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UNLOCKING HYDROPOWER POTENTIAL OF PENNSYLVANIA

Understand and Maximize the Immense Hydropower Potential of Existing Non-powered Dams in Pittsburg District, PA.

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Executive Summary

Pennsylvania's existing nonpowered dams (NPDs) have an immense untapped hydropower potential, ranking 6th in the nation, with a total estimated energy capacity of up to 520 MW. Effectively utilizing this capacity, Pennsylvania will be able to increase renewable energy production and expedite meeting PA Renewable Portfolio Standard. This potential renewable energy will also allow a greenhouse gas reduction of close to 2.1 billion pounds of CO_2 equivalent. This report aims to provide a comprehensive understanding of the great energy potential of Army Corps non-powered dams in Pittsburg District of Pennsylvania and identify the challenges as well as the benefits in actualizing this hydropower potential. The report also offers a general guideline for a cost and time effective development track for dams retrofitting.

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I. Introduction

In 2012, the U.S. Department of Energy published a comprehensive report on assessing the potential amount of energy that could be generated by the current non-powered dams (NPDs) in the United States. It estimated that there was approximately 12,000 Megawatts (MW) of potential energy that could be added to the current energy fleet by NPDs in the U.S. This was equivalent to up to 15% of the existing total hydropower in the U. S. (Hadjerioua, Wei, & Kao, 2012). Ohio River Region and the State of Pennsylvania were among the regions and states that were estimated to possess the highest potential hydropower capacity. Due to the high river flow and a series of locks on the Ohio River, the Ohio hydrologic region was demonstrated to be capable of generating up to 3, 200 MW. Within in this region, the state of Pennsylvania alone was judged to have the potential hydropower capacity of 678 MW, ranking 6th in potential energy from NPDs, among the 48 states in the U.S. (Hadjerioua et al, 2012). And among the top 100 NPDs with highest hydropower potential, 80% of which belonged to the U.S. Army Corps of Engineers (USACE) (Hadjerioua et al, 2012). The following year, in 2013, USACE themselves conducted their own studies on the hydropower potential of each USACE's NPD. According to this report, in Pittsburg District, Pennsylvania alone, there are 24 NPDs, located along the three major rivers: Allegheny River, Monongahela River and Ohio River, which had been estimated to have potential to generate a total of 904 MW of hydropower capacity; within this, approximately 520 MW is deemed economically feasible (*Hydropower resource assessment at non-powered USACE sites*). These two reports indicated a great untapped potential of hydropower of the existing NPDs in the U.S. in general as well in Pittsburg District of Pennsylvania especially. Currently, Pennsylvania's major source of energy are natural gas and nuclear power, which account for up to 39% of state's total energy consumption. On the other hand, hydropower is currently playing a very small role in the state's energy consumption, accounting for only about 35% of renewable energy or about 1.75% of total energy consumed (*Pennsylvania State Profile and Energy Estimates* 2019). However, as the entire nation is now shifting toward renewable energy to reduce greenhouse gas emission, Pennsylvania is following the trend by aiming to cut the state's greenhouse gas emission, 38% of which is from of natural gas and nuclear power energy production, by 26% by the year 2025 (Althoff, 2019). As a result, hydropower is now emerging as promising great candidate for a new source of energy that is both economically and environmentally beneficial. With up to 24 already existing NPDs, many of which are placed among top 100 NPDs with highest energy potential according to the Oak Ridge report, it is highly advantageous for Pittsburg District to consider retrofitting these NPDs to incorporate power generating functions. This report will present the cost and benefit of NPDs conversion to assist the local Pittsburg government and public with this decision-making process.

