissolved air flotation (DAF), gravity belt, rotary drum, and centrifuge thickening
Dewatering	Centrifuge and belt filter press dewatering

- **2: Mesophilic anaerobic digestion.** Anaerobic digestion was identified as a preferred stabilization process for WPCP solids due to its ability to reduce biosolids quantities and produce methane, as well as its footprint, etc. It produces Class B biosolids, and biogas that can be used as fuel.
- **3: THP + anaerobic digestion.** This combined process yields Class A dewatered biosolids and biogas.
- **4: Anaerobic digestion + drying.** Like option 2, the mesophilic digestion process in this option produces biosolids that can be dewatered. The dewatered material can then be dried thermally to produce a Class A product with significant volume reduction compared to other options.

Detailed evaluation

Nineteen evaluation criteria were developed at the start of planning. They were distributed between economic, operational, environmental, and social categories, to support a 'Quadruple Bottom Line' evaluation. Figure 2 is a graphical diagram of the category assignments and weightings assigned to the criteria.

Detailed evaluation of the four options involved further development of process sizing, CAPEX and OPEX, and facilities layouts, as well as applying the evaluation criteria. Figure 3 presents the alternative scoring results after detailed evaluation. Option 1, lime-stabilization (the current process) has the lowest CAPEX and life cycle costs of those evaluated, but also has the greatest sensitivity to contractor costs for hauling and land application. The uncertainty of costs associated with Class B land application over the planning period is reflected in the scoring. Options 2, 3, and 4 all use anaerobic digestion, and have significantly higher capital costs. They reduce the amount of solids to be hauled from the site, however, and offer lower annual costs than option 1. Process options 3 and 4 can both produce Class A biosolids, which is the long-term aim.

Economic criteria

Option 2, mesophilic anaerobic digestion, received the highest score against economic criteria. The factors influencing the score include:

- Moderate CAPEX and lowest annual OPEX, resulting in a low life cycle cost
- Reduced quantity of product leads to reduced hauling, and hence reduced life cycle cost sensitivity to variables like haulage and energy costs
- Class A biosolids – produced by the processes in options 3 and 4 – led to better scores for the 'end use management & control' criterion. The criterion is weighted lower, however, than the cost-focused criteria.

Table 3 | Process options assessed

No.	Option	Primary solids thickening	WAS thickening	Blending/ holding	Solids screening	Pre-dewatering	Thermal hydrolysis	ATAD	Anaerobic digestion	Final dewatering	Lime addition	Thermal drying	Off-site processing
1	Lime-stabilization (baseline)	X	X	X						X	X		
2	Anaerobic digestion (mesophilic, Class B)	X	X	X					X	X			
3	Thermal hydrolysis pre-treatment (THP) + anaerobic digestion			X	X	X	X		X	X			
4	Anaerobic digestion + drying	X	X	X					X	X		X	
5	Anaerobic digestion (Class A, TPAD[a] or similar)	X	X	X					X	X			
6	ATAD	X	X	X				X		X			
7	ATAD + drying	X	X	X				X		X		X	
8	THP + anaerobic digestion + drying			X	X	X	X		X	X		X	
9	THP (WAS[b] only) + anaerobic digestion + drying				X	X	X		X	X		X	
10	Thermal drying	X	X	X						X		X	
11	Off-site (haul cake)	X	X	X						X			X
12	Off-site (haul liquid)	X	X	X									X

[a]TPAD = Temperature phased anaerobic digestion.
[b]WAS = waste activated sludge.

