Can New York Supply Water While Generating Clean Energy?

Inspiration and Recommendation for Renewable Energy Recovery Through Conduit Hydropower

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Executive Summary:

Conduit hydropower (CH) offers New York (NY) a uniquely innovative and reliable opportunity to promote energy, economic, environmental, and social sustainability which can and should be pursued. To achieve NY's goal of 100% clean energy by 2040, they must deploy all available renewable energy resources (NYSS, 2019). Along with those which provide power independently, the next frontier of NY's mission for energy sustainability will depend on its ability to integrate and hybridize these energy systems. The state already has a strong hydropower platform, offering a historically strong foundation to expand from. CH takes advantage of the fact that water distribution systems not only require energy, but can simultaneously produce it.

CH is the incorporation of hydroelectric turbines within pre-existent water supply infrastructure, working to recover otherwise wasted energy from water conduits such as pipelines, aqueducts, and canals. A variety of private and public sectors depend on these systems, including municipal waste and drinking water facilities, agriculture, as well as industries such as manufacturing, food processing, mining, and thermoelectric power (DOE & ORNL, 2019).

Water supply systems produce excess energy through the force of pressure within a given conduit, often causing damage to the infrastructure. For example, pipelines can rupture and canal walls erode, leading to costly repairs and maintenance over time (DOE, 2015). To limit this potential degradation, energy dissipating devices such as pressure-reducing valves (PRVs), flow control valves (FCVs), and conduit drops are required. These pressure controls also constitute energy-harvesting sites, usually being in locations where hydroelectric power can be captured (DOE, 2015). Currently, this excess energy is wasted as these devices remove it from the infrastructure, offering an opportunity to take advantage of a pre-generated source of renewable power as well as reduce excess pressure to avoid infrastructural damages. Although these hydropower hotspots may offer individually small amounts of energy, capturing the electricity contained can be extremely worthwhile both for non-intermittent on-site energy recycling along with collective economic, social, and environmental benefit.

Overall, CH offers a holistic sustainability appeal by providing six co-benefits:

1. The technology holds a *regulatory advantage* on the federal level, as systems with a capacity of less than 40 MW are exempt from the FERC licensing and permitting process, requiring only a "short form" Notice of Intent to gain federal approval within 30 days.

2. Conduit hydro is uniquely *environmentally benign*, as its installation within existing water management infrastructure requires no additional land-use change or new environmental development. Instead, it works to mitigate greenhouse gas (GHG) pollution to support environmental along with human health, as well as contribute to global decarbonization.

3. Rather than environmental impact, the main concern with conduit hydro relates to the maintenance of a given water supply's functionality and safety. However, conduit-specific turbines can work to *solely capture excess energy without changing conditions which are vital to the water supply system's function*. This conversion of otherwise wasted energy to renewable electricity actually works to reduce the risk of infrastructural degradation by capturing the potentially harmful excess pressure, being beneficial to the maintenance of the given conduit's quality.

4. Conduit hydropower can be *affordable* through federal and state grants and loans, as well as allowing for *on-site economic efficiency*. It reduces water supply management expenses by limiting pressure and maintenance costs resulting from infrastructural damage, offsetting or even neutralizing load and producing a new baseload, and creates a new revenue stream by providing a source of energy through which excess electricity can be resold to the local grid operator. This saving and profit works to increase funds, which can be diverted to invest in infrastructural improvements along with enhanced benefits for facility employees.

5. The technology may provide high energy generation based on national and state projections, as well as demonstrating success according to active systems in Oregon, Colorado, and California.

6. Conduit hydro also offers the unique opportunity to avoid disturbance of environmentally, economically, and culturally significant areas, making it appealing to the public. In addition, through the reselling of excess energy to the grid, the technology can provide a decentralized source of renewable energy access and cost-efficient pathway for improvement to infrastructure such as wastewater treatment systems, which ultimately can empower energy as well as human and environmental health sustainability. This potential is particularly pertinent for communities who are disproportionately facing exposure to water pollution related environmental justice issues.

Together, these prospects can intersect to not only support economic efficiency, but also attend to environmental justice. For socioeconomically marginalized communities in NY who may be disproportionately exposed to inadequately treated drinking and waste water as well as without access to renewable energy, CH can be a tool to promote equity. By posing the potential to increase funding for treatment improvements and localized renewable energy access, CH can support the alleviation of environmental justice concerns.

Although the technological potential of CH has been demonstrated, efforts for its development in NY have been slow. Regardless of the potential for energy recovery through the state's seemingly massive water supply infrastructure, barriers to the integration of CH have proven difficult to surmount. Current limits to NY's CH advancement are largely nested in political and research based issues. However, given the mobilization and collaboration of interdisciplinary and multi-actor efforts this unique energy opportunity can certainly be achieved by the state.

The specific barriers to CH development in NY are described below:

- *NY has not conducted an up-to-date assessment of possible resources that are eligible for CH integration* in the context of public water supply systems, let alone for irrigation canals and industrial water supplies. CH technology has been revolutionized since a New York City Department of Environmental Protection (NYCDEP) evaluation of potential for development was done in 2013, and additional research is needed.

- *The state lacks a CH specific or encompassing financial support program*. CH development in Oregon, Colorado, and California have exemplified that some level of grant or loan assistance has been key to their CH success. NY's Water Infrastructure Improvement Act (WIIA) and Canalway Grant Program (CGP) could be applicable to CH projects. However, for NY to jumpstart expansion of the technology, it's clear that a program which is explicitly inclusive of CH should be developed to support municipalities, government agencies, communities, farmers, and private industries.

- *NY lacks any level of policy which coordinates necessary resources of CH relevant information, stakeholder collaboration, research, and general strategic guidance*. Although the Introduction legislation 0419-2018 is a hopeful first step toward policy that incentivizes CH integration by including its consideration in general water infrastructure advancement projects, broader frameworks must be implemented. The value of informative resources involving interconnection, permitting, and overall CH implementation in the form of a guidebook or other assistance has also been demonstrated to be valuable by the states studied in this report, being an important pathway for CH advocacy that NY should pursue.

- *CH faces an unnecessary regulatory disadvantage.* CH development in NY is delayed and challenged by potential requirements to undergo the same environmental review and permitting processes as conventional hydropower systems. Although CH should not be freely developed without regard to environmental impact, it is clear that the technology poses a distinctly benign impact on environmental health. This quality must be recognized by NY energy policy.

In accordance with these challenges, this report identified five specific recommendations to help NY pursue CH development. These insights are detailed below:

- *Updating and expanding resource assessments* are vital steps to confirming the potential NY has to integrate CH with their extensive water supply systems. Evaluation of New York City's (NYC's) water supply should be updated to account for new energy and cost-effective innovations of CH turbine technologies. As well, resource assessment should be expanded to consider potential for energy recovery through (1) municipal water processing facilities in upstate which are in dire need of funding for upgrades, and (2) NY's immense agricultural industry which depends on over 100 canals to support economic and food security, but will soon be facing drought and other climate change related threats.

- *Financial assistance for CH is essential to its potential for expansion,* which can take place through loans with low or no interest rates along with grants. Government-sponsored CH funding can not only encourage municipalities, farmers, and water intensive industries to adopt the technology, but be implemented strategically to incentivize specific applications. For example, funding can be used to target CH development in areas which lack renewable energy resources, are in need of water treatment upgrades, or depend heavily on irrigation for agriculture. The funding programs highlighted in the OR, CO, and CA case studies all offer informative examples of how NY could structure financial assistance that is CH focused or inclusive.

- *Regulatory accommodation for CH is necessary*. CH and other energy recovery technologies which are integrated into pre-existing water supply infrastructure must be provided their own pathway for development given this unique quality. For example, unless the proposed project aims to take place in an irrigation canal where ecological factors are important to evaluate, state level CH permitting should devote attention to maintenance of water supply quality and functionality rather than environmental impact (Swindle, 2020). As well, before regulatory frameworks and funding programs can accommodate for CH, it must be explicitly recognized by the New York State Energy Research and Development Agency (NYSERDA) as a qualifying renewable energy facility under NY's tier 1 Renewable Energy Standard (RES). Currently, the only eligible new hydropower developments are upgrades to existing dams and low-impact run-of-river systems under the stipulation that no new storage impoundment is constructed (NYSERDA, 2020c). As of July 2020, NYSERDA and the New York State Department of Public Service (NYSDPS) are in the process of modifying the definition of qualified renewable energy facilities to better align the Clean Energy Standard (CES) with the Accelerated Renewable Energy Growth and Community Benefit Act (AREGCBA) (Peterson, 2020). Hence, there is a window of opportunity for NY to take action regarding the inclusion of CH into renewable energy programs.

- *Organizing a CH stakeholder alliance* is key to streamlining its development. Numerous actors are involved, and there is a need for efficient coordination and communication across electric utilities, wholesale and retail water agencies, landowners, developers, state agencies, and communities. Organization of this network through top down state level leadership in balance with bottom up initiative will be essential to not only the development of CH and avoidance of conflict among actors, but also to spread accurate and accessible information about the benefits which it offers. Public-private partnerships (PPPs) should be prioritized as a pathway for interested municipalities and communities to easily access resources concerning their ability to develop CH, working to empower bottom up action and collaboration. For example, they can provide a strategic cost-advantage for CH development as only municipalities can gain production tax credits. PPPs can promote maximized savings in CH projects as both private and public actors have access to different forms of funding and can pool collective financial and technical resources.

- *Framing the co-benefits of CH in a clear and appealing way* makes an exceptional difference in motivating its development and public excitement. NY has an opportunity to use CH toward advancing energy, economic, environmental, and social sustainability. However, the state must frame CH in a way that recognizes the potential for these intersectional benefits to be attended to rather than perceiving it solely as an energy recovery project. Utilizing wasted energy certainly is CH's primary appeal, yet it can be much more than that. Realizing, studying, and communicating its broader capabilities is an important strategy to achieve co-benefits and gain the acknowledgement CH needs. NY should consider developing a linked water-energy resilience and equity plan which frames CH as an engine for the improvement of energy efficiency along with human and environmental health.

1. Introduction:

Access to dependable renewable energy resources is inextricably linked to addressing climate change. In an effort for decarbonization, expanding current systems of electricity production to transition away from fossil fuels and deploy renewable energy supplies has been a key pursuit of climate policy action across the past decade. Although renewable energy has experienced an astonishing evolution that poses a hopeful future for the resiliency of our energy systems, understanding how different forms of renewable energy technologies can most effectively coexist remains a pervasive dilemma. Wind and solar have gained much of the spotlight for some time, however the often overlooked potential of hydropower offers an exciting pathway for renewable expansion which can no longer be ignored. Being a uniquely reliable, predictable, and non-intermittent source of energy, hydropower serves the dual purpose of providing increased renewable energy capacity while working as a platform to compliment, backup, and balance the less dependable production of wind and solar energies.

Today, hydropower in the U.S. generates 101 GW of electricity annually, mitigating 200 million metric tons of CO_2 (DOE, 2016). Yet, opportunities for growth in the hydropower sector may allow for an additional generation of 50 GW to be advanced by 2050. Achieving this goal could work to reduce greenhouse gas (GHG) emissions by approximately 5.6 million metric tons, saving $209 billion in avoided damages from pollution (DOE, 2016). Such relief can substantially improve human health, working to decrease cases of acute respiratory symptoms by 5 million as well as cases of childhood asthma by 750 thousand (DOE, 2016). Although federal initiatives to empower hydropower are quickly growing, in the past they have often missed the mark. State level efforts to develop a hydropower-led energy future demonstrate astounding examples of success. New York (NY) in particular has a rich history of reliance on hydropower to meet its energy needs while fortifying environmental, economic, and social sustainability.

1.1 New York's energy mission

NY is considered a national energy leader as it uses less (and spends less) on electricity per capita than any other state in the nation. Furthermore, the state produces more hydropower than any state east of the Rocky Mountains, accounting for 70% of their renewable energy production and at least 17% of total electricity demand (NYPA, 2020; EIA, 2020). In 2018, it was the third-largest hydropower generating state, contributing 11% of total U.S. hydropower generation (EIA, 2020). Hydroelectric supply is largely generated through 7 NY Power Authority (NYPA) owned facilities, including dams and pumped-storage units. As well, 345 small conventional hydropower station units are owned by numerous government and non-government actors across the state (NYSDEC, 2020). Hydropower in NY has worked to provide a foundation for renewable energy production today, and will play an instrumental role in the state's future efforts to decarbonize.

In 2019, NY passed legislation which expanded their Climate Leadership and Protection Act to call for 100% clean energy by 2040 and become carbon neutral by 2050 (NYSS, 2019). In addition to the development of offshore and land based wind along with large scale and distributed solar arrays, the state aims to expand their hydropower resources to reach their energy goals.

Current objectives to further develop hydropower in NY across the next 30 years include efforts to (1) repower existing generation facilities through upgrades to existing plants, (2) retrofit over 6,600 non-powered dams (NPDs) spread throughout the state, and (3) deploy community-scale and distributed micro-hydropower (MHP) in low head scenarios (NYSDEC, 2020). As well, two major projects to develop hydroelectric supplies are underway. The first is a tidal energy initiative called "The Roosevelt Island Tidal Energy" (RITE) pilot project, which uses 6 hydrokinetic turbines to capture energy from tides in the East River of New York City (NYC) (Verdant Power, 2020). RITE is operated by Verdant Power, and has been in testing stages since 2006. In 2012, the Federal Energy Regulatory Commission (FERC) issued Verdant Power a 10-year license to install up to 1 MW of power, making it the first commercially-licensed tidal power project in the U.S (Verdant Power, 2020).

The second extensive hydropower project being pursued is "The Champlain Hudson Power Express" (CHPE), a planned transmission cable which will deliver energy from the Canadian hydropower-based electric utility Hydro-Quebéc to NY residents in the downstate region (CHPE, 2020). The cable will bring 1,000 to 1,250 MW of renewable energy, which is enough energy to power over one million NY homes (CHPE, 2020). In addition, construction and operational work is estimated to create 3,400 jobs and add $28.6 billion of benefits to the state's economy (CHPE, 2020). This project has completed necessary regulatory reviews by federal, state, and local authorities and will begin development once energy contracts are established.