II. Overview of hydropower and its potential in the U.S. power grid

1. Hydropower benefits and potential

Electricity, from sources such as water, coal or nuclear power, is produced on the same principle where a metal shaft in the generator of a turbine is turned, thus, producing electricity. Nuclear power and natural gas power both use heat, either from nuclear reaction or burning of natural gas, to heat up water and use the steam to turn the generator. This nuclear reaction or burning process unavoidably produce harmful byproducts such as radioactive materials (*Backgrounder on Byproduct Materials* 2020), greenhouse gases, particulates, and carcinogenic compounds (*Environmental Impacts of Natural Gas* 2014). On the other hand, instead of using steam to turn the turbine, hydropower takes advantage of the flow of water to produce energy. As water falls or flows through a hydraulic turbine, it turns the metal shaft and generates electricity. As a result, hydropower does not produce any byproducts that can harm human or environmental wellbeing. Furthermore, unlike nuclear or natural gas power, whose energy source is gradually depleted when used, water quantity is not reduced in the power generation process; thus, hydropower is a clean and renewable source of energy. This renewability also makes hydropower relatively cheap compared to other energy source. In addition, since water is always available and can be stored in a reservoir or pump storage during a low-energy demand period to be quickly released and deliver energy to the grid when energy demand rises, hydropower is a comparatively much more reliable source of energy than other energy sources, including renewable ones like solar or wind (*Hydroelectric Power: How it Works*). Having such significant environmental and economic benefits, hydropower is, currently, the most widely use renewable energy, making up 51% in renewable energy production, and 17% in total energy production in the U.S. (*Hydroelectric Power Water Use*). This impressive energy contribution to the national grid comes from 2,500 hydropower plants which produce 100 Gigawatts (GW). Still, as the U.S. is still considered a fossil-fueled energy country, the full potential of hydropower has not yet been reached (Grey, 2016). And as renewable and clean energy is becoming more popular in this time of high environmental awareness, the U.S. is looking into fully realize the nation's full potential in hydropower through two main options: building new hydropower dams or retrofitting existing non-powered dams to include power generation capacity. The option of constructing new dams, however, would involve many considerations such as large construction cost, major environmental effect from the new construction, significant impact on the natural water flow, complicated and time-consuming licensing and permitting time and their usually being long-term projects till energy can be produced (Grey, 2016). Hence, the second option, which is converting the existing NPDs into power generating ones is a much more advantageous option for hydropower development in the U.S. Since the construction cost and the major environmental impacts from construction process has already been incurred, adding hydropower features into existing NPDs can be achieved at much lower cost, in much shorter timeframe, with notably lower risks and more environmental favorability than new construction projects (Grey, 2016). As a result, NPDs conversion is the most advantageous option to add more reliable and renewable energy into the nation's power production and usage. Pennsylvania with 83,000 miles of streams and rivers, along with a total of nine NPDs rank among top 100 NPDs with highest hydropower potential in the U.S., is among one of the country's leading power in hydro energy (*PA Hydropower Summit* 2011). With the price of natural gas, PA's current main source of energy production, is expected to rise in the years to come (*Low-Impact Hydropower* 2017), effective realization of PA's great hydropower potential is crucial for developing a reliable and economical energy future for Pennsylvania.

