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# Colonial technopolitics in the Dutch East Indies: A study of hydroelectric power in Pamanoekan and Tjiasemlanden Plantation

***Abstract**. This study aims to explore the historical development of hydroelectric power technology in the Dutch East Indies during the early 20th century, with a* *particular focus on the Pamanoekan and Tjiasemlanden plantation, currently managed by PTPN VIII Tambaksari-Ciater Plantation area in Subang, West Java. It seeks to investigate the transformation of water engineering technology from indigenous vernacular irrigation systems to modern irrigation and eventually to hydroelectric power plants. The study also examines the process of technological adaptation, the role of colonial engineers, the origin of technical components, and the operational mechanisms of hydroelectric stations within the broader context of Ethical Policy and colonial technocracy. The study integrates textual archives, and material remains into an interpretive narrative using a historical archaeology method. Private colonial plantations are treated as sites where domination over natural resources was enacted. Fieldwork focused on three hydroelectric stations – Cijambe, Gunungtua, and Cinangling – and was complemented by diverse textual sources, including newspapers, engineering journals, speeches and proceedings of Dutch engineers, colonial water regulations, company booklets, geological surveys, and plantation maps. This study's analysis applies the concept of technopolitics, framing technology not as a neutral instrument but as integral to the political-economic agendas of colonial rule. Findings indicate that the three hydroelectric stations expanded the colonial infrastructure regime following the implementation of irrigation projects in Pamanoekan and Tjiasemlanden. The Ethical Policy provided a civilizing narrative that legitimized technical rationalization. Through water flow engineering, colonial authorities and private enterprises – mediated by engineers – rendered rivers calculable and measurable, sustaining plantation-based industrial production while maintaining indigenous subsistence rice cultivation. Thus, the development of hydroelectric technology in Pamanoekan and Tjiasemlanden was not merely a technical achievement but a technopolitical project that mobilized water resources to consolidate economic productivity through networks of private enterprises, technocratic agencies, and international equipment distributors.*

***Keywords:*** *hydroelectric power station; technopolitics; technocracy; ethical policy; colonialism; Pamanoekan and Tjiasemlanden*

## Introduction.

Hydropower emerged as a key technology during the industrialization and modernization of the early 20th century. In the aftermath of World War I, amid growing competition in technological innovation, industrial expansion, and modern imperialism, countries such as Germany, Britain, and Switzerland developed hydropower as an alternative energy source (Cramer, 1914, p. 27) Beyond supplying electricity for urban lighting, it powered tram networks and stimulated new industries in electrochemistry and electrometallurgy (Floud, 1980). For imperial powers like the Netherlands, the rapid advancement of water engineering – through irrigation and hydropower – was strategically deployed to reinforce liberal economic policies (1870) and to legitimize the so-called civilizing mission of the Ethical Policy in the Dutch East Indies (Indonesia) (Bruno, 2023; Ravesteijn, 2007).

The modernization projects and the introduction of new technologies in the Dutch East Indies during the first decade of the 20th century were largely driven by the Ethical Policy – an initiative aimed at improving the welfare of the indigenous population. The Ethical Policy emphasized three main pillars: immigration, education, and irrigation. Yet in practice, irrigation projects often benefited private investors who had already established large-scale plantation industries in the colony (Moon, 2007). For the colonial government, the development of irrigation technology served a dual purpose: strengthening the agricultural sector that sustained the indigenous population's livelihood, while supporting foreign investment in plantation enterprises. Java became the center of these initiatives, as its population had historically been an agrarian society skilled in managing water circulation for farming (Christie, 2007). Moreover, Dutch imperial profits in the 19th century heavily depended on agricultural cultivation – coffee, rubber, cinchona, tea, rice, and sugar – making irrigation a vital factor in boosting production. The technical execution of these projects was entrusted to engineers trained at the Delft Institute of Technology, a leading institution renowned for its expertise in hydraulic engineering (*waterstaat*) (Oud-Alblas, 2012).

The development of irrigation engineering in the Dutch East Indies laid the foundation for more advanced technological applications, particularly hydropower, which played a crucial role in supporting the expansion of plantation industries, railway networks, and urban electricity systems. Before 1900, the Dutch engineer J. C. Melchior introduced the Melchior Method, a hydrological and technical design approach for calculating the optimal capacity of water in colonial hydropower projects. Recognizing the potential of water power, the colonial government established the *Waterkrachtbureau* (Water Power Bureau) in 1910, followed by the *Dienst voor Waterkracht en Electriciteit* (Government Service for Water Power and Electricity) in 1917 (Stibbe, 1939). The use of electricity was part of the colonial rationalization project, in which modern technology was deployed to strengthen control and increase production efficiency, in line with the logic of colonial capitalism, which is rooted in the exploitation of natural resources. In the Javanese sugar industry, for example, electric motors replaced steam engines powered by bagasse, reducing operational costs while enhancing production capacity (Knight, 2014). Similarly, in the tea plantations of the West Javanese highlands, small-scale hydropower was employed to operate factory machinery, provide lighting for administrative offices, and supply electricity to nearby urban areas (Stibbe, 1939). The geographical conditions of West Java – with its abundance of rivers, springs, and fertile volcanic soils in the uplands – provided the ecological basis for the successful development of hydroelectric power technology in the region (Bemmelen, 1934).

Notably, the hydropower infrastructure built by the colonial government and private companies continued to operate after Indonesian independence and remains in use today, particularly in West Java. Several large-scale hydropower plants, such as Dago, Lamajan, and Ubrug, are now managed by the state-owned company

*Perusahaan Listrik Negara* (PLN) to support electricity supply in urban areas. Meanwhile, smaller hydroelectric stations such as Cijambe, Gunungtua, and Cinangling, located on former Pamanoekan and Tjiasemlanden plantation lands, are still utilized by PT Perkebunan Nusantara to provide electricity for estate offices and, to a limited extent, nearby settlements. Yet despite their persistence, colonial hydropower systems remain understudied, often approached as heritage sites rather than as technopolitical instruments of domination. Examining these infrastructures is crucial for understanding how colonial engineering materialized power relations through the control of water, labor, and energy, leaving a tangible legacy of governance embedded within Indonesia's postcolonial physical landscape.