Hydropower has been providing renewable, dependable, and cheap energy for NY's residents and businesses for over a century. These efforts for hydropower expansion will certainly act to bolster the state's ambition to become carbon neutral. However, another opportunity to build upon its already strong hydropower platform is to integrate renewable energy recovery within water supply infrastructure. Conduit hydropower (CH) poses a promising potential toward achieving this goal by stepping beyond the addition of new units to adapt NY's energy systems on a structural level.

1.2 What is in-conduit hydropower?

By incorporating hydroelectric turbines within pre-existent water management infrastructure, CH works to recover otherwise wasted energy from water conduits such as pipelines, aqueducts, and canals. A variety of private and public sectors depend on this kind of infrastructure, including municipal drinking and waste water processing and distribution facilities, agriculture, as well as industries such as manufacturing, food processing, mining, and thermoelectric production (DOE & ORNL, 2019). This innovative technology takes advantage of the fact that water use not only depends on energy, but can concurrently produce energy.

Water conveyance systems produce excess energy through the force of pressure within a given conduit, often causing damage to the infrastructure. For example, pipelines can rupture and canal walls erode, leading to costly repairs and maintenance over time (DOE, 2015). To limit this potential degradation, energy dissipating devices such as pressure-reducing valves (PRVs), flow control valves (FCVs), and canal drops are required. These pressure controls also serve as energy-harvesting sites, usually being in locations where hydroelectric power can be captured (DOE, 2015). Currently, excess energy is wasted as these devices remove it from the infrastructure, offering an opportunity to utilize a pre-generated source of renewable electricity as well as reduce excess pressure to avoid infrastructural damages. Although these hydropower hotspots may offer individually small amounts of power, capturing the energy contained can be extremely worthwhile both for on-site energy recycling along with collective financial, social, and environmental benefit.

1.3 Conduit hydropower is an appealing renewable energy pathway

Aside from the reliable nature of hydropower, there are six specific rationales which explain why CH systems offer a particularly unique opportunity to integrate hydropower generation while providing a variety of co-benefits (Fig. 1). This potential is detailed in the sections below.

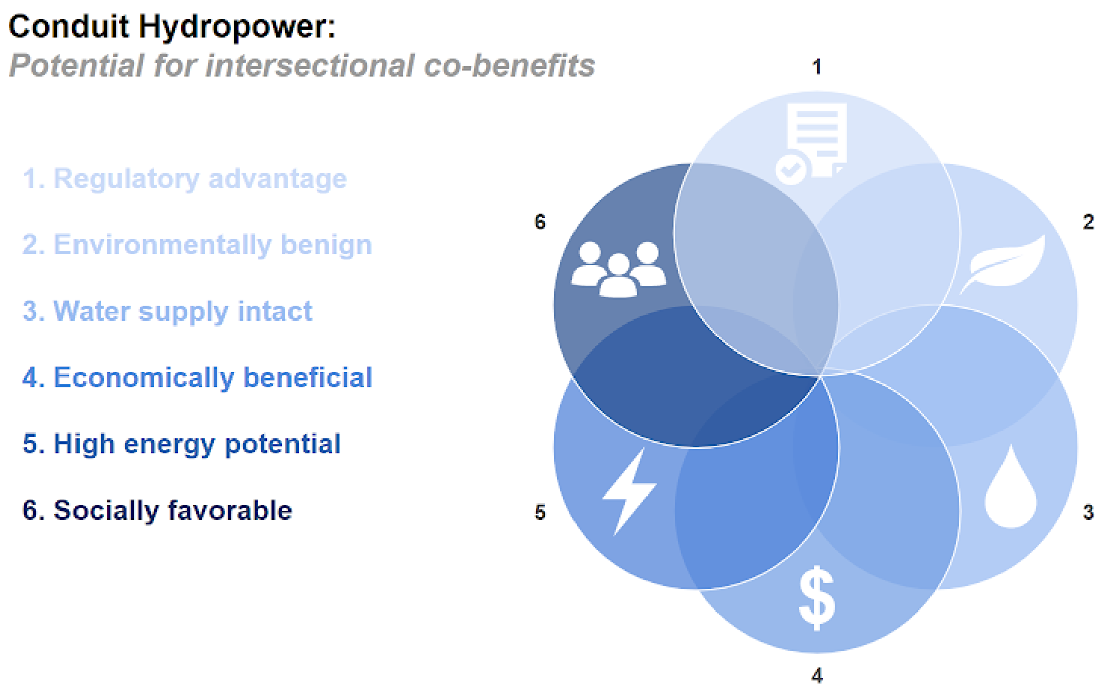


Figure 1. Conduit hydropower is an appealing source of renewable energy due to its potential for intersectional co-benefits across political, environmental, infrastructural, economic, energy, and social dimensions (*Source:* Sebastian Grimm)

1. The necessary *regulatory support* for CH already exists on a federal level, providing it a substantial advantage over other renewable energy technologies. Thanks largely to the Hydropower Regulatory Efficiency Act (HREA) of 2013, there exists a window of opportunity to rapidly deploy CH systems. The original act exempts any "qualifying conduit hydropower facility" which produces under 5 MW of energy from the FERC licensing process, and based on their judgement allowed the possibility for systems between 5 and 40 MW to also gain exemption (FERC, 2013). The U.S. Bureau of Reclamation (BR) Small Conduit Hydropower Development and Rural Jobs Act also incorporated this exemption in 2013, working to amend the Public Utility Regulatory Policies Act of 1978 (BOR, 2013). The next year, Congress provided appropriations for the section 242 program under the Energy Policy Act (EPACT) of 2005, providing federal incentive payments for new hydropower generation built using existing infrastructure, including CH systems (DOE & WPTO, 2014). Lastly, in 2018 America's Water Infrastructure Act (AWIA) updated the HREA to state that small and medium sized CH projects with an installed capacity of under 40 MW are explicitly exempted from licensing, and can receive full federal approval from the FERC within 30 days (EPA, 2018). Today, all that is required is a "short form" Notice of Intent, working to eliminate generally all oversight by the FERC and dismiss any future administrative reporting requirements which are associated with conventional hydropower.

2. Unlike any other source of renewable energy, CH is generally *environmentally benign*. Being installed within existing water management infrastructure, these systems require no additional

land-use change or new environmental development (CEC, 2020a). Specifically, most projects are Categorically-Excluded or Categorically-Exempt from environmental topics (Swindle). However, some irrigation canals are inhabited by aquatic species such as native trout, making the ecosystem impact a necessary dimension to assess (Swindle). The main environmental focus of CH development surrounds water quality, working to ensure that the health and functionality of a given water supply system remains intact. Hence, all aspects of a CH turbine technology which interact with water supplies must be either ANSI-61 compliant or certified (Swindle). The only other environmental impact that most CH systems pose is a beneficial one. They mitigate GHG pollution by providing a renewable energy alternative as well as avoid land-use change and the involved environmental degradation which other systems pose.

3. Although threat to water health and its delivery is a salient concern, CH can be installed *without any negative impact on water supplies*. Turbine technologies are often integrated with PRVs, however they work to solely capture excess energy without changing conditions which are vital to the system's function (NYCC, 2019; NREL, 2017). As long as the turbine is integrated in this way and ANSI-61 compliant or certified, the given water being delivered remains undisturbed. This recovery of otherwise wasted energy actually works to reduce potential infrastructural degradation by capturing the potentially harmful excess pressure, being beneficial to the maintenance of the given conduit's quality and functionality.

4. CH is often e*conomically feasible and financially beneficial*. The technology is usually financially viable if total project costs are between $5,000 to $15,000 per kW and poses a pay-back period of less than 15 years (CEC, 2020a). As well, a variety of funding resources can support affordability. For example, under section 242 of EPACT, the Water Power Technologies Office (WPTO) of the DOE is now accepting applications for $7 million, which will select qualified facilities based on the kWhs they generated in 2019. Applicants can receive up to 2.3 cents per kWh produced during 2019, with a maximum of $750,00 per facility. In 2018, the WPTO awarded $6.6 million to 48 recipients who established projects on existing water infrastructure or upgraded existing hydropower projects (DOE & WPTO, 2020). As well, several states have introduced local funding resources which are applicable to CH hydropower projects, such as California, Colorado, and Oregon (DOE & ORNL, 2017; DOE, 2015).

CH can also work to provide localized financial benefits by (1) reducing electricity costs on site by offsetting load and producing a new baseload, (2) creating a new revenue stream by providing a source of energy through which excess electricity can be resold to the local grid operator, and (3) freeing up funds which were originally spent on electricity and can be diverted to invest in infrastructural improvements along with enhanced benefits for facility employees (CEC, 2020a; DOE & ORNL, 2017; DOE, 2015). By increasing the cost-efficiency of water management, CH may provide a pathway for particularly municipal public water supply (PWS) systems such as drinking and wastewater plants to undergo necessary treatment upgrades. These facilities spend 25% to 40% of their budget on electricity, are often old, non-updated, and lacking funding for treatment advancements which can drastically improve localized environmental and human health (ASCE, 2017a; ASCE, 2017b).

5. CH *poses a high energy generation potential*, and resulting mitigation of GHGs (Fig. 2). The nation has an estimated 1 to 2 GW capacity, however was an especially rough projection that cannot be relied on alone (NREL, 2017). More specifically, the BR found that federally-owned water conveyance facilities across the country pose an estimated 104 MW of capacity and 365 GWh of annual generation at the 373 Reclamation canals evaluated (Pulskamp, 2012). As well, state specific estimates and current production data highlight further possibilities. For example, based on 89 public water supply facilities in Oregon, the state is projected to hold a 12,380 kW capacity which can produce 65,068 MWh each year, while 63 facilities in Colorado may pose a 33,990 kW capacity to generate 202,475 MWh annually (DOE & ORNL, 2019). As well, California has already pursued over 142 CH systems which are in various stages of development. 8 sites in particular have been identified as being particularly successful, generating between 433,000 to 6,100,000 kWh annually (CEC, 2020a). Overall, California's potential capacity has been estimated to be between 368 to 414 MW, with their current total installed capacity being 343 MW (CEC, 2020a). Based on a conservative estimate, their CH energy generation can currently power at least 343,000 homes. NY has many forms of water supply infrastructure both concentrated in NYC and spread across the state, posing a major potential to be utilized for energy recovery and generate similar if not more power than these other states. These include (1) public water supply (PWS) facilities such as drinking and waste water treatment and processing facilities, (2) agricultural irrigation canals, and (3) industrial wastewater plants (NYSDEC, 2019a; NYSDEC, 2019b; NYSDEC, 2019c; CC, 2019). As well, it's important to remember that CH can not only generate renewable energy for a specific facility and the local grid, but depending on its generation capacity can work to backup intermittent renewable energy sources and improve general electricity demand and supply efficiency.

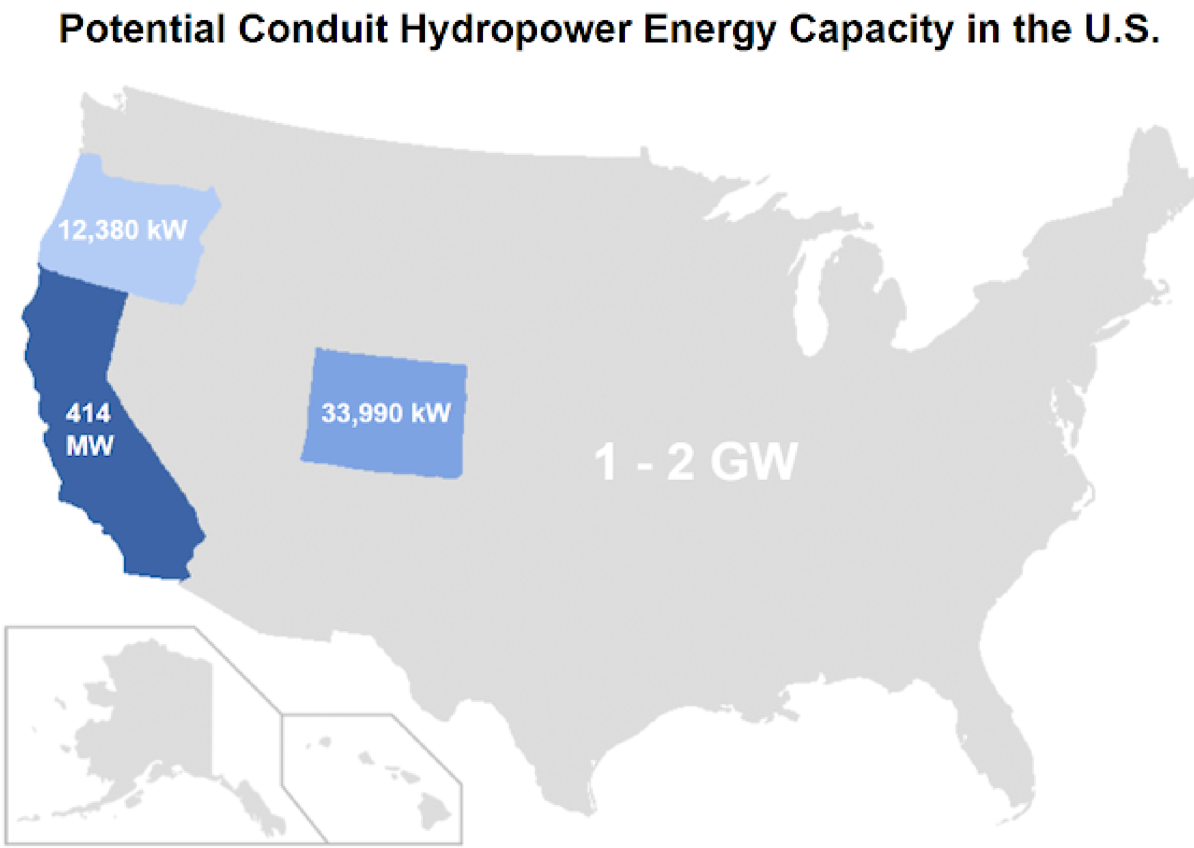


Figure 2. Current estimates of potential energy capacity from conduit hydropower in the U.S. The nation may hold a total capacity of 1 to 2 GW, while California poses 414 MW, Colorado 33,990 kW, and Oregon 12,380 kW (*Data from:* NREL, CEC*)*

6. CH can be *socially acceptable and beneficial*. Conventional dams can cause environmental threats, which are of concern to the public (Boyé & Vivo, 2016; WCD, 2001). Attempts to repower NPDs in an environmentally safe manner through MHP turbines also faces public opposition due to worries involving historic preservation and environmental health (Microhydro, 2020). In addition, wind and solar technologies can pose disruption to viewsheds, property values, and historically or culturally significant sites, which has led to social displeasure and the abandonment of renewable energy development in some instances (WETO, 2020; Al-Hamoodah et al., 2018; Testa, 2012). CH offers the unique opportunity to avoid these disturbances, as it can be integrated with pre-existing infrastructure without impact on the local environment, historic characteristics, or water supply being conveyed.