2. Hydropower retrofitting challenges

Although possessing great potential as clean, renewable and cheap energy source, the state of Pennsylvania, and even the nation ourselves, is hesitant to make a decisive shift in our energy source from natural gas to hydropower. In Pennsylvania specifically, major challenges that hinders the development of hydropower include the time-consuming, confusing and burdensome licensing process required by the Federal Energy Regulatory Commission (FERC), the absence of effective coordination and communication between different state and federal agencies, public perception, troubles with utility interconnection, and hindrances from governmental policy. The major obstacle that discourages public and private attempt to convert existing NPDs into hydropower dams is the complicated, costly and time-consuming licensing requirement of FERC. As of this time, in order before the FERC licensing process can begin, it is required that a project must obtain approval from all relevant state agencies and the USACE (*PA Hydropower Summit* 2011). This process, due to its extensiveness and its complexity, usually requires the assist of attorneys or specialized consultant services, which would make the permitting process of a project become significantly costly (*Low-Impact Hydropower* 2017). Furthermore, the mis-sequencing between the permit application requirement of the USACE and FERCE can also pose financial risk that many developers are unwilling to take (*PA Hydropower Summit* 2011). Furthermore, the lack of staff and funding of many state and federal agencies creates a lack of communication and guidance along the permit seeking process making the process time-consuming and unnecessarily confusing (*PA Hydropower Summit* 2011). The lack of funding for hydropower, despite its benefits, also makes effective public education on those benefits challenging. Consequently, many times, NPDs conversion projects fail to gain the support of the public despite the significant benefits that the new hydropower source could have brought to the region. The lack of incentive in PA's energy policy is another reason for hydropower potential of the state being overlooked. As an attempt to increase the use of renewable energy, PA's Alternative Energy Portfolio Standard (AEPS) requires that by 2020, 18% of the state's electricity production must come from either of the two tiers of alternative energy sources. Large-scale hydropower is categorized as tier II and small-scale hydropower is categorized as tier I. In tier II, because of the profusion of waste coal as an alternative energy source, large-scale hydropower is often overlooked. Meanwhile, in tier I, although there is financial incentive through the state's renewable energy credits (RECs), small-scale hydropower source must be certified by the Low Impact Hydro Institute, which also required certification renewable every two years. This renewable process would add time and cost into the project implementation, making the financial incentive of RECs rather insignificant. (*PA Hydropower Summit* 2011) These are the main challenges that developers, states and federal agencies as well as the USACE must work together to overcome in order to fully unlocked that great potential of hydropower.

III. Assessment of existing NPDs in Pittsburg District, PA

According to the federal report "*An Assessment of Energy Potential at Non-Powered Dams in the United States*" published by U.S. Department of Energy in 2012, out of the top 100 NPDs with highest hydropower potential, eight out of nine NPDs in the state of Pennsylvania belong to USACE. In fact, the USACE has authority over 80% of all NPDs in the U.S. (Hadjerioua et al, 2012). Furthermore, USACE dams are shown to have highest hydropower potential, licensing and permitting processes for redevelopment of USACE-owned dams are also more involved and complicated that for non-USACE dams. As a result, this research will focus on assessing the convertibility of 24 NPDs in Pittsburg District, PA, which are owned by USACE as this approach would provide a more extensive and comprehensive analysis of both the costs and benefits of NPDs conversion process.

1. Overview of 24 NPDs in Pittsburg District, PA

There are 24 USACE owned NPDs in the Pittsburg District of Pennsylvania, locating along three major hydrologic regions: Allegheny River, Monongahela River and Ohio River (Figure 1). These are mostly gravity dams originally constructed for the purpose of navigation. There are also a few earth type, flood control dams. The total installed capacity of these dams, based on the current data of the national energy zone mapping, is estimated to be around 620 MW. (Table 1) Understanding the retrofitting ability and requirement for these dams is crucial in the mission of maximizing PA's clean energy potential.

Figure 1. Pittsburg District, PA Non-Powered Dams (Hydropower resource assessment at non-powered USACE sites)