This study examines the development of hydroelectric technology on former colonial private plantations, where both natural and human resources were simultaneously exploited and controlled. The analysis focuses on the Pamanoekan and Tjiasemlanden Plantation in Subang, Indonesia, one of the largest private plantations in West Java during the 19th and 20th centuries. It explores the technological transformation of hydroelectric power, the processes of technological transmission, and the actors involved in its implementation. Rather than treating hydroelectric plants as neutral technical instruments, this study frames them as integral components of the political-economic objectives of colonial governance (Hecht, 2010; Mitchell, 2002). Timothy Mitchell (2002) demonstrates that technologies embody particular ways of organizing visibility, calculability, and control – what he terms colonial rationality. We argue that the modernization and rationalization of water engineering, both in irrigation and hydropower, in the Pamanoekan and Tjiasemlanden Plantation displaced vernacular systems of water management grounded in the empirical experience of local communities, which James Scott (1998) refers to as "metis."

The implementation of modern technologies in the colony depended on the technocratic role of engineers (Mrazek, 2002; Ravesteijn, 2007) as well as on global hardware networks that transmitted hydropower infrastructures into the colonial sphere. Components such as intakes, penstocks, and turbines can be read as material expressions of colonial governance. Their design carried assumptions of efficiency and order, projecting colonial ideals of modernity and discipline onto the landscape. Thus, we position hydroelectric technology not merely as a technical project but as a colonial instrument of control – by both state and private actors – over natural resources that sustained economic productivity, legitimized through narratives of civilization and claims of improving indigenous welfare.

This study represents an initial attempt to examine hydroelectric technology in colonial private plantations through a science, technology, and society (STS) lens. Historical studies that employ STS approaches – or STS studies focusing on Indonesia – remain limited. Previous study has examined electrification (McCawley, 1971), irrigation within the framework of the Ethical Policy (Moon, 2007), colonial public works (Nispen & Ravesteijn, 2009; Ravesteijn & Kop, 2008), technology and national imagination (Mrazek, 2002), post-independence modernization (Fakih, 2020), and the technocratic visions of the New Order regime (Amir, 2012). In contrast, research on hydropower in Indonesia has largely treated it as colonial material heritage, whether from archaeological (Fadlurrahman, 2023; Hermawan, 2016) or historical (Kholis Sofiah & Hakim, 2020) perspectives, without engaging critically with its colonial political-economic context. To our knowledge, no study has addressed hydropower technology in colonial private plantations through an STS framework. This study seeks to fill that gap.

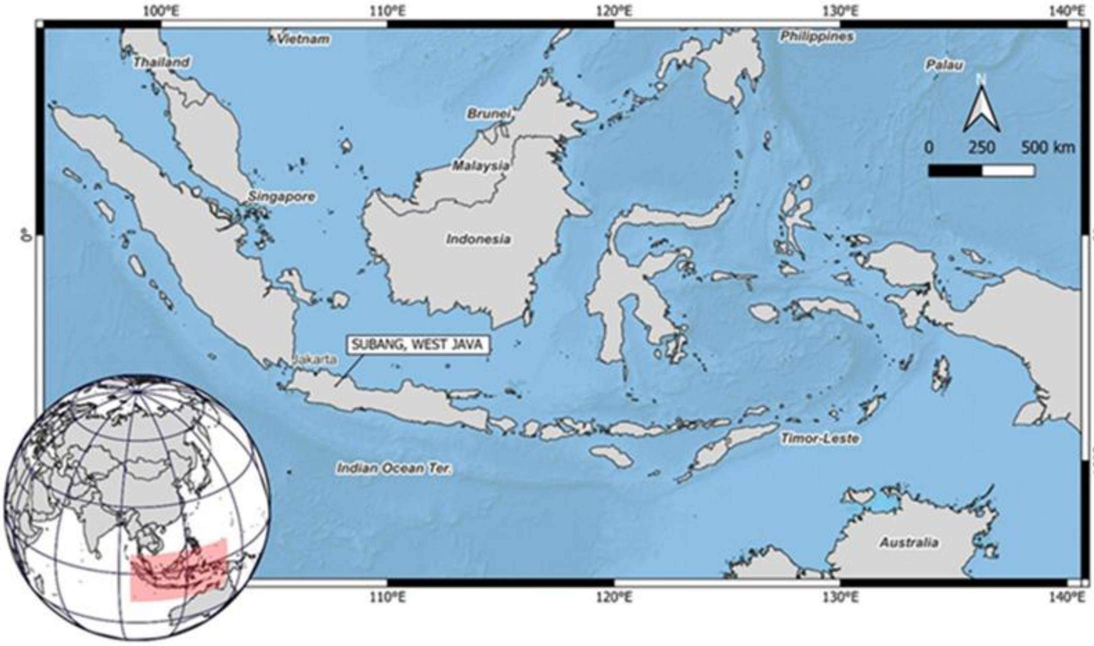


**Figure 1.** Research location in Subang, West Java, Indonesia (Author's Source).

**Research Location.**

We conducted this study in a former plantation area known as Pamanoekan and Tjiasemlanden, located in present-day Subang, West Java (Figure 1), which is now operated by PTPN VIII as the Tambaksari-Ciater Estate. Pamanoekan and Tjiasemlanden were the largest privately owned plantations in Java during the 19th and 20th centuries, cultivating a variety of estate crops (Imadudin, 2014). British entrepreneurs Muntinghe and Shrapnell, affiliated with Skelton and Co., established the estate in 1812. Shrapnell acquired approximately 212,900 hectares of land defined by specific geographical features: the Java Sea to the north, the Cilamaya River to the west, part of the Cipunagara River and the Cirebon prefecture to the east, and Mount Tangkuban Parahu to the south (P & T Land, 1954, pp. 5–6). In 1840, Dutch brothers Peter Willem Hofland and Thomas Hofland acquired the P&T Land. In 1853, they divided the land into eight administrative units: Tjiasem, Pamanoekan, Malang, Pagaden, Soebang, Kalidjati, Sagalaherang, and Batoe Sirap (P & T Land, 1954).