As well, through the reselling of excess energy to the grid, CH technology can provide a decentralized source of renewable energy which ultimately can empower energy and health sustainability. This potential is particularly pertinent for communities who are disproportionately facing exposure to water pollution related environmental justice issues. Using renewable power from CH technologies may help to avoid localized GHG pollution and the associated threat to human and environmental health. In addition, over the long term CH can also work to provide a revenue stream for public water utilities to fund much needed improvements to their water treatment systems and infrastructure toward better safeguarding the equitable health of local communities and ecosystems.

1.4 The role of conduit hydropower for New York

In order to meet NY's climate goals, every feasible source of renewable energy development is necessary to pursue. Although NY has successfully been working to expand renewable energy resources across the state so far, the next frontier of their mission for energy sustainability will depend on their ability to integrate and hybridize these systems. CH is a rapidly deployable, innovative, and non-disruptive energy technology which can offer the state a pathway to reaching the next level of renewable energy transition while providing a variety of social, economic, and environmental co-benefits.

Although the technological potential of CH has been demonstrated, efforts for its development in NY have been slow. Regardless of the seemingly massive potential for water supply derived energy recovery in the state, barriers to the integration of CH have proven difficult to surmount. Current limits to NY's CH advancement are largely nested in political and research based issues. However, given the mobilization and collaboration of interdisciplinary and multi-actor efforts this unique energy opportunity can certainly be achieved by the state.

2. Background:

2.1 Energy mechanics of conduit hydropower

2.1.1 Physics

CH aims to harness potential energy from (1) changes in hydraulic head due to elevation changes in waterways (such as pipeline or canal drops), (2) pressure released by PRVs and FCVs, and (3) capture the kinetic energy of moving water (Fig. 3) (CEC, 2020a; DOE, 2015). None of these energy sources are in any way recovered through current water infrastructure systems, yet they all offer opportunities for both renewable energy generation and the enforcement of sustainable infrastructure quality by reducing potentially damaging excess pressure. Potential energy capture through water head or pressure can take place through a variety of conventional and emerging turbine technologies, while kinetic energy can only be generated through newer hydrokinetic turbines.

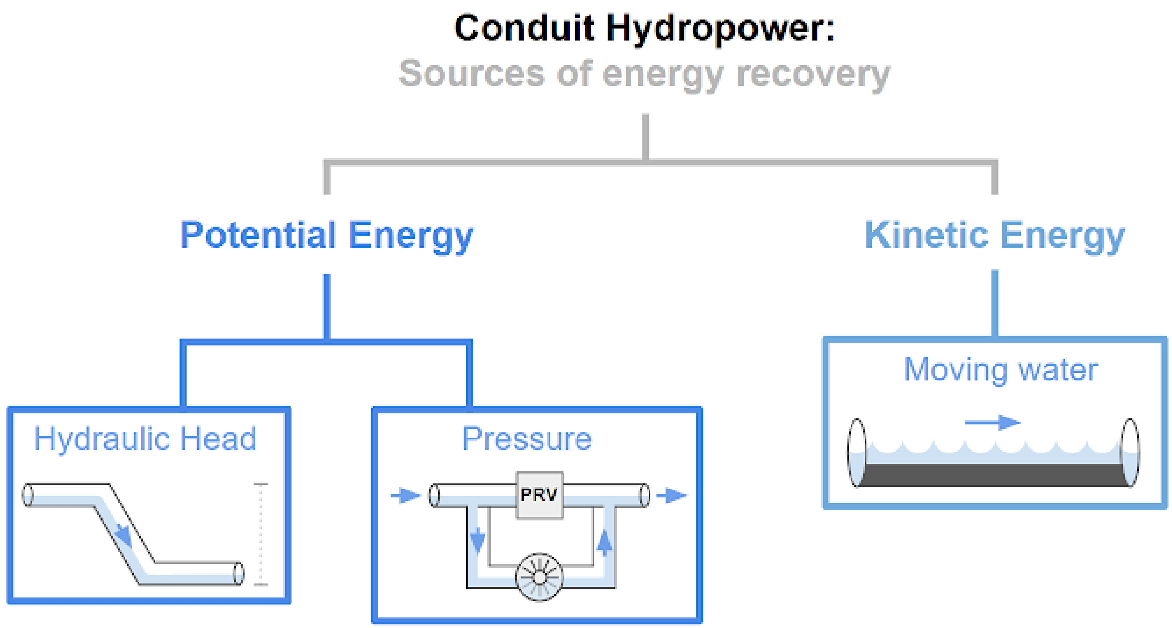


Figure 3. Sources of energy recover in water management infrastructure which can be harnessed by CH technologies (*Source:* Sebastian Grimm).

2.1.2 Technology

Technology choice is a function of the energy source, water type, and general site characteristics such as flow, head, and tailrace layout (CEC, 2020a; DOE, 2015). Selecting efficient and effective turbines for a CH project decides its capacity for dependable electricity production, with different technologies offering a variety of important tradeoffs to consider. Conventional CH turbine technologies are largely proven, while newer systems hold an incredibly enhanced yet less matured potential for power production. Although new modular systems can provide major cost savings, their short timeline of on-site usage so far poses a challenge for CH developers.

2.1.2.1 Conventional turbines

Conventional turbine technologies can work to recover potential energy from hydraulic head and pressure in conduits, generally categorized according to their reaction or impulse based operating principles. Reaction turbines are submerged in a water flow to harness the combined force of pressure and water motion which produces a hydrodynamic force that rotates their runner blades forward (CEC, 2020a; DOE, 2015). These turbines are most effective in sites with low head and high flow, often being installed in canals, dam spillways, pipelines, irrigation channels, and aqueducts (CEC, 2020a). Common reaction turbine types include Francis, Kaplan, Bulb, and Pump-as-Turbine (PaT). On the other hand, impulse turbines rely solely on the velocity of water movement to rotate runner blades, without any suction occurring on their down side. They are generally suitable for sites with high head and low flow, and have been mainly deployed in overflow pipes, irrigation ditches, aqueducts, and siphons (CEC, 2020a). Prominent impulse turbine types are Pelton, Turgo, and Crossflow.

PaT systems have demonstrated particular success in California, being used in six out of eight of their most studied CH projects (CEC, 2020a). In comparison to other conventional turbines, PaTs are especially attractive due to their capacity for application across a range of head and flow conditions (Agarwal, 2012). As well, their standard pump motor can be used as a generator, allowing for a compact design. PaTs have worked to successfully replace PRVs in water distribution infrastructure at a low-cost and with improved energy-efficiency (Lima et al., 2017; Agarwal, 2012). However, the application of PaTs are limited by their sensitivity in performance to water flow variation, being most suitable for systems where flow rate remains stable (CEC, 2020a; Lima et al., 2017).

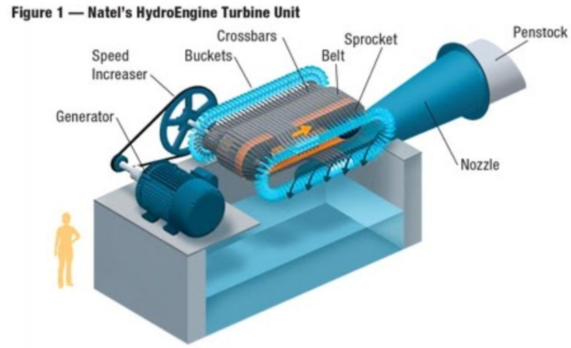

Source: World Pumps, 2013

2.1.2.2 Emerging turbines

Emerging turbine technologies have rapidly expanded over the last decade, working to surpass conventional turbines through often increased efficiency and lower costs. As well, many systems have been specifically designed for application to water conduit infrastructure. They offer an opportunity to both enhance and expand CH energy recovery, as well as contribute to the proliferation of performance-based information about the potential of these novel and innovative turbines, helping to increase confidence in their usage.

Emerging technologies include turbines which are able to capture kinetic as well as potential energy. They bring three main advancements to the table. First, newer turbines have a modular construction, defined as a "water-to-wire" technology which integrates the turbine and powerhouse in one system (CEC, 2020a; Hegde, 2019). Powerhouse construction alone can account for 40 to 70% of the initial costs related to construction of civil works and structures. These constructions constitute 40 to 55% of the total project cost, meaning that the powerhouse alone can make up for about 16 to 38% of the entire cost (Zhang et al. 2012). This up-front investment is avoided through modular turbine systems, being a necessity for cost-effective CH development. The second advancement of emerging turbines is that their generators have much lower power requirements. Lastly, their designs allow for easy scalability to specific infrastructural characteristics and power needs, also providing for generally shorter installation periods than conventional systems (CEC, 2020a).

Several prominent categories of these new energy recovery systems include the Water Wheel, Axial-type Propellor, Archimedean Screw, Inline, Micro, and Siphon turbine technologies (CEC, 2020a). As well, various leading hydroelectric engineering companies have developed specific systems which build upon these newer turbine types and hybridize their design with more conventional technologies. One example is the HydroEngine®, developed by Natel Energy. This turbine has been installed in two projects so far. The first was for the Monroe Hydro Project in Madras, Oregon, where it has been to produce approximately 1,000 MWh annually from an irrigation canal drop since 2015 (Natel Energy, 2015). The second installation took place in a mill renovation project in Freedom, Maine, working to generate around 60 MWh per year (Natel Energy, 2016).



Source: Natel Energy, 2017

Another fascinating example of a new system that harnesses energy potential, is the LucidPipe™ by LucidEnergy. The technology is an in-line type turbine designed for installation in a variety of pipeline systems across a spectrum of pressures, flows, and pipe diameters. It has been tested and certified by the National Science Foundation (NSF) International and American National Standard Institute (ANSI) Standard 61 for application in potable water, agricultural, industrial, and wastewater systems (LucidEnergy, 2015a). Current installations exist in California and Oregon, both proving to be cost-effective sources for hydropower energy recovery. In Portland, Oregon, four LucidPipe™ turbines have been installed upstream from a PRV in a public water distribution pipeline, together working to generate around 900 MWh per year. This generation provides enough energy for export to the grid, working to power approximately 100 homes in the city (LucidEnergy, 2015b).

Source: Lucid Energy, 2019

Aside from capturing potential energy, emerging turbine systems are able to harness kinetic energy from moving water in conduits without a practical hydraulic head. These technologies are classified as hydrokinetic turbines, and are designed to mimic wind turbines based on either axial-flow or cross-flow structures (CEC, 2020a). Axial-flow turbines are set up parallel to the water current, while cross-flow turbines are perpendicular. Hydrokinetic turbines are appealing due to their low-impact and modular design, which allows for multiple turbines to be installed in a variety of configurations to

Source: Emrgy, 2018

generate maximum power. Some of these systems can also be stacked vertically to capture greater cross-sectional flows (CEC, 2020a). Although hydrokinetic energy is mainly being developed for tidal and wave driven power production (such as NYC's RITE project), application for CH systems is an important opportunity to further investigate. One example of a popular hydrokinetic turbine system is the EmrgyFlume™ by Emrgy, being made up of a portable frame which provides stability without requiring permanent anchoring or other infrastructural changes (Emrgy, 2020). Based on a pilot study conducted in Colorado, 10 turbines continuously operating on a canal were able to generate about 800 MWh annually (Chesney, 2017).

2.1.2.3 Turbine tradeoffs

In comparison, although newer turbines offer a look into what will be an exciting future for CH, their development has been slow with information on their performance and usage just beginning to become sufficiently dependable. Conventional turbines with application to water conduit infrastructure have a much longer history of proven success, are highly durable, and are supported by abundant information (CEC, 2020a). However, these older systems hold three major downsides, being that (1) they generally require expensive powerhouse construction, (2) can be less energy and cost efficient, and (3) can require a large energy input when a more robust generator is required (CEC, 2020a). Emerging technologies have been able to often circumvent these shortcomings, yet can also be especially risky to pursue for small developers. Some technologies are still in the prototype phase, and those that are ready for implementation have only been operating for the past 10 years. Immaturity has led to a lack of long term information particularly involving their effectiveness, durability, and life-cycle costs (CEC, 2020a). CH projects which are supported by reliable funding sources and led by larger developers along with government agencies should take the lead in advancing experience with and knowledge about emerging turbines. This leadership may bolster the work of less robust CH projects by developing a network of useful and dependable expertise.

At the same time, although newer technologies offer innovative approaches to CH generation, they are not always the most cost-effective choice. Equipment cost comparison is complicated due to a wide variety of sites and turbines. Yet, even if construction and installation costs are cheaper for modular systems, their hydromechanical and electric operating costs can be more expensive than conventional turbines (CEC, 2020a; Ak et al., 2017). For example, research has estimated that for wastewater discharge sites the Archimedean Screw turbine poses a greater hydromechanical and electrical cost than Kaplan turbines (Ak et al., 2017). Yet, the Archimedean Screw turbine has a lower installation cost than the Kaplan as it doesn't require a separated powerhouse construction and offers a cheaper intake structure. Ultimately, between conventional and emerging turbine technologies, selection depends heavily on (1) funding availability, (2) site characteristics, (3) energy source and (4) electricity generation needs.