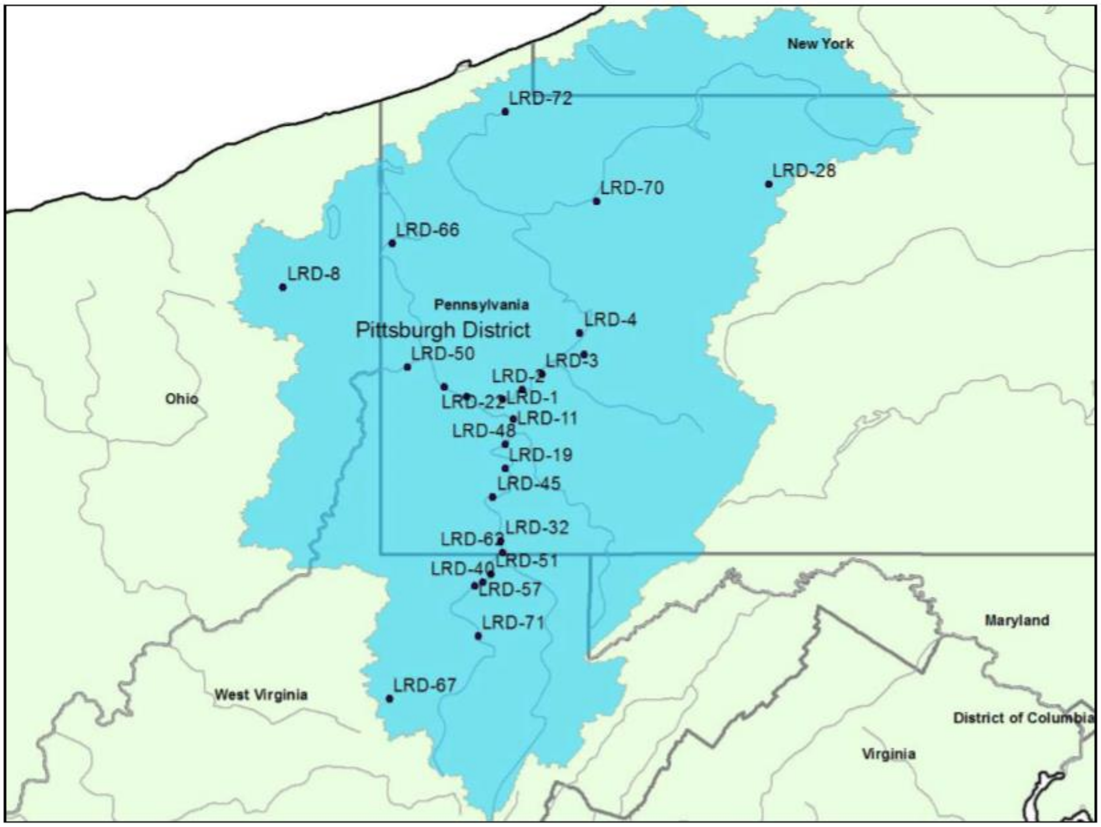

Table 1. Pittsburg District USACE Non-Powered Dams (National Energy Zone Mapping 2020)

Name	ID-Number	Installed Capacity (MW)
Allegheny Lock and Dam 02	LRD-01	34.69
Allegheny Lock and Dam 03 (C.W. Bill Young)	LRD-02	43.78
Allegheny Lock and Dam 04	LRD-03	34.05
Allegheny Lock and Dam 07	LRD-04	31.65
Berlin Dam	LRD-08	3.52
Braddock Locks and Dam	LRD-11	19.48
Charleroi Lock and Dam	LRD-19	26.15
Crooked Creek Dam	LRD-21	6.08

Dashield Locks and Dam	LRD-22	47.1
East Branch Dam	LRD-28	3.39
Emsworths Locks and Dams	LRD-30	84.41
Grays Landing Lock and Dam	LRD-32	19.4
Hildebrand Lock and Dam	LRD-40	15.8
Maxwell Locks and Dam	LRD-45	29.3
Monongahela Locks and Dam 03	LRD-48	12.61
Montgomery Locks and Dam	LRD-50	99.84
Morgantown Lock and Dam	LRD-51	12.99
Opekiska Lock and Dam	LRD-57	16.46
Point Marion Lock and Dam	LRD-62	15.25
Shenango Dam	LRD-66	7.48
Stonewall Jackson Dam, WV	LRD-67	2.72
Tionesta Dam	LRD-70	5.89
Tygart Dam	LRD-71	46.99
Union City Dam	LRD-72	4.99

2. PA permitting process

Permitting and licensing process for NPDs conversion is usually one of the major costs in the planning phase of dam reconstruction, and therefore, obstacle in the retrofitting process. Typical licensing period for a project can take up to 2-5 years, involving many federal and state agencies and authorities (*Hydroelectric Permitting Manual for Pennsylvania*, 8). With each project, there is a different set of steps that developer must take, depending on the individual project itself, in applying for permit. However, the licensing process for NPDs redevelopment in PA can be oversimplified into a most basic sequence as followed:

1. Enter discussion with FERC about the project and applicable license and exemption
2. File FERC Notice of Intent; contact DEP's regional manager for consultation meeting; apply for PHMC consultation
3. File for Water Quality Certification (401)
4. Receive FERC license or Exemption

5. File for DEP permits; file for USACE 408 permits if applicable

(*Hydroelectric Permitting Manual for Pennsylvania,* 5)

The permit application is both a time-consuming and involved process, requiring developers to contact and consult many federal, state and local authorities. In the state of Pennsylvania specifically, some agencies that typically involve the licensing process includes but not limited to the followings:

1. FERC
2. PA Department of Environmental Protection (PA DEP)
3. USACE
4. PA Historical and Museum Commission (PHMC)
5. Department of Conservation and Natural Resources
6. Pennsylvania Fish & Boat Commission
7. National Park Service
8. U.S. Environmental Protection Agency
9. U.S. Fish & Wildlife Service Pennsylvania
10. National Marines Fisheries Service (NOAA Fisheries)
11. Counties and Municipalities
12. Indian tribes

(*Hydroelectric Permitting Manual for Pennsylvania*, 10)

FERC has the authority to regulate all hydropower developments on navigable waterways and therefore is the most important licensing agencies in this process. The Commission performs studies on the impact of the proposed project on environmental resources such as fish and wildlife, visual resources, historical and cultural resources, and recreational opportunities. This is a part of FERC's "Environmental Assessment." It will use the evaluation from its own studies in combination with the environmental studies required from and submitted by applicant in order to make a decision of granting or withholding license (*Hydroelectric Permitting Manual for Pennsylvani*, 8). The impact studies required from applicants typically includes: Water quality study, project hydraulics study, terrestrial habitat study, wetland delineation study, archaeological and historic resources study, recreation resources management plan, aquatic habitat assessment, sediment quality survey, mussel survey, fish entrainment and passage study (*Hydroelectric Permitting Manual for Pennsylvania*, 14). These are the typical environmental studies required in the license application; however, which studies to be performed is very site-specific. Consultation with FERC is highly advisable to decide which are the necessary impacts studies for each individual project in order to save both time and money for developers. FERC typically has two main tracks which a project's permit application could take: Traditional Licensing Process (TLP) or the Integrated one (ILP). ILP is much more involved and required extensive communication between developer, authorities and stakeholders; whereas TLP is much simpler with less-prefiling steps, deadlines and required studies and therefore, it is a much more cost and time effective tract that is available for smaller and simpler redevelopment project (*Hydroelectric Permitting Manual for Pennsylvania*, 9). Developer, thus, should contact FERC in order to discuss early on whether his project is qualified for TLP so that the project costs is reduced.

USACE is another major authority that is highly involved and demanding in the licensing process. Because all 24 NPDs studied in this report belong to USACE, it is important to understand the permit requirement of this agency. Section 408 permission, section 404 permit and section 10 authorization, sequentially, are major USACE's license. All USACE-owned

NPDs are required to obtain the 408 permission, which is the Corp's approval for any modification of existing NPDs (*Hydroelectric Permitting Manual for Pennsylvania,* 25). Following section 408, generally, section 404 permit is required for most USACE NPDs. This permit is for the purpose of sediment control, ensuring the project construction practices will comply with the federal Clean Water Act. Section 404 permit is required before obtaining the 401- water quality certification which is issued by PA DEP; however, USACE requires final engineering plans as part of the application, which is costly to incur, whereas PA DEP's 401 certification only asks for conceptual design drawings (*PA Hydropower Summit* 2011). This is a mis-sequencing that tends to discourage developers from taking on USACE projects because they would not want to take such major financial risk incurring the engineering plan so early on in the project before having any guaranty that they would receive FERC license (*PA Hydropower Summit* 2011). Fortunately, USACE and FERC are working together to resolve this mis-sequencing, now, developer and request USACE to issue a provisional permit, stipulating the validity of the 404-permit pending the provisions of the 401 (*Hydroelectric Permitting Manual for Pennsylvania,* 25).