The Hofland brothers established *N. V. Maatschappij tot Exploitatie der Pamanoekan en Tjiasemlanden* in 1886. However, the company lasted only briefly due to poor financial conditions and the decline in coffee prices in the international market during the 1880s. All Hofland shares, valued at 2,300,000 guilders, were sold to *N. I. Landbouw* in 1905 (Broersma, 1938). Subsequently, *N. I. Landbouw* resold the shares to The Anglo-Dutch Plantation of Java Ltd in 1910 (Broersma, 1938). Since then, the 212,900 hectares of land have been managed by the Anglo-Dutch Plantation, becoming the largest private estate in Java (Imadudin, 2014). By 1940, before the outbreak of World War II, the Pamanoekan and Tjiasem estate produced various commodities such as tea, rubber, cassava, sisal, kapok, pepper, cocoa, cinchona, coffee, rice, teak, balsa wood, Chinese tung oil tree (*Aleurites Montana*), derris root, and cashew nuts (P & T Land, 1954).

The establishment of the Pamanoekan and Tjiasemlanden plantation industry stimulated the development of infrastructure, settlements, and urban facilities that laid the foundation for the town of Subang, West Java (Pranata & Akbar, 2022). Within the Tambaksari-Ciater Estate area, three hydroelectric power stations (*waterkrachtwerk*) remain (Figure 2): Cijambe Hydroelectric Power Station (established in 1912), Gunung Tua (established in 1922), and Cinangling (established in 1936). Currently, two of the three stations – Cijambe and Gunung Tua – are still operational, supplying electricity to the Tambaksari-Ciater Plantation industry, which comprises four plantation sites inherited from Pamanoekan and Tjiasemlanden: Kasomalang, Tambakan, Sarireja, and Bukanagara.


**Figure 2.** Photographs of the Cijambe, Gunung Tua, and Cinangling Hydroelectric Power Plants (Authors' Source).

**Research Methods.**

To achieve the objectives of this study, we employ the method of historical archaeology, which integrates oral accounts, textual sources, and material remains into an interpretive narrative (Wilkie, 2006). This approach is particularly appropriate given that the objects of our investigation are closely tied to material elements such as power stations, generators, transformers, pipelines, and cable networks. We consider colonial private plantations ideal for examining how domination and authority operated over natural resources and human labor. In this context, colonialism is a material phenomenon in which power was embedded in material culture and practices associated with symbolic centers (Lawrence & Shepherd, 2006).

Our archaeological data were collected from three hydroelectric power stations – Cijambe, Gunung Tua, and Cinangling – including generators, turbines, penstock pipes, sluice gates, and surrounding geomorphological features such as rivers and artificial lakes. Textual sources were drawn from newspapers such as *Bataviaasch Nieuwsblad*, *De Koerir*, and *Sumatera Post*; magazines such as *Nederlandsch-Indië Oud & Nieuw*; civil engineering journals such as *De Ingenieur*; proceedings and speeches published in *De Ingenieur in Nederlandsch-Indië op Etechnisch en Sociaal Gebied*; water management laws and regulations compiled in *Agrarische Regelingen voor het Gouvernementsgebied*; technical papers authored by Dutch engineers; company profiles of the Pamanoekan and Tjiasemlanden plantation; geological reports on Java (*Geologische Kaart van Java*); and historical maps including *Kaart van de Afdeeling Krawang*, *Kaart Pamanoekan en Tjiasem*, as well as maps of power stations and distribution networks.

Our research followed four stages. (1) Data collection and classification: this stage involved surface surveys focusing on the three hydroelectric power stations and their environmental settings, a review of relevant literature, tracing of historical maps, and identification of early 20th-century printed sources. (2) Sorting, selection, and verification of data. (3) Contextualization and analysis: verified data were analyzed by cross-checking historical information with visible material culture, including spatial analysis of power stations, penstocks, sluice gates, and adjacent waterways. (4) Interpretation: In this stage, material elements were read as autonomous texts containing diverse kinds of information (Ferguson, 2011; Hicks & Beaudry, 2006). The material evidence was then compared with textual sources to identify connections, gaps, and tensions between them. We produced a critical interpretation from this process, which was subsequently organized into a historical narrative.

**Results and Discussion.**

**Governing through Water and the Transition from Vernacular Irrigation to Colonial Hydropower.**

Since the 19th century, colonial maps – ranging from the *Kaart van de Afdeeling Krawang* (1853) and the *Map of Krawang* (1914) to the specialized map of

Pamanoekan and Tjiasemlanden (1955) – depicted Subang primarily through its waters: river networks, hydrological forests, and toponyms beginning with "Tji" or "chai," meaning water in Sundanese (Carnbee et al., 1853; Oudemans, 1914; *Pamanoekan en Tjiasemlanden*, 1955; Rigg, 1862). The Sundanese, the largest ethnic group in West Java, have historically grounded their spatial orientation and cultural practices in water. Place names such as Tjiherang ("clear water") were not merely geographical designations but cultural markers, underscoring water as the center of Sundanese cosmology. From the outset, therefore, this landscape was envisioned both by indigenous communities and colonial authorities as one that was articulated through water.

The abundance of Subang's water resources is evident in the presence of numerous springs – Cimutan, Cileuleuy, and Cipabeasan – as well as three major rivers, the Cipunagara, Ciasem, and Cilamaya, which originate in West Java's volcanic mountains. Geologically, this abundance is linked to Quaternary volcanic deposits and the topography that shapes the southern Subang plain (Silitonga, 1973; Bemmelen, 1934). These conditions rendered Subang a "hydrological enclave," where nature provided fertile ecological resources while simultaneously offering colonial administrators and plantation entrepreneurs a strategic reserve of water and potential energy.