2.2 Developmental Insight

2.2.1 Feasibility analysis

Before beginning construction of a CH project, analysis of feasibility across a variety of important political, legal, economic, technical, and social dimensions must be completed. This assessment undergoes similar processes to those which all new hydropower projects must follow. However, the main differences are that CH is exempted from licensing requirements on the federal level, and generally excludes substantial environmental impact studies to shift emphasis on protecting the functionality of the water supply infrastructure which it is being integrated with (FERC, 2013; DOE, 2015).

2.2.1.1 Stakeholder inclusion

Development of CH projects depends on the cooperation of multiple actors. These stakeholders all pose different interests and concerns which are relevant to the operation of pre-existing water supply infrastructure and the integration of CH (CEC, 2020a). Hence, outreach to and coordination with relevant interest groups is an essential prerequisite to evaluation of feasibility. As well, continuous communication throughout all stages of a project must be maintained. Even if the project ends up being impractical, cultivating trust and transparency across public, private, and government parties is a key aspect of any successful sustainable development project, particularly in the energy sector (Herington et al., 2017; Mansuri & Rao, 2013; Putnam, 1994). Over the long term, the failure of collaborative projects such as this effort for energy recovery is often a result of insufficient stakeholder inclusion. Important parties include state environmental sustainability agencies, electric utilities, irrigation district authorities, wholesale and water retail agencies, the public utility commission, landowners, and local communities more generally depending on the given project (CEC, 2020a). Communication strategies to engage with some of the most influential groups across these various stakeholders are detailed in the following section.

Government agencies
On the federal level, an licensing exemption must be obtained from the FERC. This can be accomplished by providing a short form Notice of Intent. On the state level, local environmental regulatory agencies will be the main authorities who decide whether or not a project can take place. Further detail regarding cooperation with state agencies in NY is explained in section *2.2.1.5.*

Electric providers and utilities
Collaboration with electric providers and utilities should aim to (1) predict possible issues that CH may add to operation of the involved water facility and local grid; (2) develop relationships with electric utility account representatives as they are vital to advancing approval processes before funding deadlines or other time sensitivities; and (3) seek assistance from the electric

utility's analyst in order to confirm the cost-benefit analysis done by the given hydropower developer, as well as share input on the system's efficiency to decrease costs (CEC, 2020a).

Utility board

The decision-making of utility board members has a substantial influence on the implementation of CH projects, making their cooperation essential to successful development. Difficulty with gaining the approval of board members can arise due to often high initial capital costs (CEC, 2020a). One important insight toward attending to this financial disincentive is to evaluate project costs in contrast to the costs of maintaining existing PRVs and FCVs in the given water infrastructure, working to determine whether or not a CH system would provide savings over the long term. This kind of comparative analysis works to provide the empirical framing necessary to highlight the potential financial efficiency that CH can provide (CEC, 2020a).

Wholesale and retail water agencies

Partnership with wholesale and retail water agencies who play a role in the water supply of a given project is a vital relationship to cultivate for CH development. Wholesale agencies often have a large reserve account, staff, and overall capacity to work as a leading agency for project development, providing administrative support to smaller and less resourceful retail agencies (CEC, 2020a). As well, seeking shared learning from other utilities and agencies involved in the development of similar projects is a useful opportunity to ask questions and gain knowledge. The more knowledgeable a water utility is about the details of CH systems (especially those that are already in operation), the better able they are to effectively communicate with the public (CEC, 2020a).

Landowners

If a project will occupy land owned by a private or government party, it is not only necessary to engage with landowners in order to obtain certain permits, but also in order to develop a cooperative relationship (RAPID, 2019; RAPID, 2016). Especially in a situation where the project or connected utility lines are on private land, gaining property rights from the owner may be a difficult task unless they feel a sense of respect and trust from those involved in its development, let alone willingness to sell or lease property rights. In this case, it will only help the potential for private landowner cooperation if they are consulted with before other steps of development take place. For land owned by the state or federal government, although CH is exempt from BR and FERC licensing, a right-of-way lease must still be obtained through the relevant land management agency (RAPID, 2019; RAPID, 2016).

Local community

Although community outreach is often overlooked due to being perceived as an unnecessary component of CH development, particularly if energy will be exported to the grid for public use it is worth establishing clear and consistent communication with local residents. Providing useful information about what the CH project entails, its energy generation potential, and possible co-benefits involving pollution mitigation, cost savings, and support for funding infrastructural advancements (such as improving wastewater treatment technologies) can help communities to accurately understand and get excited about how CH will benefit them. CH is fairly unknown to the general public, and putting a concerted effort into sharing knowledge with them is not only important to enhance public understanding, but also to potentially inspire social movement surrounding advocacy for a CH driven energy recovery strategy.

2.2.1.2 Site evaluation

There are a variety of water distribution infrastructure components which offer energy-harvesting potential. These areas generally include, PRVs, FCVs, elevation drops, and places where kinetic energy can be harnessed from moving water. As well, site characteristics such as yearly flow availability, usable space, grid proximity, trailrace layout, and downstream pressure requirements are essential to determine whether these spots are feasible locations for integration with one or more CH turbines. Several examples of infrastructure where CH can be installed include (Fig. 4):

- Dam releases into bulk supply
- PRVs installed in inlets to service and distribution reservoirs
- Flow control facilities
- Water distribution pipelines
- Run-of-river site where water storage is minimal
- Wastewater treatment plant outfalls
- Irrigations systems: specifically being at diversion structures, weir walls, chutes, check structures, and along the length of canals
- Groundwater recharge pipelines

Sources: CEC, 2020a; MWA, 2016; Loots et al., 2015.

2.2.1.3 Energy estimation

Understanding the potential for energy generation from a given site is essential to the feasibility of a CH project. In general, CH must be able to provide enough electricity to make up the energy which would have been purchased from the grid to offset the costs of its construction in the short term along with maintenance and operation in the long term. Hence, energy capacity must be coupled with the necessary project costs to determine viability. As well, information about power production can be an important incentive for building relationships with involved stakeholders and demonstrating the project's value.

Predicting electricity production depends on whether the CH system will be harnessing power based on potential energy through hydraulic head and pressure or kinetic energy through moving water. Although the potential for conduit hydrokinetic energy systems is high, few resource assessments have been conducted involving water conveyance infrastructure with most information being related to ocean and river projects (CEC, 2020a). For projects which capture potential energy, information regarding changes in elevation, flow, along with upstream and downstream pressure must be obtained to model energy potential (CEC, 2020a). Manual measurements are ideal for calculating accurate estimations, however preliminary assessment can be achieved by using preexisting historic hydrological data, if available. The longer term this information has been collected, the more useful it can be toward predicting current characteristics as flows and pressure often pose high seasonal variation and can change according to water demand by end-users (CEC, 2020a). This variability results in system losses, which must be factored into energy calculations. Several resources which are worth examining include USGS topographical maps, BR monitoring information, GIS data, barometric altimeter data, state level data sharing websites (for example, NY has an OpenData page), and Google Earth (CEC, 2020a; Johnson & Hadjerioua, 2015). To ensure the most correct estimation, historic data should be compared to direct measurements to assess current viability and to project future changes in water supply.

Once necessary data has been collected, cost predictions can be calculated. Although this can be manually determined, several useful tools for computing energy production estimates, project costs, along with selecting appropriate technologies include:

- *In-Conduit Hydropower Business Case Assessment Tool*: provides assessment of the CH potential at specific sites, recommends suitable CH technologies, estimates preliminary life-cycle capital and operations and maintenance costs, and determines potential greenhouse gas emissions. The most recent and comprehensive tool for CH feasibility assessment.

- *Alden Screening Tool:* evaluates pressurized pipeline opportunities in water supply and wastewater treatment facilities, with a focus on infrastructure maintained by municipalities or districts.

- *RETScreen*: works to predict the energy production and savings, costs, emission reductions, financial viability and risk for central-grid, isolated-grid and off-grid hydro power projects in general.

- *HydroHelp:* focused on turbine selection, starting with the least-cost option. Not specified to conduit hydropower projects.

Sources: CEC, 2020a; DOE, 2015.

In general, sites with high head are more attractive as smaller CH systems can be installed, hence presenting less cost barriers (CEC, 2020a; Uhunmwangho & Okedu, 2009). Sites with smaller head are more common, and can still be feasible up to a minimum of 5 ft (Pulskamp, 2012). Yet, emerging technologies are pushing this boundary as Archimedean Screw turbines have been demonstrated to allow for viable energy generation with a head as small as 3.3 ft (CEC, 2020a). Based on surveys of 142 CH sites in California from 2010 to 2018, on average canal drops have been shown to offer lower head and greater flow than other infrastructure, compared to water treatment plants which hold the largest head but lower flow (CEC, 2020a).

2.2.1.4 Technology selection

Based on (1) head and friction losses, (2) flow availability and stability, and (3) downstream pressure needs, a suitable CH turbine can be selected. Reaction turbines work best for smaller head, while impulse are most appropriate for medium to high head sites (CEC, 2020a). However, some newer impulse turbine technologies can function in smaller head environments and across a wide range of flow rates (CEC, 2020a).

If the turbine chosen is a conventional system, a generator must also be selected. The two most common generators used for small-scale hydropower are synchronous and induction generators, although direct current (DC) generators can also be applicable (CEC, 2020a). Synchronous generators don’t require a supply of reactive power from the grid, making them better for more isolated mini-grids, and offering a high full-load efficiency. Induction generators pose a simple grid interconnection process, are more durable, and less expensive. Lastly, DC generators offer the most straightforward technology when the CH system is unable to produce enough energy for peak load as they allow for battery storage. For grid interconnection they rely on a grid-tie inverter which is vital to be chosen appropriately, as a mismatch can cause degradation.

2.2.1.5 Regulatory considerations

Aside from CH holding a strong federal advantage due to being exempt from FERC licensing, attending to state level regulatory requirements and opportunities are essential to the success of a new project. In NY, the State Environmental Quality Review Act (SEQR) which regulates new development is superseded by the federal level HREA and AWIA, allowing CH projects to theoretically avoid an environmental assessment (EA) or environmental impact statement (EIS) which are necessary for conventional hydropower and other energy expansion. Yet, NY State environmental agencies (DEP, DEC, EPA) still hold the final authority regarding whether or not a CH project can undergo development or if the SEQR is applicable and additional activities such as a EA, EIS, 401 or 402 permit, and water-rights are required (Fig. 5). Regardless of the federal advantage CH holds, these agencies remain a somewhat unpredictable filter which must be passed through to achieve full approval (Swindle, 2020). State level decision-making surrounding the allowance of a CH project is not explicitly prescribed, and seems to depend more on the opinions of and relationships with government authorities. Along with government authority, NY provides opportunities for NGOs to voice their opinions through the SEQR, Public Service Law, and the DEC. Transparent and informative communication about the highly beneficial prospects of CH with these parties is vital to encouraging their approval and understanding, as discussed in section 2.2.1.1.

Additionally, Article 10 of NY’s Public Service Law which applies to projects with a capacity of over 25 MW is currently being replaced through the Accelerated Renewable Energy Growth and

Community Benefit Act (AREGCBA) (Young/Sommer LLC, 2020). Specifically, the new Section 94-c titled “Major Renewable Energy Development” introduces a new review process and uniform permit standards for siting, design, construction, and operation of each type of major renewable energy facility (Young/Sommer LLC, 2020). Further, where site-specific environmental impacts cannot be addressed by these standards, the newly-established Office of Renewable Energy Siting (ORES) will draft site-specific conditions to evaluate environmental impacts. In the case where these conditions are insufficient, ORES will determine off-site mitigation measures to be conducted (Young/Sommer LLC, 2020). However, the majority of active CH systems have a capacity of below 1 MW, suggesting that the application of this new process may only be applicable in rare situations (CEC, 2020a; Swindle, 2020)

As well, there are four specific exceptions to the federal licensing exemption for CH which may require further regulatory processing. First, the FERC can still require an EA if the proposed project is recognized to be an environmental threat, which could be a possibility for installation in irrigation canals as the proximate aquatic ecosystem can be more sensitive to construction and land-use changes (Gibson, 2020; Swindle, 2020). Second, If the CH project aims to take place on land owned by the U.S. Bureau of Land Management (BLM) or U.S. Forest Service (FS), an EA will likely be required (Sorenson, 2020). Third, for projects which influence navigable waters of the U.S. or U.S. Army Corps of Engineers (ACE) infrastructure, authorization by the ACE may be needed (CEC, 2020a). Lastly, non-federal projects being installed on BR infrastructure will need a BR lease of Power Privilege (CEC, 2020a).

Although environmental review processes are usually not necessary, in NY a right-of-way agreement is still required either from a privately or government owned area of land (Fig. 5). As well, if the proposed project will be located in, on, or above state owned underwater lands, an easement from the NY State Office of General Services (NYSOGS) is also necessary (Fig. 5) (RAPID, 2019). This NYSOGS description is somewhat vague, but shouldn’t apply to most CH projects as they take place in pre-existing infrastructure, which is likely not underwater.

Being a low-impact hydropower source, CH may also be eligible for NY’s Renewable Energy Standard (RES), which requires any load-serving entity to obtain Tier 1 renewable energy credits (RECs) associated with new renewable energy resources. RECs can be sold, traded, and verified through the NY Generation Attribute Tracking System (NYGATS) (NYSERDA, 2020c). Cooperation with the RES is a requirement for CH systems, but also can provide a source of revenue through the NYGATS REC market. However, CH is not explicitly mentioned in the RES, making it unclear as to whether or not the technology would currently be able to participate in the REC market.