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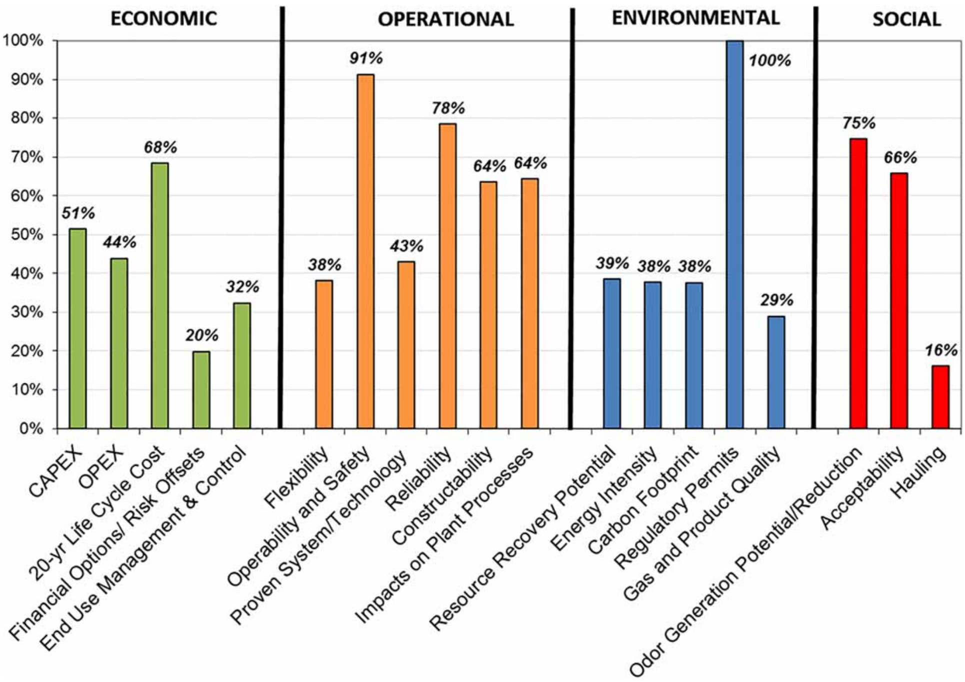

Figure 2 | Evaluation criteria categories and weightings.

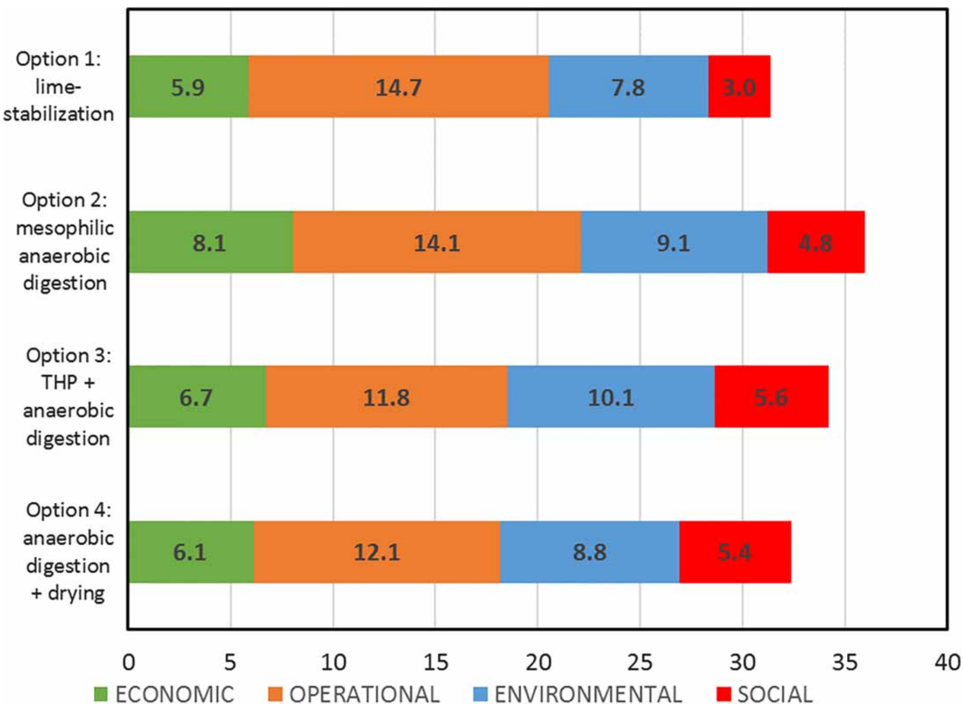

Figure 3 | Option scoring results.