For the Sundanese communities, the hydrological landscape had long been managed through a combination of cosmological and ecological practices. Spatial divisions – upstream areas as sacred sites, midstream areas as centers of agriculture and settlement, and downstream zones for ponds and sanitation – reflected a circulation system in harmony with the environment (Kus, 2019; Prestasi & Kim, 2020). Before the 16th century, Sundanese communities practiced swidden cultivation alongside vernacular forms of water use, while also maintaining cosmological notions of sacred springs and ecological order. The expansion of Mataram's influence in West Java during the 16th century further introduced and consolidated irrigated rice cultivation, transforming shifting fields into more permanent wet-rice systems supported by traditional irrigation (Wertheim, 1956). Technologies such as the *pantjoeran* (bamboo water spout) and communal irrigation channels thus represented a vernacular water management system that was adaptive and sustainable. This embodied a logic of water use distinct from colonial technical calculation: one rooted in sacredness and ecological balance rather than exploitation and efficiency.

Thus, Subang's geographic, geological, and cultural landscape should not be read merely as a descriptive backdrop but as a historical arena where two knowledge regimes intersected: the traditional Sundanese system that integrated water into everyday life, and the colonial regime that regarded water as a resource to be mobilized for plantation production and energy. This contrast set the stage for the emergence of colonial technopolitical projects in the late 19th century, when Subang's water potential was redirected from local systems to modern irrigation schemes.

In the 19th century, the Subang region – later incorporated into the private plantation domain of Pamanoekan and Tjiasemlanden – underwent a gradual transformation in water engineering. During the first half of the century, the plantation relied on a relatively simple irrigation system known as *slokkan bezaar* or *sorotan*. Constructed with locally available materials, including bamboo, coconut trunks, and stones, this small-scale system diverted water from rivers or springs. Its construction was carried out through communal labor or forced labor under the supervision of the village head (Lekkerkerker, 1938). Such arrangements reflected a vernacular mode of water management: low-tech, adaptive, and embedded in local social obligations and responsibilities.

Archaeological evidence substantiates this practice, most notably a commemorative monument dated 1861 in Purwadidi Village, which records the construction of a major canal in Curugagung (Figure 3). The inscription attributes the project to Mas Tjakra Pradja, a local official, who carried it out under the order of Mr. Hofland, the European administrator of the plantation (Nuralia, 2016). While the monument rhetorically portrays the canal as serving "the benefit of the common people," (*boeat orang ketjiel*), its location reveals its primary function: supporting plantation expansion and strengthening colonial administration. Indigenous elites, such as Mas Tjakra Pradja, thus operated as intermediaries who lent local legitimacy to projects that, in practice, subordinated vernacular irrigation systems to the priorities of estate agriculture. This shift illustrates the early displacement of vernacular water management by colonial rationalities. What had once been communal practices rooted in ecological adaptation was reconfigured into projects framed as public works but materially aligned with plantation needs.

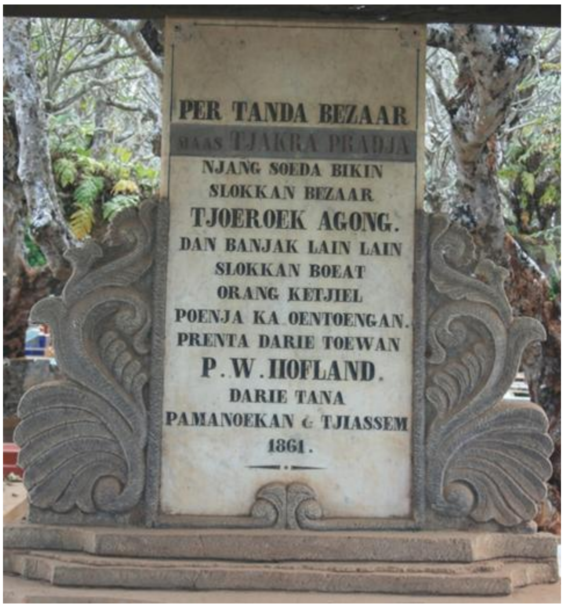


**Figure 3.** Commemorative monument of the irrigation canal construction, inscribed with the year 1861 (Nuralia, 2016).

In the 19th century, alongside irrigation channels, a rudimentary dam was constructed at Curugagung to regulate the flow of the Ciasem River ("Opening Der Tjoeroegagoeng-Werken," 1933; "Pembukaan Tjoeroegagoeng," 1932). Early structures, such as the Curugagung dam, built from stacked stones, reflected the limitations of colonial water control: they were fragile against floods and insufficient for the growing needs of plantations (Numans, 1918). By the 1870s, however, the colonial state, through the *Burgerlijk Openbare Werken* (Department of Public Works), introduced reinforced concrete dams, precisely mapped irrigation channels, and engineered intakes calibrated through hydrological measurements (Figure 4) (Numans, 1918; Nispen & Ravesteijn, 2009). By the late colonial period, such systems irrigated nearly 1.5 million hectares across Java (Ravesteijn, 2007).

**Figure 4.** Modern irrigation system with concrete framework in Java, early 20th century (Numans, 1918).

Yet these developments were never neutral technical improvements. The expansion of irrigation was embedded in the Dutch Ethical Policy, a reform agenda framed as a moral obligation to improve indigenous welfare while in practice reinforcing colonial control (Kartodirdjo, 1990). Irrigation, along with migration and education, was promoted as evidence of benevolent governance. Still, it was equally indispensable for the plantation economy, particularly the expanding sugar industry at the end of the nineteenth century. Irrigation thus served a dual role: stabilizing subsistence production to secure labor and legitimacy, while simultaneously guaranteeing the water supply required for colonial agribusiness. Irrigation became more than an agricultural aid; it functioned as a technopolitical infrastructure that translated Ethical Policy rhetoric into material control over land and people. Standardized dams and intakes transformed water into a calculable, governable resource, subordinating vernacular practices to colonial priorities. This shift also laid the groundwork for subsequent hydropower development. By reconfiguring rivers into rationalized flows and measurable discharges, the colonial irrigation regime established the technical and institutional foundations upon which hydroelectric power plants would later be constructed.