If electric transmission line construction is necessary, a Certificate of Environmental Compatibility and Public Need from the New York State Public Service Commission (NYSPSC) that is at least 125 kV and one mile long, or with a capacity between 100 kV and 125 kV that a minimum of 10 miles long (Fig. 5) (RAPID, 2018).

Lastly, if the site where a proposed CH project is taking place is designated as a historic location and influences its contributing features, the National Historic Preservation act will be triggered. In this case, mitigation measures will be necessary to allow development, being specific to the given site (Fig. 5) (Gibson, 2020).

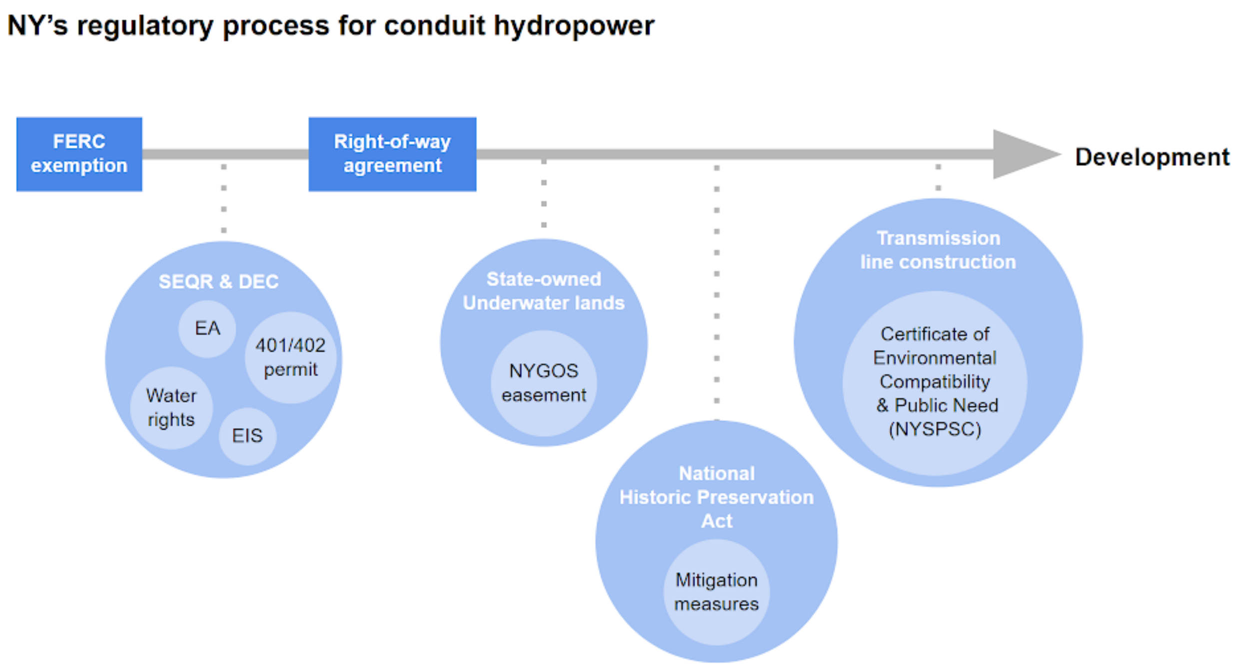


Figure 5. NY's regulatory process for developing CH consists of two direct procedures to attend to being the (1) FERC exemption and (2) right-of-way agreement. In addition, there are four indirect regulatory filters which a CH project may experience, including (1) attendance to SEQR requirements through the DEC, (2) a NYGOS easement if construction will take place on state-owned underwater lands, (3) triggering of the National Historic Preservation Act if a the site is historically designated, and (4) a certificate for transmission line construction through the NYSPSC if necessary (*Source:* Sebastian Grimm).

2.2.1.6 Grid interconnection process

Aside from CH providing a source of on-site energy, the system can also be connected with the local grid. Although interconnection is not necessary for CH to function, it can allow for several added benefits by providing (1) the ability to draw power from the grid when on-site generation is insufficient to meet demand, (2) the electricity necessary to start up induction generators, and (3) the option to sell excess energy to the grid through a Power Purchase Agreement with the electric utility, creating a new revenue stream for the given facility (CEC, 2020a).

As well, NY in particular offers three forms of net metering (NM), including virtual, aggregate, and remote NM, the third of which NY is the only state to allow (Liu, 2019). All three forms allow for energy to be shared, energy credits gained, and costs reduced, however a different type of

NM may be most applicable for a certain CH system and site. For example, if a water treatment facility utilizes several meters, aggregate NM may be most useful. Yet, in general remote net metering is a beneficial opportunity for CH projects to take advantage of, as it is specifically set up for farms and non-residential customers to gain credit through excess energy production (NYSERDA, 2020d)

However, the process to obtain an interconnection agreement often poses an extraordinary obstacle to CH development. Logistically, it can be challenging to maintain frequency and voltage regulation as well as coordinate the operation of protective relays and reclosers (CEC, 2020a). In addition, interconnection costs can be difficult to estimate. For example, a project being developed by the hydropower developer Sorenson Engineering Incorporated that the Public Utilities Commission (PUC) originally quoted to cost $140,000 doubled to become $300,000 when the final bill was received (Sorenson, 2020). Especially if the project is small (producing less than 500kW), interconnection costs can be such a burden that the project becomes financially unfeasible (Sorenson, 2020). Overall, a lack of transparency in the interconnection process and even reluctance from the utility's perspective stands out as a common issue (Elliot). Small developers may face the most challenges during the interconnection process as it is time consuming, costly, and complex (CEC, 2020a). As well, PUCs face heavy lobbying by utilities to artificially lower the avoided cost of power. This effort has not only decreased the price of hydropower-derived electricity, but also substantially lowered the prices of solar and natural gas which creates a difficult environment for competition across energy resources (Sorenson, 2020).

2.2.1.7 Financial viability assessment

Initial capital investment is generally the main driver of CH feasibility, with high up-front costs often representing a major barrier to development. Total initial CH system costs are based on (1) civil, electrical, and mechanical components, (2) regulatory and permitting processes, and (3) available funding sources (CEC, 2020a). Since powerhouse construction can account for over half of the civil works costs, using a newer turbine system can provide substantial savings for initial costs as long as the technology is a practical option for energy production in the given site. During the operation and maintenance (O&M) of an CH system, costs are based on loans, land leases, maintenance and interim replacement insurance, personnel and labor, taxes and duties, general operation administration, transmission line maintenance, FERC, and contingencies (CEC, 2020a).

CH energy production costs depend heavily on capacity, as the cost per kW of a CH system has been demonstrated to decrease as power capacity increases. For example, based on an analysis of 142 sites in California, systems with less capacity than 100 kW average at $28,000 per kW, those from 100 to 1,000 kW cost an average of $9,000 per kW, and from 1,000 to 5,000 kW average out at $3,500 per kW (CEC, 2020a). Although larger projects are more affordable, there are several funding opportunities on the federal and state levels which can offset costs across systems of varied power capacity.

Federal grants

The section 242 program of EPACT stands out as the major funding resource for hydropower development. Although the program offers up to $750,000 in grants per facility, its good intentions are fragmented by a narrow and unpredictable review process. Because new funding must be applied for each year and the grant application undergoes annual changes, hydropower developers are unable to rely on this potential funding during the planning and cost-analysis process (Elliot, 2020). As well, although there is $7 million available for 2020, the funds authorized per year are reduced depending on the amount of total kWh which all applicants offer, resulting in annual appropriations (Swindle, 2020). For larger scale and continuous development, the program has been a helpful source of financial support. However, for small scale projects this program is difficult to depend on as its impact can be unpredictable and application acceptance narrow (Elliot, 2020). It's certainly worth applying for this funding when developing CH systems, however ought to be coupled with other financial resources.

Another more reliable option is the BOR's WaterSMART grant program, which provides 50/50 cost share funding to irrigation and water districts, tribes, states and other entities with water or power delivery authority (BOR, 2020).

For CH projects involving agricultural waterways, the U.S. Department of Agriculture's (USDA) Rural Energy for America Program (REAP) provides grants and loans to agricultural producers and small businesses in eligible rural areas (USDA, 2020). As long as the CH system will produce under 30 MW, it is eligible for this funding. Grants for renewable energy systems range from $2,500 to $500,000, and are offered for up to 25% of total project costs. As well, loans are available for $5,000 to $25 million, guaranteed for up to 75% of total project costs (USDA, 2020).

New York grants

On the state level, there are several broader programs which may aid the development of CH systems across NY. Organized by the NY Environmental Facilities Corporation (EFC), the Water Infrastructure Improvement Act (WIIA) of 2017 works to provide at least $1 billion toward water quality infrastructure projects across the state. The EFC is offering $350 million in grants to assist municipalities for the enhancement of water quality and public health, applicable for both drinking and waste water projects. Although CH does not explicitly improve water quality and is not mentioned in this act, its potential to allow for dramatic energy cost savings and even revenue when installed in a public water supply facility can encourage not only improved energy efficiency, but may make funding that would have been spent on electricity available for treatment upgrades. According to the EFC, CH development would be eligible for the funding as the program is fairly flexible, however would not be a priority if presented alone. Instead, coupling an CH project in a public water supply facility with plans to utilize cost savings for treatment upgrades over the long term would make it a much more appealing funding recipient . By framing CH as not only an energy efficiency advancement but also a cost-effective strategy for water quality and public health improvement, there is a chance to gain funding through the

WIIA. Hence, for municipalities in NY looking to incorporate CH into their public water supply facilities, it's certainly worth applying for a grant through this program.

For canals specifically, the Canal Corporation (CC) of NY offers the Canalway Grant Program (CGP). In 2019, this opportunity included up to $1 million in competitive grants available to eligible municipalities, and 501(c)(3) non-profit organizations to support canal related capital projects (CC, 2019). The minimum grant request amount was $25,000, while the maximum was $150,000. However, the last funding round for the CGP was oriented toward tourism, recreation, and recreation focused development (CC, 2019). CH projects may not have much of a chance to gain funding through this opportunity, however if the development fits this program's requirements it may still be a worthwhile resource to apply for. Since the next round of funding has not yet been advanced, there may also be an opportunity to advocate for expansion of the program to include CH projects.

In 2016, the NY Public Service Commission adopted the Clean Energy Standard (CES) program to help support the state's goal of 100% renewable energy by 2040 (NYSERDA, 2020a). Through the CES, the NY State Energy Research and Development Authority (NYSERDA) introduced the AREGCBA under the 2020 to 2021 enacted state budget (NYSERDA, 2020b). The AREGCBA is based on three major components, being the establishment of (1) the Office of Renewable Energy Siting (ORES), (2) the Clean Energy Resources Development and Incentives "Build-Ready" Program, and (3) the State Power Grid Study and Program (SPGSP) (NYSERDA, 2020b). Although CH development will likely be organized through the ORES and considered under the SPGSP to some extent, the aspect of this legislation which is most relevant to CH may be the "Build-Ready" program. The goal of this plan is to rapidly advance underutilized sites where renewable energy resources can be expanded, working to leverage existing infrastructure to provide benefits for host communities and protect environmental justice areas (NYSERDA, 2020b). NYSERDA aims to acquire interests in land, evaluate siting feasibility, and apply to the ORES or given locality for permits to develop renewable energy. The authority then will competitively auction the developed sites which include contracts for renewable energy payments. Their intention is to provide a risk-free package which is ready for private developers to quickly construct and operate projects at these sites (NYSERDA, 2020b).

Although this program appears to fit well with CH, NYSERDA representatives state that "Build-Ready" qualifying facilities only include those on the transmission scale which directly connect to the NY Independent System Operator (NYISO), and is not flexible to support the development of smaller distribution level systems like CH. The program's goals to leverage existing infrastructure and support environmental justice goals match well with the potential of CH, making it an unfortunately missed opportunity. For example, if a CH system is installed in a pre-existent wastewater treatment facility in a community where environmental justice issues are prevalent, local energy access and water quality may be improved and pollution mitigated. Even though CH energy production in NY will likely not be on the larger utility scale, It may be worth expanding the “Build-Ready” program’s scope to include this technology as it otherwise attends to the program’s guidelines.

Alternative funding

Aside from grant programs, funding support can be obtained through income tax credits. Through the Internal Revenue Service (IRS) production tax credits (PTCs) can make up for 30% of project costs in the first year of commissioning, being provided for through 1.5 cents per kWh payments during the taxable year (Cornell, 2020). Over the long term, PTCs per kWh can be obtained for a 10-year period beginning on the date the facility was originally placed in service. This cost off-set resource has provided major savings for hydropower developers, allowing for a straightforward and reliable source of funding (Elliot, 2020). Although tax credit based savings are more substantial for systems with larger energy capacities, this source of funding is certainly worth attending to regardless of the scale of energy production.

The main issue with PTCs is that they are only eligible for taxable entities, which excludes municipalities who may be interested in CH but lack sufficient funding. This specification provokes a need to develop public to private partnerships (PPPs), which can work to maximize savings as both actors are able to gain different forms of funding and pool collective resources (Matt).

In addition to tax credit savings, a local property tax exclusion can be pursued. In NY, properties owned by state and local public authorities are usually exempt, often including general waterways (specifically pipelines and aqueducts), certain farm infrastructure, and water supply or disposal systems (NYSDTF, 2020a). As well, public and privately owned micro-hydroelectric facilities are eligible for property tax exemption for 15 years to the extent of any increase in assessed value due to the system, following approval by NYSERDA and subjection to the local option to disallow an exemption by a county, city, town, village or school district (NYSDTF, 2020b). As well, a micro-hydroelectric facility which owned by a NY State agency or department which has agreed with the energy system owner or operator to purchase the produced energy or the environmental credits or attributes created by the system’s operation is permanently exempt from taxation, special ad valorem levies and special assessments, but is also subject to local option (NYSDTF, 2020b).