Operational criteria

Option 1 (lime-stabilization) scored highest (most favorable) against the operational criteria. These criteria favor:

- System operability and safety because of lower operating and maintenance staffing requirements (i.e. fewer processes and equipment)

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- More established processes with longer operating histories and greater numbers of installations, along with WPCP staff familiarity
- Processes that require smaller footprints based on preliminary layouts

The flexibility of processes yielding Class A biosolids did not influence the category's final scores significantly.

Environmental criteria

Option 3 scored highest (most favorable) against the environmental criteria. Biogas production helped all options involving anaerobic digestion as biogas is a recoverable resource. The quality of the biosolids, Class A, coupled with the reduced energy intensity and carbon footprint required to achieve Class A (compared to thermal drying), were key differentiators for thermal hydrolysis.

Social criteria

Option 3 also had the highest score against the social criteria. The Class A final biosolids quality, coupled with the reduced energy intensity required (compared to thermal drying) were key differentiators of this option.

Detailed evaluation summary

Mesophilic anaerobic digestion – option 2 – ranked highest against the evaluation criteria in the detailed scoring matrix. Option 3, THP followed by anaerobic digestion, was ranked second. Lime-stabilization achieved only low scores in three of the four categories and was not a preferred long-term solution. Because the option scores were relatively close, however, the project goals had to be re-evaluated to ensure that the option selected alternative was the best match to the County's needs.

SELECTION OF PREFERRED OPTION

Several sensitivity analyses were performed for the top four options, to enable the team to identify those most subject to life cycle cost increases based on changes to one of the operating cost parameters. Sensitivity analyses were performed on the electricity and natural gas cost rates, and the cost of hauling. The latter is one of the biggest current operating costs at the plant (approximately $1.6 M was spent in 2017 on hauling). Haulage of Class B biosolids could leave WPCP vulnerable to hauling price increases because of its limited outlets. Recent regulatory changes affecting land application in Maryland and Pennsylvania have resulted in more biosolids being brought into Virginia for land application, and it is anticipated that this alone will increase hauling costs for Virginia generators. If, however, the regulations also change in Virginia to restrict land application, the impact on site availability and operating costs of many facilities within the state could be profound.

The final rankings were reviewed and considered to determine the preferred option. All three digestion-based options were preferred over lime-stabilization. The planning goals included developing a solution that provided long-term resilience and risk reduction, and, given the uncertain regulatory future of land application, the team felt that moving to a Class A biosolids product provided the best way forward for the future. On this basis, the preferred option is THP followed by mesophilic anaerobic digestion.

THP provides Arlington County with an opportunity to produce multiple resources suitable for local use. These include Class A biosolids, biogas, and, potentially, recovered phosphorus. The biosolids will probably require additional processing for local distribution, which could include

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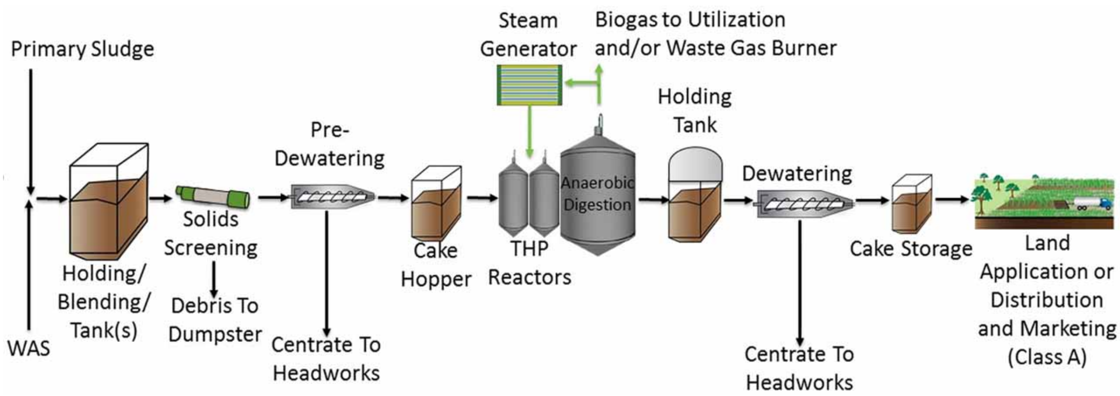