The modernization of irrigation in Subang laid the foundation for hydroelectric development in the Pamanoekan and Tjiasemlanden estates. In 1912, the Cijambe Hydroelectric Power Station was established under a government concession, making it one of the earliest plants in the Netherlands East Indies (Broersma, 1938; Stibbe, 1939). Managed by engineer Van Leeuwen and supported by C. W. Weys's broader modernization program, Cijambe powered rice mills, factory machines, and electric lighting – an achievement that marked a milestone in plantation electrification at a time when petroleum-based generation was still rare (Editor N. v. d. D. v. N. I., 1912; "Rechtzaken," 1917; "Soebang," 1930).

Following the estate's transfer to Anglo-Dutch ownership, additional hydroelectric stations were built: Gunungtua in 1922 and Cinangling in 1932, both relying on water regulated by the Curugagung Dam ("Opening Der Tjoeroegagoeng-Werken," 1933). These run-of-river facilities, together, produced under 5,000 kW – far less than larger hydro plants such as Lamadjan or Ubrug – and were dwarfed by steam power stations at Weltevreden and Sukamandi (Table 1) (Stibbe, 1939; Allied Geographical Section, 1945). Despite their modest scale, they supplied electricity across Subang, Ciater, Kasomalang, and surrounding districts, reinforcing plantation productivity and extending colonial infrastructure into the rural landscape (Figure 5).

The construction of irrigation infrastructure, both vernacular and modern, including hydroelectric power stations in Pamanoekan and Tjiasemlanden, relied heavily on the labor of local peasants and communities. Colonial private plantations that obtained state concessions (*erfpacht* rights) drew upon existing patron–client structures between peasants, workers, and indigenous elites. These elites mobilized local labor for plantation infrastructure projects, while those with professional education occupied higher-ranking positions within the plantation hierarchy, serving as intermediaries between plantation managers and workers. In daily operations, indigenous foremen (*mandor*) supervised laborers and peasants, whereas Dutch engineers held senior positions as technical heads or factory chiefs, ensuring that irrigation and hydropower electrification functioned effectively to sustain plantation production. This layered organization of labor illustrates how colonial rationality operated through infrastructures of water and power – not only to organize the flow of rivers, but also to discipline and control the workers whose labor sustained the plantation economy.

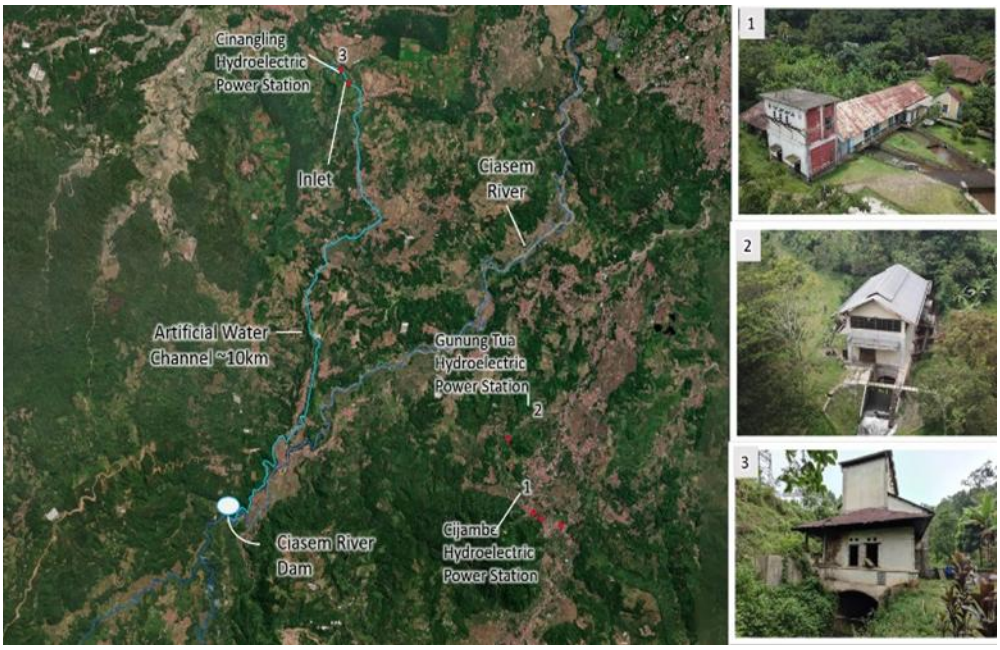


**Figure 5.** Water supply from the Ciasem River and the locations of three hydroelectric power stations: (1) Cijambe [6°37'53.24"S; 107°43'17.35"E], (2) Gunungtua [6°36'56.29"S; 107°43'19.93"E], (3) Cinangling [6°33'42.91"S; 107°41'8.38"E] (Authors' Source).

**Table 1.** Electricity Supply in West Java, Dutch East Indies (Source: Allied Geographical Section (1945)).

| Types of Power Plants | Location of power stations | Power |
|---|---|---|
| Thermal power plant | Weltevreden | 5.000 – 10.000 kW |
| | Soekamandi | 5.000 – 10.000 kW |
| | Pamanoekan | 5.000 – 10.000 kW |
| Hydroelectric power plant | Kratjak | 10.000 – 25.000 kW |
| | Oebroeg | 10.000 – 25.000 kW |
| | Lamadjan | 10.000 – 25.000 kW |
| | Tjiandjoer | Below 5.000 kW |
| | Tjinangling | Below 5.000 kW |
| | Goenoengtoea | Below 5.000 kW |
| | Tjidjambe | Below 5.000 kW |

**Materializing Colonial Control: Hydropower Engineering in Cijambe, Gunungtua, and Cinangling.**

Hydropower development in West Java illustrates how water was reorganized from a vernacular resource into a calculable force embedded in colonial governance. Rivers that had long sustained agrarian livelihoods were reframed as measurable flows, with their volume and pressure translated into horsepower; their channels were diverted into pipes and turbines. This transformation displaced local practices rooted in empirical adaptation with a rationality that privileged visibility, order, and efficiency. West Java, with its abundant water resources, became the foremost site for this transformation (Groothoff, 1921, p. 496). Private enterprises and state-related projects alike established hydroelectric plants, often using them for industrial and lighting purposes. Mountainous plantations, such as Pamanoekan and Tjiasem, had distinct geographical advantages, enabling electricity generation with relatively limited capital investment.