3. Understanding conduit hydropower potential for New York

3.1 Current development

Although NY depends on hydropower more than other renewable energy sources, there hasn’t been new development across any form of hydropower in the state since the early 21st century. Specifically, there have been no CH exemptions filed to FERC since the HREA took place in

2013. The last CH exemption was filed was in 2010, being a re-application to maintain exemption status. However, limited research has been conducted on CH potential in addition to several pilot projects being underway as of 2019.

3.1.1 Potential for expansion

CH is applicable to a variety of actors in NY who rely on water distribution infrastructure across industrial, agricultural, and municipal sectors. In 2015, the largest water demand for the state in terms of withdrawals per day was thermoelectric power which made up for 71% of total usage, followed by public supply being 22% (Fig. 5). Industrial and domestic sectors also use a fair amount of water each day, but are dwarfed by thermoelectric and public supply users.

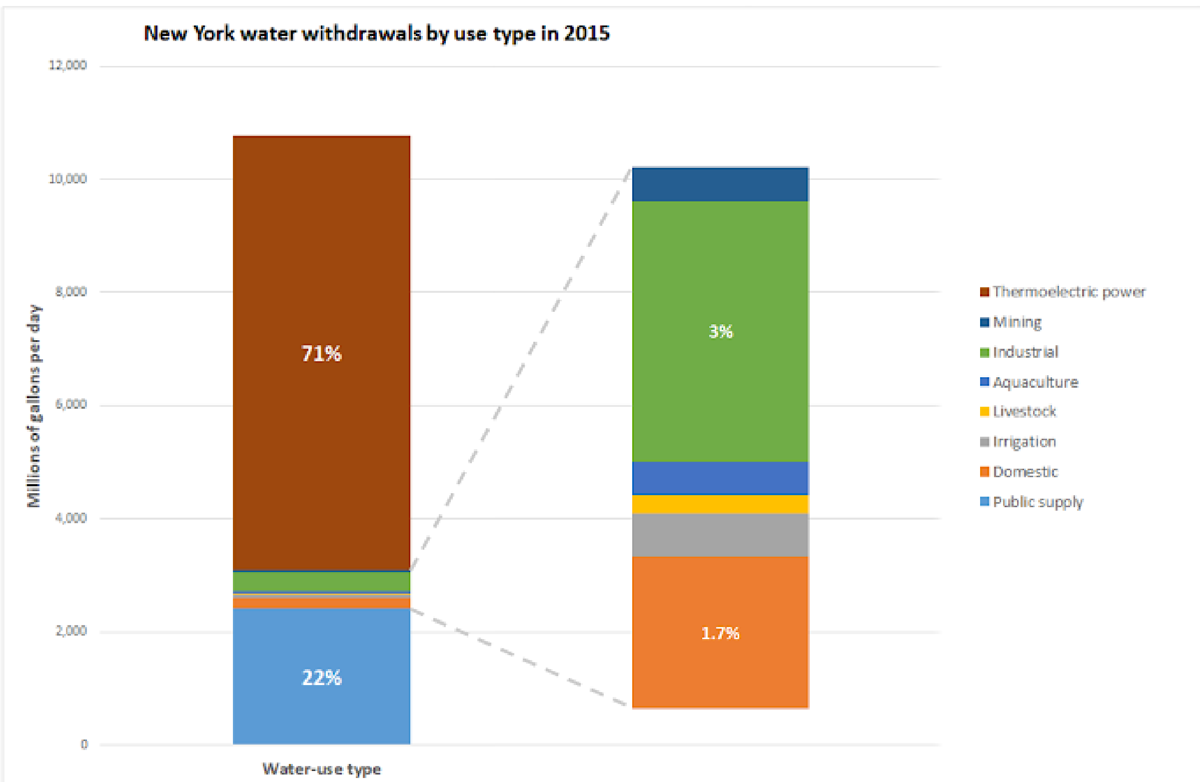


Figure 6. Water withdrawals in NY from 2015 organized by water-use type. Thermoelectric power poses the greatest demand by far, followed by public supply (*Data from:* Dieter et al., 2018).

Although there is no public record of CH being used in the U.S. thermoelectric industry, its integration with public water supplies has been substantial. Since NY transports and processes an immense amount of water every day to provide for public uses of drinking and waste water, the first step toward developing CH driven energy recovery should be to focus on this sector.

NY's most extensive public water supply system takes place in NYC. Over one billion gallons of water are provided to more than nine million residents each day, delivered from the Croton and Catskill-Delaware watersheds in upstate which extend about 125 miles from the city and encompass 19 reservoirs and three controlled lakes. Massive water distribution infrastructure is necessary to maintain this system, consisting of around 7,000 miles of water mains, tunnels, and aqueducts to deliver drinking water. Specifically, these conduits are organized into three main structures, being (1) the New Croton Aqueduct, (2) the Catskill Aqueduct, and (3) the Delaware Aqueduct. As well, 7,500 miles of sewer lines and 96 pump stations convey wastewater to 14 treatment plants throughout the city (Fig. 6).

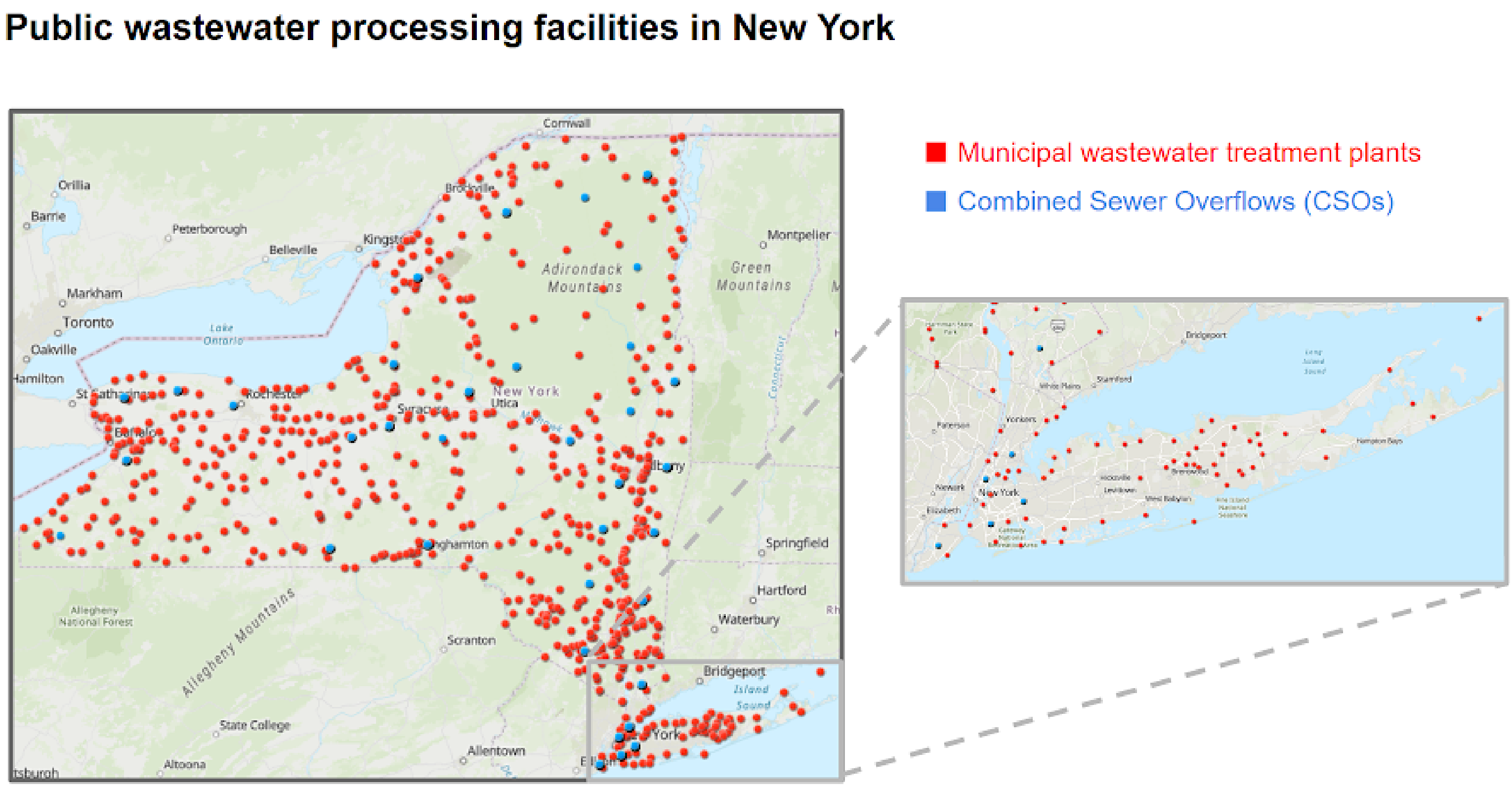


Figure 7. Public wastewater processing facilities in NY, including municipal wastewater treatment plants (red) and CSOs (yellow) (*Data from:* NYSDEC).

Along with NYC, there are over 600 municipal wastewater treatment plants spread across the state (Fig. 6) (NYSDEC, 2019a). Additionally, there are over 900 combined sewer overflows (CSOs) in NY, which discharge a mixture of stormwater and sewage when rainfall overwhelms sewage pipelines. Although they may not offer much energy generation potential individually, they can collectively allow for substantial power along with cost savings and GHG mitigation. As well, pursuing research in specific municipalities may be an important pathway to enhance access to renewable energy and encourage improvement to water treatment systems as many are in need of upgrades but lack the necessary funding.

Looking beyond public water supplies, there are around 1,500 different industries including breweries, chemical manufacturing plants, and food processing facilities which are allowed to release and in some cases pretreat their wastewater under the NY State Pollutant Discharge Elimination System (NYSPDES) (NYSDEC, 2019b). There exists no policies oriented toward encouraging these businesses to pursue CH energy recovery toward efficiency, cost savings, and pollution mitigation where possible, but is certainly an important regulatory pursuit for the state. Providing funding, expertise, and overall assistance for private actors who are interested in CH should be supported to do so, as their efforts for energy sustainability are inextricably linked to those of NY.

The state also has extensive transportation and agricultural canals, both with a potentially untapped opportunity for CH integration. There are seven major transportation canals throughout the state, detailed below:

- *Cayuga–Seneca Canal:* 20 miles
- *Champlain Canal:* 60 miles
- *Erie Canal:* 363 miles
- *Gowanus Canal:* 1.8 miles
- *Harlem River Ship Canal:* 7 miles
- *Oswego Canal:* 23.7 miles
- *Shinnecock Canal:* 0.9 miles

Source: Wikipedia

Even though NY has about 500 miles of transportation canals, CH has not yet been utilized in this infrastructure as boat traffic and recreation may limit its utility. On the other hand, irrigation canals have been demonstrated to be successful sites for CH development (CEC, 2020a). There are over 100 different irrigation canals which provide water to 7,500 acres of cropland (CC, 2018). 20% of NY's land is devoted to farming, posing a substantial opportunity for CH development where applicable. By 2050, a 20% reduction in summer rainfall is expected for the state (CC, 2018). As climate change is driving water scarcity in NY, more energy will be required to pump and transport water to maintain the agricultural economy, food supply, and job security. Not only can CH integration with irrigation canals support the state's decarbonization goals, but may be a vital tool for farmers to enhance energy efficiency, save money, sustain their livelihoods, as well as support the food needs of the state and nation.

NY's drinking and waste water infrastructure along with that of the industrial and agricultural actors there have experienced little evaluation toward potential for CH development. However, especially given the current state of turbine technology integration, it's highly probable that opportunities exist for beneficial energy recovery both publicly and privately. The limited resource assessment that has been done so far works to highlight what potential exists across the state, along with demonstrating what further research should focus and expand on.

3.1.2 Resource assessment

A major part of this lacking CH activity is due to insufficient resource assessment of water infrastructure where the technology may be viable. The only CH assessment completed was through a 2013 study that focused on the NYC water supply system, being a collaborative effort between the NYCDEP, Gomez and Sullivan Engineers, HANDS-ON! Hydro, and O'Brien & Gere (NYCDEP, 2013). The study initially identified 36 sites, which was then narrowed down to 10 based on analysis of constructability, electrical demand, operability, and economic factors. Appropriate turbine technologies for these 10 locations were then considered, working to further narrow down the potential sites to focus on the top 6 (NYCDEP, 2013). These final 6 sites were then subjected to further economic analysis based on conceptual plans, opinions of probable construction costs, and several additional metrics such as net present value modeling. Lastly, these potential projects were examined based on their capacity to provide environmental through avoided GHG emissions and pollutant reductions (NYCDEP, 2013). As a result of these thorough analyses, the study recommended four sites be developed, with their specific findings shown in the table below (ranked in order of greatest economic feasibility):

Site	**Annual generation (MWh)**	**Total capacity (kW)**	**Capital cost ($2013)**	**Economic analysis**	***Recommendation***
West Branch Reservoir Shaft #10	33,500	3,840	$8,900,000	- $0.30 per kWh - 7 year payback - Benefit/cost (B/C) ratio of 1.02* - Internal rate of return (IRR) of 200%	Highly feasible
Kensico Reservoir Shaft #17	4,300	480	$2,865,000	- $0.70 per kWh - 16 year payback - B/C ratio of 0.59* - IRR of 17%	Feasible
New Croton Lake Gatehouse	7,600	1,000	$7,599,000	- $1 per kWh - 23 year payback - B/C ratio of 0.62 - IRR of 9%	Marginally feasible
Delaware-Catskill Aqueduct Interconnection at Shaft #4	11,600	1,600	$12,962,000	- $1.10 per kWh - 26 year payback - B/C ratio of 0.58* - IRR of 7.4%	Marginally feasible

Source: NYCDEP

According to these results, the West Branch Reservoir Shaft #10 shows the most promising potential, followed by the Kensico Reservoir Shaft #17 (NYCDEP, 2013). As well, there were seven sites which the study originally excluded as it was narrowed down to the top 6 due to low energy generation expectations, but were still recommended for further study. These locations are:

- New Croton Dam
- Rondout Effluent Chamber Releases
- Ashokan Lower Gate Chamber Releases
- Croton Falls
- Croton Titicus
- Croton East Branch (Sodom Dam)
- Croton Diverting

Source: NYCDEP

Although this evaluation was rigorous and well conducted for its time, it's currently outdated as much has changed since its completion. First of all, the AWIA of 2018 has expanded federal support for CH development to allow for larger systems with up to 40 MW capacity to gain FERC approval within 30 days. As well, turbine technologies have experienced major innovation and improvement, with the oldest technology of the emergent modular turbines mentioned in section 2.1.2 having been released in 2014, and the latest being from 2017. An updated resource assessment for NYC's water supply system is vital to the expansion of CH in NY. In addition, there have been no assessments of water distribution infrastructure outside of what is connected to the city. Although the majority of water demand is concentrated in NYC, it is worth pursuing evaluation at least across other prominent cities of upstate NY, such as Buffalo, Rochester, and Albany, all with substantial water infrastructure. As well, to support access to renewable energy along with environmental justice goals, assessment of potential CH development projects in more rural regions such as Franklin County along with socially vulnerable areas like the City of Newburgh are worth pursuing.