These are the major agencies and permits required for NPDs conversion. There are still many other federal, state, and local authorities, agencies and stakeholders involved in the process, with many impact studies and assessments required before a license can be issued from FERC for any project. This is a very complex, time and money consuming, and sometimes perplexing process. Therefore, Pennsylvania Environmental Council (PECPA) is taking steps to comprise a manual to guide developer through the current process; additionally, PECPA is also working with FERC create effective and informative communications channels between agencies to help developers save time and money on the permit application processes. Furthermore, due to having less impact on the environments compared to constructing new hydropower dam entirely, the permit and licensing required for retrofitting existing NPDs are still much simpler and therefore, saving more time and money (*PA Hydropower Summit* 2011).

3. Environmental Impacts

Environmental impacts study is the most important study in any type of project, regardless of the project's size. Not only is environmental study a major driver of the cost in the planning and permitting phase, it also decides the time and cost of the construction and even maintenance phase. Some typical environmental concerns particular to retrofitting projects are the effects on water flow and quality, fish passage, and dissolved oxygens. Changes in water flow will cause major effect on a wide range of other environmental and ecological features such as water navigation, bank erosion, sediment build-up, water turbidity, and the breeding and feeding of the native habitats. Therefore, water flow and quality studies which typically include: water quality monitoring/modeling, project hydraulics study, wetland delineation study, sediment quality survey, are important in ensuring the construction of the powerplant and the following operation of the plant will not impact or have very little impact on the water flow (*Altered Water Flow* 2014). Dissolved oxygen is also another major concerns of hydropower. Development of hydropower-generating feature will result in a decrease in dissolved oxygen which will negatively affect the local water organism. Thus, it is crucial that dissolved oxygen levels upstream and downstream of dam should be closely monitored and reported, ensuring those levels remain consistent (*Monitoring Dissolved Oxygen at Hydropower Facilities* 2019). Minimizing the impact of the project on the terrestrial and aquatic habitat is also a crucial part of any project. Environmental studies such as terrestrial habitat study, aquatic habitat assessment, mussel survey, fish entrainment and passage study, are necessary. For instance, fish passage is a significant concern that should be address in considering adding energy turbines into the existing NPDs. Remediation measures like having fish ladder or in-take screen should be added to the new powerplant to ensure that fish can still safely pass through the dam without being caught in power turbines (*Environmental Impacts of Hydroelectric Power* 2013). Historical and recreational studies are also required for redevelopment project to preserve the cultural values of the existing NPDs.

There are many legal and financial incentives exist to encourage thorough environmental studies and minimizing of environmental impacts in converting NPDs. The Low Impact Hydropower Institute (LIHI) is a major organization that gives out certification for dams which will help augment economic viability of the project. LIHI certifying projects as low impact is not based on project's installed capacity (as typically defined by federal and state regulatory agency), but rather, LIHI certification depends on the extent of the environmental impact that the project would have. To obtain LIHI certification, a project must satisfy the following eight criteria:

1. Ecological flow regimes that support healthy habitats
2. Water Quality supportive of fish and wildlife resources and human use
3. Safe, timely and effective upstream fish passage
4. Safe, timely and effective downstream fish passage
5. Protection, mitigation and enhancement of the soils, vegetation, and ecosystem functions in the watershed
6. Protection of threatened and endangered species
7. Protection of impacts on cultural and historic resources
8. Recreation access is provided without fee or charge

(Low Impact Hydropower Institute Criteria)

LIHI certified projects are qualified for renewable energy credits (RECs), which is a major financial incentive for renewable energy projects. Furthermore, hydroelectricity from a LIHI certified producer is more appealing to the energy consumers (*Hydroelectric Permitting Manual for Pennsylvania*, 28). As a result, being LIHI certified will significantly benefit the economic feasibility and marketability of a project. LIHI certification, however, does required renewal every two years to ensure the environmental standard is continuously upheld. Thus, the time and cost for LIHI certification renewal in addition to the initial application fees should be added into the cost considerations of the project (*PA Hydropower Summit* 2011).