The Cijambe Hydroelectric Power Station, inaugurated in 1912, was among the earliest examples (Stibbe & Spat, 1927, p. 309). Located on the Cileuleuy River, a tributary of the Cipunagara, it produced 1000 HP and supplied energy for the estate's rice mills, machinery, and lighting. Its design diverted water through a bifurcated canal into a receiving basin, before channeling it via buried Mannesmann steel pipes that created a 30-meter head for two Francis turbines directly coupled with generators (Maassen & Hens, 1934, p. 952).

Like other private plants in West Java, Cijambe employed turbine models originally developed in mid-19th-century Europe (Groothoff, 1921, p. 496). These Francis turbines, oriented horizontally and connected to compact generators (Figure 6), exemplified efficient small-scale hydropower installations suited for plantation contexts (Slikkerveer, 1937, p. 241; Viollet, 2017, pp. 572–577). The adoption of such systems underscored how colonial engineers selectively adapted European technology to local conditions, embedding imported standards of efficiency into the everyday operations of the plantation economy.

To understand the operational logic of hydroelectric power in the Pamanoekan and Tjiasemlanden estate, we examined the surviving structures of three power stations. Hydropower plants in this region followed a standardized design that translated natural water flows into energy systems. Water captured at an intake was channeled through penstocks to drive turbines, which were directly coupled with generators to produce electricity. Transformers then elevated the voltage for distribution to plantations and surrounding facilities. These components – intake, penstock, turbine, generator, transformer, and transmission line – were not merely technical devices but material infrastructures that converted rivers into sources of industrial energy, embedding colonial ideals of efficiency and order into the landscape.

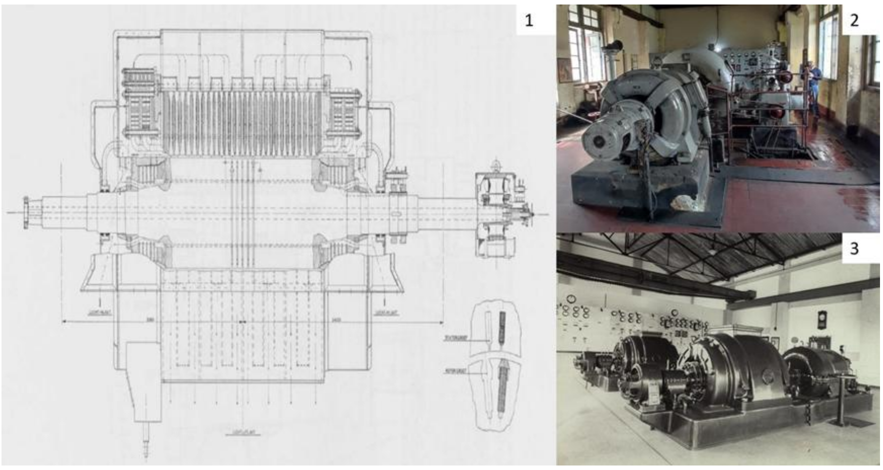


**Figure 6.** Generator design and examples used in the Dutch East Indies: (1) Horizontal generator design by Willem & Smit Co.; (2) generator unit at the Cijambe hydroelectric power station, Subang, West Java; (3) generator at the Durian hydroelectric power station, Sawahlunto, West Sumatra, in 1915 (Slikkerveer, 1937; Authors' documentation (2023); KITLV A1187).

The hydroelectric plants of Cijambe, Gunungtua, and Cinangling relied on run-of-river systems, using modest intake gates rather than large dams. At the Cijambe power station (Figure 7), water from the Cileuleuy River was diverted through two successive intakes near Pintu Village, with part of the flow channeled to rice fields while the rest entered the penstock. Gravity carried the water to the turbines, which powered a generator that supplied electricity to the plantation headquarters at Ciater, Subang. The Cijambe station remains operational today, providing energy to the Tambaksari–Ciater plantation under PTPN VIII, illustrating the persistence of colonial-era infrastructure.


**Figure 7.** Schematic of Water Supply from the Cileuleuy River to the Cijambe Hydroelectric Power Plant (Authors' Source).

The Gunungtua hydroelectric station (Figure 8), built in 1922, expanded this network. Drawing water from the Cibulakan River and the artificial Lake Sentiong, situated higher than the plant itself, ensured a regulated and powerful flow to drive its turbines. The Cinangling power station (built in 1932) relied on river diversions from the Cikopi and Pasir Nangka Rivers but is no longer operational due to a failed generator and intake system. Nevertheless, the remnants of its Dutch East Indies–era engineering remain visible, enabling us to reconstruct its former operations and revealing how colonial hydro-infrastructures reshaped landscapes to serve plantation needs.


**Figure 8.** Water supply from Lake Sentiong to the Gunungtua Hydroelectric Power Station (Authors' Source).

The Cinangling hydroelectric power station (Figure 9) harnessed kinetic energy from the Cikopi River, which originates at Curugagung and flows into the Ciasem River. According to *De Koerir* ("Pembukaan Tjoeroegagoeng," 1932), its construction was closely tied to the completion of the Curugagung Dam in 1931, which not only irrigated rice fields and plantations but also provided surplus flow for power generation. The report even claimed that Cinangling could produce more electricity than the combined output of Cijambe and Gunungtua.