3.1.3 Conduit hydropower projects

The NY DEP owns two dam facilities which are integrated within aqueducts, along with one owned by NYPA, and another which is privately owned. There are currently no active CH projects in the state. However, two pilot projects are underway.

According to a testimony from November 25th, 2019, by the DEP director Vincent Sapienza, two sites which were identified in the 2013 evaluation are being pursued. These are (1) the Croton Lake Gate House in Westchester, and (2) the Catskill-Delaware interconnect at Shaft 4 in Ulster County (Sapienza, 2019). For the Croton Lake Gate House, Mr. Sapienza stated that the project has received excel grant funding from the Department of Citywide Administrative Services (DCAS) to assess feasibility of installing a small hydroelectric turbine. The Catskill-Delaware interconnect is currently undergoing turbine technology design (Sapienza, 2019). It's great that NY has already begun these pilot projects, however it does stand out that these two sites were only identified as only marginally economically feasible by the 2013 study, while those which were noted as feasible did not end up being pursued (especially West Branch Reservoir Shaft #10, which demonstrated exceptional potential).

Although this new development is exciting for NY, aside from this testimony there doesn't seem to be any public information available to explain how these projects are progressing. Unfortunately, Mr. Sapienza was not able to provide comments. The advancement of these sites may have been delayed due to the COVID-19 pandemic, however no new update has been released since Mr. Sapienza's statement. Hopefully the DEP's efforts to begin CH integration within NY's public water supply infrastructure means that transition toward diffusing energy recovery will soon gain much needed government attention. To support NY's energy evolution, there are several policies in development which are working to encourage CH expansion.

Additionally, NYSERDA produced a study in 2011 which focused on CH integration with wastewater effluent outfalls. The project was done in collaboration with Advanced Energy Conversion LLC, Turbo Solutions Engineering LLC, along with Clark Engineering and Surveying, who together worked to design and demonstrate a modular turbine system developed based on experimentation with wastewater facilities in NY (NYSERDA, 2011). Along with prototyping this system, the study worked to analyze its market potential within and outside of the state. Their turbine proved successful, and was able to generate 15kW of electricity with a flow of 12 million gallons per day and a head of 12 feet (NYSERDA, 2011). In addition, analysis of the U.S. wastewater hydropower market highlighted a potential size of $50 to $100 million based on implementation for 2,600 viable facilities. However, they note that accessing this market would require modest cost reductions in the turbine technology which should be achievable. Although this study seems to be advanced for its time, it quickly lost momentum. Advanced Energy Conversion was bought by Loxus in 2010, who subsequently pivoted away from CH related work (Hogan). According to the person responsible for this study at NYSERDA, they are not planning on using the research in the future, and have no current plans to pursue CH development (Hogan).

3.1.4 Conduit specific policy

So far, only one prominent CH related regulation has been pursued in NY. In 2018, NY City Council member Costa G. Constantinides first mentioned the introduction legislation 0419-2018 (Int 0419-2018), working to amend the administrative code of NYC to focus attention on including CH development. The local law requires that any future construction, upgrades, and maintenance of NYC's water supply infrastructure assess the possibility for underground vaults, internal drops, and high pressure pipes to accommodate the installation of a hydroelectric system for energy generation on-site along with for the grid. Specifically, it provides impetus to move forward with the 2013 resource assessment of CH potential in NY toward developing identified sites and pursuing continued research on further capacity for development. The effort to link CH development with general water supply infrastructure improvement is a strategic way to stimulate energy recovery by framing it as an important pathway for advancing NYC's water supplies.

Unfortunately, this legislation has not yet been enacted. According to Councilman Constantinidies's Legislative Director and Counsel Nicholas Widzowski, the administration is not fully committed to moving forward. They are interested in the idea, but disagree regarding specific implementation, feeling that there is less potential for energy generation than was argued and that the legislation may not be necessary. Constantinidies's office is still interested in pushing for the law to be passed, however it is not a current priority due to the pandemic. Mr. Widzowski explained that the office is in an especially difficult position right now as the state is moving to cut non-essential programs, let alone that the law itself is still disputed.

In the meantime, during the committee hearing from 2019 a variety of concerns and recommendations were brought to the table by different hydropower experts and NY constituents which offer important insights toward revising the legislation and increasing its potential to be accepted. Specifically, there are several comments which should be attended to if the law is to be pursued in the future, described below.

- The VP of NY's Real Estate Board Zachary Steinberg brought up the concern that turbines may threaten water supply. He asked that the law be updated to (1) address explicitly water pressure maintenance, which is not directly stated in the most recent documentation, and (2) expand on energy capture to include thermal energy. Heat recovery from water has experienced limited development and testing, however an Italian renewable energy company called Innova Renewing Energies seems to be leading the field and has developed a thermal recovery technology which seems to demonstrate preliminary success based on initial beta testing (IRE, 2020).

  In terms of Mr. Steinberg's first request, although this disturbance has been shown to be easily avoidable, to attend to this concern it is certainly worth revising the law proposal to specify that water pressure and flow will be maintained. Considering his second request, CH and thermal energy recovery are not so easily comparable. While CH has experienced over a decade of development, testing, and overall knowledge building, thermal energy recovery is in a much more immature stage of invention. Although it certainly appears to be a useful way to recover renewable energy from water supplies, including it in this law would likely hamper the potential for CH expansion as it would require additional research, funding, and labor which may restrict the time that can be spent on CH. Perhaps CH can act as an initial starting point for water supply energy recovery in NY, and after it has been demonstrated in the state will establish a platform for thermal energy recovery to be more efficiently expanded from.

- The CEO of in-pipe hydropower engineering firm Rentricity, Frank Zammataro, shared a testimony during the hearing which includes a useful point about maintaining water supply quality and functionality. He explained that Rentricity offers a Energy Recovery Regulator Vault technology which adds a by-pass loop to a PRV or FCV, allowing energy to be generated while required pressure and flow and maintained downstream. Although there are a variety of turbine systems which are able to sustain water supply needs while producing power, his example is a helpful way to solidify that capacity for policy-makers (specifically working to address Mr. Steinberg's concern).

- Matthew Swindle, the CEO of another leading in-pipe hydropower company Nline Energy, also shared his insight about how the law can be revised to provide the most effective support for CH development. He shared five important points, all which should be attended to as the legislation undergoes continued adaptation. These recommendations are listed below:
  1. Any past CH feasibility studies that are over two years old are likely obsolete due to the significant technology advancements which have occurred, providing increased cost-effectiveness and reliability.
  2. The current legislation draft should be amended to require "ANSI-61 compliant" technologies instead of being "NSF-61 certified." He explained that NSF-61 certified technologies is an incorrect term which will greatly limit applicable turbine systems by putting an unnecessary restriction on CH developers, as ANSI-61 is actually the national standard for water applications.
  3. The state should establish a "tiger team" to organize collaboration among all of the stakeholders essential to CH development, working to coordinate resources, avoid conflict across organizations, and include Con Edison, who he advised to be an important partner for interconnection.
  4. Development grants and no or low-interest loans should be accessible for CH projects.
  5. PPPs to maximize pending federal legislation renewable tax attributes should be prioritized.

- The Director of Sales and Marketing at the international in-pipe hydropower group Voith Hydro, Carl Atkinson, also suggested that the legislation be modified to include equipment that is ANSI-61 compliant rather than NSF-61 certified. He explained that the current requirement is excessive, and will limit the number of technology options along with energy recovery potential.

  Source: NYCC, 2019.

It is clear that Int 0419-2018 must be revamped to accommodate for these valuable considerations, being fairly easy to implement as they simply require replacing inadequate terminology with more appropriate standards in the legislation proposal. The only insights that may call for more extensive work that could span beyond this law are Mr. Swindle's advice about strategic support for CH development, suggesting funding and cross-stakeholder collaboration programs be considered. Although there are some possibilities for CH eligible funding in NY, they are scarce and may be unreliable. This recommendation does not discredit the legislation nor limit its potential, but instead provides a vital point about expanding more long term support for CH. Based on the research conducted by this report, there is definitely a need for the development of CH inclusive or focused funding programs along with multi-actor cooperation structures.

4. **Conclusion**:

In addition to the learnings that can be realized from Int 0419-2018 and the testimonies of interested parties, CH projects, policy, and research done in Oregon, Colorado, and California offer helpful examples of strategies which NY should pursue in order to support CH development. Following these examples, this report will finalize its review to outline the identified barriers and remedial recommendations which NY faces in their path to CH expansion, energy recovery, and the expedient attainment of their decarbonization goals.

4.1 Case studies

Alike NY, Oregon, Colorado, and California all have introduced renewable energy standards that call for 50% to 100% renewable energy by the mid 21st century. Along with a variety of traditional renewable energy resources such as wind and solar, these states have expanded their energy portfolios to include innovative storage and production systems such as waste-to-energy, hydrogen fuel cells, marine power, and CH (ODE, 2020a; CEO, 2020a; CEC, 2020b). CH development has proven to be particularly successful, allowing for a variety of insightful takeaways to be noted.

4.1.1 Oregon

Oregon (OR) has several active state-owned CH systems, with their two most prominent projects being located in (1) the City of Portland's water supply pipes (mentioned in section 2.1.2.2), and (2) the North Unit Irrigation District at a Bureau of Reclamation facility near Madras (ODE, 2020b). As well, several private irrigation canal based projects have been successful, (1) being associated with the Farmers Irrigation District, working to save up to $150,000 on annual operations and maintenance costs, and (2) the Three Sisters Irrigation District where a 700 kW hydropower plant produces 3.1 million kWh annually, powering 275 average Oregon homes a year (ETO, 2020).

These astounding projects were only possible through the Energy Trust Program (ETP), offering substantial funding for hydropower projects which take place in irrigation canals, municipal water supply infrastructure, existing dams, and in some cases natural streams (ETO, 2020). Eligible projects must be under 20 MW in capacity and located in or deliver power to the service territory of Portland General Electric or Pacific Power in OR. The program provides a comprehensive resource for supporting CH development, providing support for expert project development assistance including, but not limited to, grant writing assistance, feasibility studies, final design, permitting, utility interconnection and construction management (ETO, 2020). As well, the ETP provides direct funding. It may fund up to 50% of the cost related to hiring an outside consultant to provide expert assistance, up to a maximum of $200,000. Lastly, the program establishes installation incentives for CH, working to provide additional funding based on a project's cost in contrast to the market value of the energy produced (above-market cost). There is no fixed cap for this financial support, however it requires that the project provide the ETP with a negotiated share of their RECs, which are put in a trust for the ratepayers who pay the public purpose charge (ETO, 2020).

In addition to these assistance opportunities, the ETP has developed several guidebooks which aim to help new and experienced developers understand and cooperate with OR's permitting requirements and utility interconnection procedures. These processes have been recognized by other studies to be often difficult and confusing, limiting the potential for CH development (CEC, 2020a; DOE & ORNL, 2019; NREL, 2017; DOE, 2015). OR's effort to produce these guidebooks as well as provide financial and technical support have been key to their CH success so far, highlighting important policy efforts for NY to also pursue. Their strategy to trade funding for RECs is an especially attractive technique to motivate rapid CH growth and renewable energy production.

4.1.2 Colorado

Colorado (CO) has also developed several successful CH systems. One example is in Montrose, CO, where the Uncompahgre Valley Water Users Association have installed five turbines into their canal system, providing irrigation to over 83,000 acres of farmland (Segerstrom, 2018). This project works to provide for about 13% of the electricity used by the approximately 70,000 people who draw power through the member-owned cooperative Delta-Montrose Electric Association (Segerstrom, 2018).

The state recognized that FERC licensing requirements for CH have made it the most economically-feasible and time-efficient option for hydropower expansion early on, and has worked to follow suit on the state level over the past decade. Through the Colorado Energy Office (CEO), the state offers numerous resources in support of CH. These assistance assets include (1) free site assessments, (2) $15,000 matching grants to support project feasibility and engineering for municipalities and agricultural producers, along with (3) low-interest loans which can provide 100% of project construction costs (CEO, 2020b). The CEO has also completed several resource assessments, with the most recent study from 2019 highlighting 63 public water supply facilities which may pose a 33,990 kW capacity to generate 202,475 MWh annually (DOE & ORNL, 2019). As well, they have produced several publicly available guidebooks to help explain interconnection, permitting, and overall development. Finally, Colorado worked to streamline the electrical inspection process to only require a one-page form signed by a CO-registered Professional Engineer to certify compliance with electrical standards (CEO, 2020b).

Again, CO's efforts to advance CH development through government-led technical, funding, and assessment based activities have been instrumental to their success. In particular, providing focused attention to municipalities and agricultural producers has allowed for those who are most able to develop CH systems to do so easily. As well, their work to simplify the electrical inspection process may be a method for NY to consider.