4. Cost Estimates

In the 2015 Oak Ridge report, *Hydropower Baseline Cost Modeling*, a construction cost model for NPDs is developed to give developers a rough estimate of the baseline initial capital cost for NPDs retrofitting. The report also found that most NPDs redevelopment project cost falls in the range of $1,000 - $10,000 in 2012-dollar value (O'Connor, Zhang, DeNeale, Chalise, & Centurion, 23). The cost estimate model for NPDs construction is developed as followed:

$$\text{Construction Cost (in 2012\$)} = 12{,}038{,}038 \times P^{0.980} \times H^{0.980}$$

(O’Connor et. al., 25)

Where P in the site’s installed capacity in MW and H is the average hydraulic head in ft. Additionally, USACE’s 2013 *Hydropower resource assessment at non-powered USACE sites*, also developed a cost model for operation and maintenance cost of dam retrofitting based on NPD’s specific installed capacity and heads. Using installed capacity estimate from national energy zone map, and available hydraulics head on the USGS database, this report has produced a rough cost estimates for a number of NPDs where there are enough data available calculation

(Table 2). Overall, the total cost of these NPDs in Pittsburg district is around $5,500 - $6,000 per kW in 2012-dollar value; these values lie within the middle of the estimated range in the Oak Ridge's report (O' Connor et. al., 23). These are only general estimates of the redevelopment cost and they are mostly influenced by the cost of construction and operational phase. The cost of planning phase, which mostly determined by the permit and licensing process is much more varying from site to site, depending on each dam's specific environmental assessment. In table 2, the historical and cultural status of the site is included to provide a rough idea for the cost estimate process of the planning phase. The historical and cultural status of each site is obtained from PHMC's CRGIS database; although there are many sites which are not specifically listed as either SHPO eligible or nationally registered as historical site (listed N/A in Table 2) on CRGIS. It should not be assumed that archeological and historical studies are not required because there is no guaranteed that the information on CRGIS being the most up-to-date information. The historical/ cultural status provided in table 2 should only be used as a guideline for which site is most certainly required historical studies and thus, sufficiently accounting this requirement in the planning cost.

Table 2. Pittsburg District NPDs Retrofitting Cost Estimate.

Name	**ID-Number**	**Installed Capacity (MW)**	**Hydraulics Head (ft)**	**Construction Cost Total ($)**	**Operation and Maintenance Cost ($)**	**Total cost per kW ($/kW)**	**Historical/ Cultural Status**
Allegheny Lock and Dam 02	LRD-01	34.69	12.362	199,780,184	5,309,194	5,912	N/A
Allegheny Lock and Dam 03 (C.W. Bill Young)	LRD-02	43.78	13.734	244,056,139	6,462,055	5,722	Eligible

Braddock Locks and Dam	LRD-11	19.48	12.237	113,793,910	3,098,333	6,001	N/A
Charleroi Lock and Dam	LRD-19	26.15	14.603	144,910,821	3,935,623	5,692	N/A
Dashield Locks and Dam	LRD-22	47.1	15.196	255,245,408	6,775,956	5,563	Eligible
Emsworths Locks and Dams	LRD-30	84.41	16.233	444,289,504	11,568,893	5,401	Eligible
Grays Landing Lock and Dam	LRD-32	19.4	11.431	115,400,871	3,129,800	6,110	N/A
Maxwell Locks and Dam	LRD-45	29.3	9.886	179,641,022	4,748,163	6,293	N/A
Monongahela Locks and Dam 03	LRD-48	12.61	12.984	73,148,132	2,040,343	5,963	N/A
Montgomery Locks and Dam	LRD-50	99.84	12.602	560,089,885	14,316,651	5,753	N/A
Point Marion Lock and Dam	LRD-62	15.25	12.142	89,706,362	2,468,916	6,044	N/A