Remains of the Cinangling station – three intake gates, a filtering gate, a penstock, a powerhouse, and a damaged generator – still reveal its operation. Water descended from 231 meters above sea level through the penstock to the powerhouse at 139 meters, where turbines and generators supplied electricity to Wangunreja and Jalupang plantations as well as the Cijambe station.

Field surveys show that even today, water overflow from Cinangling continues to irrigate local rice fields, confirming the dual function of these infrastructures as both industrial energy sources and irrigation providers. This duality was formalized in the 1919 land lease agreement between the Anglo-Dutch Plantations of Java Limited and the colonial state, which restricted hydropower use to prevent disruption of indigenous irrigation rights (Departement van Gouvernementsbedrijven, 1924, p. 46). Ultimately, the Three hydroelectric power station illustrates how colonial hydropower embodied both the rationalized order of plantation modernity and the negotiated persistence of local needs. While framed as advancing productivity and welfare, its design reveals a technopolitical compromise: transforming rivers into engines of colonial industry while maintaining just enough flow to sustain the subsistence agriculture of surrounding communities.

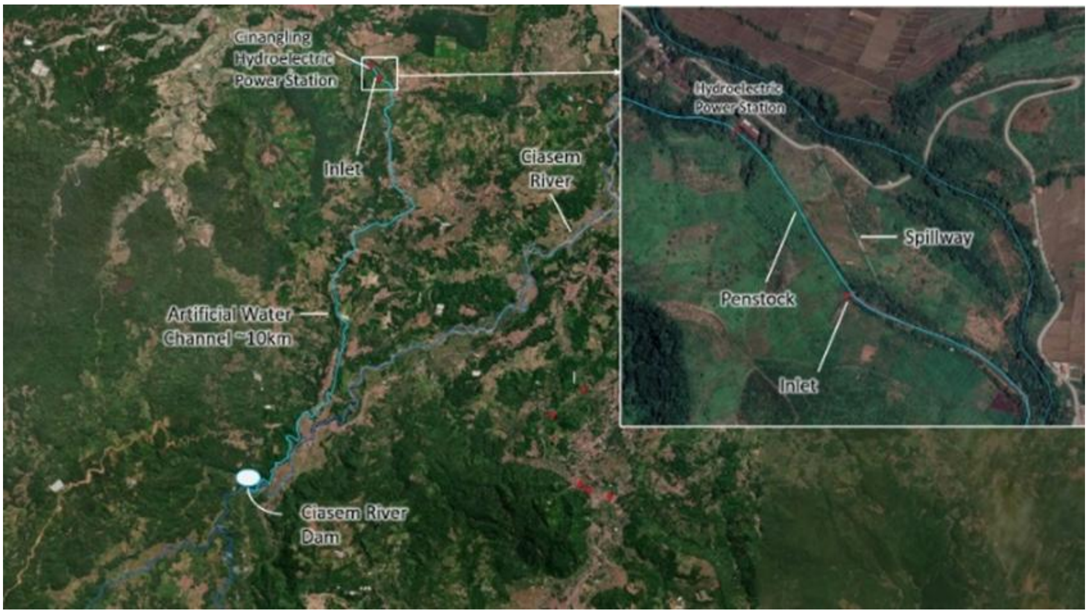


**Figure 9.** Water supply from the Cileuleuy River to the Cinangling Hydroelectric Station. Overflow water is channeled to local peasants' rice fields (Authors' Source).

**Technological Circulation, Industrial Networks, and the Role of Engineers.**

Based on field observations, the Cijambe hydroelectric power station utilizes a generator manufactured by Bell Maschinenfabrik AG of Kriens, Switzerland, a company established in 1855. The generator currently in use was installed in 1952 as part of post-war rehabilitation efforts following damage sustained during the Indonesian National Revolution (1945–1949) (Indie West-Java's Rijstpellerijen," 1947). Although the transformer and switchboard at Cijambe have not been definitively identified, archival sources and technical records (Hermsen & Ahlers, 2008; Hermsen, 2015) suggest that these components were manufactured by *Willem Smit & Co. Slikkerveer* (Figure 10). Similar equipment was employed at the power plants in Tanjungpriok (1894) and Lamajan, Pangalengan (1923), reflecting the dominance of

Dutch electrical firms in colonial infrastructure (Hermsen, 2014). It is therefore plausible that the original Cijambe generator, before wartime destruction, was also a product of *Willem Smit & Co.*

**Figure 10.** Switchboard at the Cijambe hydroelectric power station (Authors' Source).

Further archival evidence indicates that the *Heemaf Agency* in Surabaya, with branches in Bandung and Batavia, distributed *Willem Smit & Co.* transformers and generators throughout the Dutch East Indies ("Agentschap Heemaf Soerabaia," 1922; "Het Droogdok Voor Soerabaja," 1913). The agency imported electrical components from Nijmegen and supplied port illumination systems in Surabaya. Its catalog included a range of European electrical products – cables from Delft, mechanical parts from Hengelo, *Philips* lamps from Eindhoven, and wire materials from Amsterdam (Figure 11) ("Agentschap Heemaf Soerabaia," 1920). Registered in the *Handboek voor Cultuur en Handelsondernemingen in Nederlands-Indië* (Bussy, 1925), *Heemaf* – founded in 1909 as the *Hengelosche Electrische en Mechanische Apparaten Fabriek* – served as the exclusive colonial representative for *Willem Smit & Co.* transformers. To ensure optimal performance in tropical climates, the agency established testing facilities, oil-drying units, and climate-controlled warehouses, and employed Dutch engineers to oversee installation and maintenance ("Uitbreiding Hollandsche Electrische Zaken in Indië.," 1920).