Figure 4 | Process flow diagram for the THP plus anaerobic digestion option.

blending with soil or a bulking agent to create a soil amendment, and developing a distribution center. Biogas can be used to generate electricity with heat recovery, cleaned and converted to compressed natural gas (CNG), or cleaned and injected into the natural gas grid. Phosphorus recovery is a potential for all digestion options but the feasibility of recovery is also a function of the liquid stream process.

Figure 4 shows a simplified THP with anaerobic digestion process flow. The two types of solids (primary solids and WAS) are blended, screened, and pre-dewatered ahead of the THP reactors, whose hydrolyzed solids are subsequently digested and dewatered. The dewatered solids can be land applied in bulk or distributed to other markets such as soil blenders. The estimated cost of implementing the option is $105 M and a breakdown of capital costs is presented in Table 4.

A critical element of the final plan is the beneficial use of biogas generated by anaerobic digestion. The potential impacts of various biogas uses on-site on air quality in the vicinity of WPCP is a concern to civic and neighborhood groups. As part of the master plan, an emission study was conducted to evaluate the potential air pollutant contributions under various biogas use scenarios. It was concluded that, with suitable control technologies, biogas use on- or off- site will not impact air quality significantly in the vicinity of WPCP and that the health of sensitive populations bordering the facility will be fully protected.

Table 4 | Capital costs for THP with anaerobic digestion

Process	Capital Cost
Primary solids holding	$ 700,000
WAS holding	$ 700,000
Blended solids holding	$ 700,000
Screening	$ 1,800,000
Pre-dewatering	$ 10,100,000
THP	$ 17,900,000
Mesophilic digesters and building	$ 25,600,000
Digested solids holding	$ 3,400,000
Post-dewatering	$ 25,600,000
Biological solids processing building demolition	$ 3,500,000
Allowance for odor control system improvements	$ 5,000,000
Alternative capital cost	**$ 95,000,000**
Biogas utilization	$ 10,000,000

Planning level costs to an accuracy of −30%/+50% are given in 2017 dollars.

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CONCLUDING REMARKS

Implementation of the Solids Master Plan's recommendations is likely to take several years with completion targeted for 2027. The next phase is to prepare a Facility Plan, which will advance the master plan concepts and is expected to confirm assumptions used in developing the master plan. A more detailed biogas utilization study and a nutrient side-stream treatment analysis, including revisiting phosphorus recovery opportunities, will also form parts of the Facility Plan. In relation to biogas utilization, the assumptions in the master plan's economic evaluation will be reviewed as more information becomes available and discussions with potential stakeholders continue.

Implementation of THP with anaerobic digestion, as recommended in the Solids Master Plan, meets Arlington County's goals and objectives. The recommendations provide a roadmap for the County to implement a long-term solids management strategy aligned with the County's energy goals, while reducing greenhouse gas emissions, and reducing the risks associated with the continued land application of Class B lime-stabilized biosolids.

There are several unique aspects of the master planning process described, including:

- Proactive outreach and communications in which considerable effort went into soliciting input and buy-ins from interest groups. A detailed communication plan was developed at the start, and quarterly meetings were held with key interest groups, who participated actively in ranking evaluation criteria and bought-in on the evaluation methodology.
- Detailed emission impact study – potential concerns expressed by interest groups regarding biogas production associated with anaerobic digestion – led to detailed modeling to assess current emissions of priority pollutants both on- and off-site, and the projected impact of implementing the recommended facilities, including several gas use options (CHP, CNG, and pipeline injection).
- Detailed condition assessment and criticality evaluation of the unit process selected. The condition of several existing process units in relation to the projected master plan implementation time is such that several have been identified for detailed condition assessment and criticality evaluation. Improvements were recommended to enable them to continue in use until plan implementation.