5. Greenhouse Gas Reduction

Since hydropower utilized the kinetic energy of the water flow to turn the turbine and produce electricity, there is no burning of fuels involved. As a result, hydropower can avoid greenhouse gas emission which is unavoidable in PA's other source of energy like coal or nuclear power. Assuming a capacity factor of 0.25, this report calculated the estimated total energy generation of all 24 NPDs in kW-hr. The greenhouse gas emission avoided can be calculated as CO_2 equivalent from this estimated generation of each NPDs. From this calculation, it is estimated that energy produced from 24 Pittsburg District's NPDs can helped reduced greenhouse gas emission by 2.1 billion pounds of CO_2 equivalent (Table 3). This is equivalent to the amount of greenhouse gas emitted by burning up to 1 billion; this amount of greenhouse gas avoided is also approximately equal to amount of carbon sequestered by 1.3 million acres of U.S. forests in a year (*Energy and the Environment* 2020). Hence it is evident that the hydropower capacity of existing NPDs has great potential to reducing greenhouse gas emission and improving the environmental quality of Pennsylvania.

Table 3. Greenhouse Gas Reduction Estimates

Name	**ID-Number**	**Installed Capacity (MW)**	**Generation (kW-hr)**	**CO_2e reduced (Million lb)**
Allegheny Lock and Dam 02	LRD-01	34.69	75,971,100	118
Allegheny Lock and Dam 03 (C.W. Bill Young)	LRD-02	43.78	95,878,200	149
Allegheny Lock and Dam 04	LRD-03	34.05	74,569,500	116
Allegheny Lock and Dam 07	LRD-04	31.65	69,313,500	108
Berlin Dam	LRD-08	3.52	7,708,800	12
Braddock Locks and Dam	LRD-11	19.48	42,661,200	66
Charleroi Lock and Dam	LRD-19	26.15	57,268,500	89
Crooked Creek Dam	LRD-21	6.08	13,315,200	21
Dashield Locks and Dam	LRD-22	47.1	103,149,000	161
East Branch Dam	LRD-28	3.39	7,424,100	12
Emsworths Locks and Dams	LRD-30	84.41	184,857,900	288
Grays Landing Lock and Dam	LRD-32	19.4	42,486,000	66

Hildebrand Lock and Dam	LRD-40	15.8	34,602,000	54
Maxwell Locks and Dam	LRD-45	29.3	64,167,000	100
Monongahela Locks and Dam 03	LRD-48	12.61	27,615,900	43
Montgomery Locks and Dam	LRD-50	99.84	218,649,600	341
Morgantown Lock and Dam	LRD-51	12.99	28,448,100	44
Opekiska Lock and Dam	LRD-57	16.46	36,047,400	56
Point Marion Lock and Dam	LRD-62	15.25	33,397,500	52
Shenango Dam	LRD-66	7.48	16,381,200	26
Stonewall Jackson Dam, WV	LRD-67	2.72	5,956,800	9
Tionesta Dam	LRD-70	5.89	12,899,100	20
Tygart Dam	LRD-71	46.99	102,908,100	160
Union City Dam	LRD-72	4.99	10,928,100	17

IV. Conclusion

With 24 existing NPDs within the Pittsburg District having an estimated total potential installed capacity of up to 620 MW, Pennsylvania is possessing an extremely valuable source of clean, renewable energy. Although there are challenges in obtaining retrofitting license for these USACE NPDs due to the current complicated and ineffective permitting process, the benefits coming from the amount of additional energy added into the grid as well as the quantity of greenhouse gas cutback from switching to hydropower are proven to be immensely significant and worthwhile compared to the cost. Furthermore, with the state of Pennsylvania working tirelessly to simplify and improve the licensing process and creating economic incentives for both renewable energy in general, and retrofitting NPDs specifically. Thus, it is highly advisable to that energy developers start looking into and maximizing the great potential of hydropower in Pennsylvania's existing non-powered dams, as they are the future of energy production.

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