4.1.3 California

California (CA) is currently leading the CH frontier in the U.S. in terms of number of active projects, with 142 systems in varied stages of development and eight sites which have demonstrated particular success. These projects are located in water treatment plants and groundwater recharge sites, with the oldest site having begun operation in 2013 and the most recent in 2019 (CEC, 2020a). Together, they provide CA with a capacity of 343 MW, which is enough to power at least 343,000 homes let alone allow for on-site energy recycling (CEC, 2020a).

The Sandhill Water Treatment Facility owned by the San Gabriel Valley Water Company (SGVWC) has been the longest operating CH system in CA, having been launched in 2013. The facility has a 310 kW capacity, and generates 1,000 MWh per year by utilizing two PaT units upstream of their treatment plant (CEC, 2020a).This project offers several informative highlights from its long term of experience and learning, working to exemplify exciting opportunities for cost savings, energy generation, and successful development processes for a CH project in public water supply infrastructure. These key takeaways are described below:

- *Energy neutrality and hydro-powered revenue:* All energy produced on-site is exported to the grid and SGVWC is provided credit according to water treatment based energy demand, being at the same tariff as could have been purchased through their net metering agreement (CEC, 2020a). In 2018, the facility's energy production was able to completely offset the plant's total energy needs, and SGVWC made an extra $12,000 from Southern California Edison (SCE) in return for the excess energy produced (CEC, 2020a).

- *A model development timeline:* The feasibility assessment for SGVWC's Sandhill CH development took about three months, and all environmental and federal permitting requirements were achieved in the following year (CEC, 2020a). The design and construction stages took around 1.5 to 2 years, including the interconnection process as it can only be carried out once design specifications are determined (CEC, 2020a). Following their interconnection agreement, the project began operation in November of 2013.

Along with insight from CA's active CH systems, their energy technology funding initiative called the Self-Generation Incentive Program (SGIP), has been an important engine to drive widespread CH adoption. Organized by the California Public Utilities Commission (CPUC), the SGIP provides funding for on-site distributed energy systems through the support of several gas and electric utilities in the state (CEC, 2020a). For turbines installed in PRVs specifically, the program offers $1.25 per W according to the rated capacity of the CH system. Projects which receive funding through the SGIP are also required to offset their on-site energy usage before they can export power to the grid, capped at 25% of their net energy generation (CEC, 2020a).

Six out of the eight CH facilities which have gained the most attention in CA received funding through this program, adding up to over $2 million dollars (CEC, 2020a). The two projects that did not receive grants were groundwater recharge basins which were ineligible due to being unable to use produced energy on-site (CEC, 2020a). Additionally, alike OR and CO, the California Energy Commission (CEC) recently produced an intensively-researched CH implementation guidebook. It shares information and advice regarding areas from turbine selection to the permitting process (CEC, 2020a). As well, the report describes interviews with prominent technology providers, and provides a tutorial on the usage of their new Microsoft Excel-based Business Case Assessment Tool. This tool works to compute preliminary data as well as offer guidance on energy production, life cycle costs and GHG emissions, and turbine selection (CEC, 2020a).

CA's experience with CH poses much to learn across current CH projects, funding policy, and informational resources. As well, their guidebook and Excel-based tool are useful resources for general CH development. Overall, CA will likely be an area of substantial growth for the CH industry.

4.2 Barriers to CH development in New York

The potential for NY to take hold of the expansive potential for energy recovery, grid stability, infrastructural improvement, GHG mitigation, and renewable energy access that CH offers the state is currently limited by four main factors.

- First, NY has not conducted an up-to-date assessment of possible resources that are eligible for CH integration in the context of public water supply systems, let alone for irrigation canals and industrial water supplies. CH has been revolutionized since the 2013 NYCDEP evaluation was done, and new research is essential. At a minimum, new study should consider CH integration with NYC's massive water distribution infrastructure.

- Second, the state lacks a CH specific or encompassing financial support program. As exemplified by OR, CO, and CA, some level of grant or loan assistance has been key to their CH success. Although the WIIA and CGP could be applicable to CH projects, for NY to jumpstart expansion of the technology it's clear that a program which is explicitly inclusive of CH should be developed to support municipalities, government agencies, communities, farmers, and private industries.

- Third, although Int 0419-2018 is a hopeful first step toward policy that incentivizes CH integration, NY lacks any level of policy which coordinates necessary resources of CH relevant information, stakeholder collaboration, research, and general strategic guidance. The value of informative resources involving interconnection, permitting, and overall CH implementation in the form of a guidebook or other assistance has also been demonstrated to be valuable by the states studied in this report, being an important pathway for CH advocacy that NY should pursue.

- Fourth, CH faces an unnecessary regulatory disadvantage. CH development in NY is unnecessarily delayed and challenged by potential requirements to undergo the same environmental review and permitting processes and as other hydropower systems. Although CH should not be freely developed without regard to environmental impact, it is clear that the technology poses a distinctly benign influence on environmental health, an important factor to be recognized in NY's renewable energy development policy.

4.3 Recommendations for conduit hydropower development in NY

Other states have demonstrated that CH is a valuable investment in terms of social, economic, and environmental benefits. Based on the extensive water infrastructure in NY along with the preliminary research that has been done, it seems highly likely that the state can attain the same if not more success locally. To summarize the findings of this report, five specific recommendations for NY to support CH development are detailed in the sections below.

4.3.1 Updating and expanding resource assessments

It seems that many opportunities for CH integration with water supply infrastructure exist in NY, however the state should confirm this potential through an updated resource assessment. This does not need to be an all-in-one study, and could simply begin with a re-evaluation of the possibility for CH development in NYC's water distribution system. Since Gomez and Sullivan Engineers, HANDS-ON! Hydro, and O'Brien & Gere worked with the NYCDEP to produce the 2013 study, partnering with them again would be a useful way to take advantage of their previous experience in this context. As well, including an in-line hydropower (ILH) developer who works on pipelines and aqueducts specifically would be an essential resource to provide an expert perspective on how modular turbine technologies can play a role. The groups who voiced their insight toward the Int 0419-2018 hearing likely already have relationships with NY environmental and energy focused agencies, including Nline Energy, Rentricity, and Voith Hydro (NYCC, 2019). Nline Energy may be an especially beneficial company to collaborate with, as they played an instrumental role in the research and development done for CA's recent "In-conduit Hydropower Implementation Guidebook" (CEC, 2020a). As well, they offer ILH development across the entire lifecycle of a project, from feasibility studies to maintenance (Nline Energy, 2020).

As well, it may be important for NY to evaluate potential in public water supply facilities across the counties and municipalities which border the Hudson River and into upstate. The cost-effective approach to energy generation that CH offers may be particularly valuable for these communities, as treatment for drinking water from and the disposal of wastewater into the Hudson River demands high electricity consumption and resulting costs (Riverkeeper, 2019). Many of these facilities also lack recent upgrades, as water treatment technologies have also experienced much innovation over the past decade. For example, the latest advancement to a wastewater treatment plant in the Hudson Valley was in 2003 and the oldest being in 1972, with the majority of these facilities in the region not having been improved since the 1990s (NYSDEC, 2019). NY has the largest documented need for investments in water infrastructure. Specifically, based on a 2017 water quality analysis done by the water health advocacy group Riverkeeper, the state needs about $1.3 billion in funding to maintain and improve its facilities, with the vast majority of those funds being attributed needs in the Hudson River Estuary, Mohawk River, and Upper Hudson River watersheds (Riverkeeper, 2017). Energy recovery through CH may be an essential strategy for water treatment infrastructure in these regions to save money on electricity consumption and possibly gain revenue by selling excess energy to the grid. This financial gain can then be redirected toward funding infrastructural and treatment technology maintenance and improvements, as well as supporting employee salaries toward strengthening their wellbeing and incentivizing a stronger water treatment job market. As well, CH can work as a pressure dissipating device, working to help maintain the quality of infrastructure.

Lastly, pursuing resource assessment which specifically attends to irrigation canals for NY’s immense agricultural industry should be considered. OR and CO have found particular CH success by devoting resources to support farmers’ abilities to implement energy recovery, demonstrating an important strategy to address. Since NY’s agricultural industry contributed $5.4 billion in gross sales value and $1.2 billion in net farm income to the national economy in 2012, it remains a major component of the state and country’s economy (DiNapoli, 2015). Over 100 different irrigation canals which provide water to this industry may be viable for CH integration given further evaluation (CC, 2018). CH can work to provide energy recovery, cost savings, and GHG mitigation for agriculture in the state, which will be an especially valuable resource as climate change increases drought risk in the near future (CC, 2018).

4.3.2 Financial assistance

Once the current potential for CH development in NY has been demonstrated, the next step in supporting its integration with the state’s water supply infrastructure is to provide financial assistance for interested parties. This can take place through loans with low or no interest rates along with grants. Government-sponsored CH funding can not only encourage municipalities, farmers, and water intensive industries to adopt the technology, but be implemented strategically to incentivize specific applications. For example, funding can be used to target CH development in areas which lack renewable energy resources, are in need of water treatment upgrades, or depend on irrigation for agriculture. The funding programs highlighted in the OR, CO, and CA case studies all offer informative examples of how NY could structure financial assistance that is CH focused or at least inclusive.

4.3.3 Regulatory accommodation

From a regulatory standpoint, CH may be unnecessarily delayed and challenged by requirements to undergo the same environmental review processes as other hydropower systems. Although CH should not be freely developed without regard to environmental impact, it is clear that the technology poses a distinctly benign impact on environmental health. CH and other energy recovery technologies which are integrated into pre-existing water supply infrastructure must be provided their own pathway for development given this unique quality. For example, unless the proposed project aims to take place in an irrigation canal, state level CH permitting should devote attention to maintenance of water supply quality and functionality rather than ecological influence.

As well, before regulatory frameworks and funding programs can accommodate for CH, it must be explicitly recognized by NYSERDA as a qualifying renewable energy facility under NY's tier 1 RES. Currently, the only eligible new hydropower developments are upgrades to existing dams and low-impact run-of-river systems as long as no new storage impoundment is constructed (NYSERDA, 2020c). As of July 2020, NYSERDA and the New York State Department of Public Service (NYSDPS) are in the process of modifying the definition of qualified renewable energy facilities to better align the CES with the AREGCBA (Bram). Hence, there is a current and potentially ongoing window of opportunity for NY to take action regarding the inclusion of CH in renewable energy development and funding programs.

4.3.4 Organizing a conduit hydropower stakeholder alliance

Establishing an administrative and political structure to promote the collaboration of stakeholders relevant to CH development will be especially important to the smooth expansion of the technology in NY. Numerous actors are involved, and there is a need to streamline coordination and communication across electric utilities, wholesale and retail water agencies, landowners, developers, state agencies, and communities. Organization of this network through top down state level leadership in balance with bottom up initiative will be essential to not only the development of CH and avoidance of conflict among actors, but also to spread accurate and accessible information about the benefits which it offers.

In addition to general stakeholder coordination efforts, PPPs should be prioritized as a pathway for interested municipalities and communities to easily access resources involving their ability to develop CH, working to empower bottom up action. These partnerships have been shown to be incredibly useful across a variety of sectors, allowing policy-makers and citizens to effectively engage with co-learning and co-creation by establishing equity and mutual accountability toward achieving common goals (Liu et al. 2014; Cheung et al. 2012). As Mr. Swindle advised, PPPs may be especially helpful to maximize pending federal legislation renewable tax attributes (NYCC, 2019). In particular, PPPs can provide a strategic cost-advantage for CH development as only municipalities can gain PTCs, allowing for maximized savings in CH projects as both private and public actors have access to different forms of funding and can pool collective financial and technical resources.

Lastly, global and national knowledge sharing about CH development is essential to not only NY's ability to take advantage of this unique opportunity, but support others to do the same in our collective effort to address climate change. Publishing interdisciplinary research, engaging with workshops and conferences, as well as simply offering publicly accessible resources on CH information are important avenues for NY to manage CH expansion both to support its continued innovation and encourage its market value.

4.3.5 Framing the co-benefits of conduit hydropower

CH provides the three direct benefits of (1) reliable renewable energy recovery, (2) financial stability, and (3) pressure dissipation that allows for infrastructural maintenance. However, it also supports several environmental and social interests.

Environmentally, CH works to mitigate GHG pollution by acting as a clean substitute for fossil fuels which can support the atmospheric and aquatic health of local ecosystems, as well as contribute to global decarbonization. Since environmental health is linked to that of humans, public health will also benefit. Additionally, the cost savings and revenue generation which CH offers can provide a pathway to fund infrastructure maintenance and improvements. Pursuing necessary upgrades to water treatment technologies in particular may be more affordable for communities when their water supply systems are no longer energy inefficient. These advancements can support water quality and human health.

Socially, CH can provide a source of decentralized renewable energy access through the export of excess power to local grids. This can be particularly helpful for rural communities who lack the option to use clean power. As well, the environmental benefits which CH offers will protect public health and even ability to safely recreate in water bodies as the quality of wastewater discharged into them can be improved.

Together, these environmental and social prospects can intersect to serve an environmental justice purpose. For socioeconomically marginalized communities in NY who may be disproportionately exposed to inadequately treated drinking and waste water as well as without access to renewable energy, CH can be a tool to promote equity. By posing the potential to increase funding for treatment improvements and renewable energy to local grids, CH can support the alleviation of environmental justice concerns.

NY has an opportunity to use CH toward advancing energy, economic, environmental, and social sustainability. However, the state must frame CH in a way that recognizes the potential for these intersectional benefits to be attended to rather than perceiving it solely as an energy recovery project. Utilizing wasted energy certainly is CH's primary characteristic, yet it can be much more than that. Realizing, studying, and communicating its broader capabilities is an important strategy to achieve co-benefits and gain the acknowledgement it needs. NY should consider developing a linked water and energy quality resilience plan which frames CH as the engine for the improvement of energy efficiency along with human and environmental health along with equity. For example, a study could focus on a specific municipality which is in need of water treatment upgrade to (1) estimate the power generation and cost savings of integrating a CH system, (2) based on that potential organize certain water treatment technologies to be installed based on their affordability through CH savings, and (3) predict water quality along with public health improvement

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