Together, these findings reveal a complex network of technological circulation that linked Europe and the Indies through colonial trade and expertise. Electrical innovation emerged in the Netherlands as early as 1886, when Willem Benjamin Smit established the first Dutch power plant at Kinderdijk, utilizing an 80 HP steam engine to drive two 7.5 kW dynamos (Hermsen, 2011). In contrast, electricity generation in the Dutch East Indies only began in 1897 with the government-approved power plant at Koningsplein, Batavia (Stibbe, 1939, p. 1924), followed by installations in Medan (1899), Solo (1902), and Bandung (1906). The eleven-year delay underscores not merely logistical or technical constraints, but the colonial hierarchy of innovation, where the periphery selectively and strategically absorbed metropolitan technologies according to the empire's economic priorities.


**Figure 11.** Advertisement of Heemaf, distributor of electrical equipment for industry in the Dutch East Indies (Het Nieuws van den Dag voor Nederlandsch Indie, 21 August 1920).

Ideological and administrative factors also contributed to the temporal and spatial lag in electrification. The turn of the 20th century saw the Dutch government adopt the Ethical Policy, rooted in the notion of *Eereschuld* – a "debt of honor" owed to the Javanese population (Furnivall, 2010). While framed as a moral obligation to improve indigenous welfare through education, irrigation, and migration, its implementation largely served economic and political objectives: maximizing productivity, expanding markets, and ensuring a disciplined labor supply. In this sense, technological adaptation in the Indies reflected not only material modernization but also the rationalization of colonial governance through the development of infrastructure.

Engineers were the key agents of colonial technocracy. Archival sources, such as *Bataviaasch Nieuwsblad* ("Rechtzaken," 1917), *Encyclopaedie van Nederlandsch Indie* (Stibbe & Spat, 1927, p. 309), and *De Ingenieur* (Groothoff, 1921), record that Engineer C. W. Weys and his assistant, F. A. Janssen van Raay, led major water-engineering projects at Pamanoekan and Tjiasemlanden. Their work included the construction of sluice gates, irrigation channels, and pipelines for the hydroelectric power station, culminating in the establishment of the Cijambe facility in 1912. As head engineer of the estate, Weys oversaw not only electrification but also the modernization of plantation operations. In 1911, he established a rice mill on the slopes of Mount Tangkuban Parahu equipped with mechanized processing units and electric lighting powered by a 15,000-volt dynamo (Editor N. v. d. D. v. N. I., 1912). He further initiated agricultural experiments, such as sugarcane cultivation near Pagaden, and proposed transport improvements, including a tramway line from Subang to Pamanukan, to overcome the poor road access.

Weys led the Pamanoekan and Tjiasemlanden plantation until 1912 before continuing his career as Chief Engineer at the *Burgerlijk Openbare Werken* (Department of Public Works) (Sandick, 1920). Trained at Delft, he represented a generation of engineers who bridged the gap between metropolitan expertise and colonial governance. His later role on the Education Committee for the establishment of the *Technische Hoogeschool* (Technical College) in Bandung in 1920 ("De Opening van de Indische Technische Hoogeschool," 1920). illustrates how the colonial state institutionalized this technical rationality through higher education. Weys's appointment as professor of Hydraulic Engineering at the Delft Institute of Technology further attests to his prominence within transnational engineering networks linking the Netherlands and its colonies. Alongside his academic and governmental roles, he also served as director of the private company *N. V. Rystlanden Michiels-Aroold* ("De Opening van de Indische Technische Hoogeschool," 1920), reflecting the fluid boundaries between public service, private enterprise, and colonial exploitation.

His multiple positions – as plantation engineer, state technocrat, and educator – exemplify the technopolitical nexus that underpinned Dutch colonial modernization. Professional organizations, such as the Koninklijk Instituut van Ingenieurs and the Vereniging van Delftse Ingenieurs, actively promoted this nexus through a civilizing mission aligned with Calvinist ethics and imperial ambitions. These associations framed technological advancement as a moral endeavor, preparing Delft-trained engineers to engage with "native" societies as agents of both progress and control (Cramer, 1914). The professional ethos they cultivated made technical competence inseparable from the ideological responsibility to govern and "improve" colonial subjects.

This ideological outlook was reinforced by figures such as R. A. van Sandick and Henri van Kol, who infused Dutch engineering with moral and social dimensions through *De Ingenieur* and Delft's student circles (Oud-Alblas, 2012). Their socialist and activist perspectives recast engineering not merely as a mechanical profession, but as an ethical vocation that addresses the tension between technological progress and human welfare. Van Kol, a socialist parliamentarian, even argued in the *Tweede Kamer* that colonial governance must first ensure indigenous welfare before pursuing profit (Moon, 2007). These debates gave moral legitimacy to colonial technocracy, enabling engineers to view their interventions – such as irrigation, electrification, and industrial modernization – as acts of both technical mastery and humanitarian duty. Viewed through this lens, Weys embodied the intersection of knowledge, power, and ideology within colonial technocracy. His irrigation and hydroelectric projects in Pamanoekan and Tjiasemlanden were not merely feats of engineering but tangible expressions of colonial rationality: systems designed to discipline nature and labor under the guise of welfare and modernization. Through his work, the technical, economic, and moral imperatives of the Dutch colonial project converged, materializing the belief that technological order equated to social progress.

**Hydropower Beyond Alternative Energy.**

Three hydroelectric power stations in the Pamanoekan and Tjiasemlanden region illustrate how technology extended the colonial infrastructure regime following the successful implementation of irrigation projects in Java. The Ethical Policy provided a moral narrative for continuing a more modern and "civilized" form of colonialism, in which rational technical projects and designs were mobilized by state and private institutions – through the work of engineers – to control nature and resources (Ertsen, 2007). Technical rationalization, such as water flow engineering, made water resources calculable and measurable, thereby sustaining industrial production while maintaining the cultivation of local rice fields. The science-based technologies that emerged alongside the Ethical Policy played a crucial role in shaping the transformed Dutch East Indies (Furnivall, 2010; Ravesteijn, 2007).

This transformation shifted the colony from a politically dominated territory into an imperial state oriented toward free trade and industrial development. The shift also affected local populations, particularly indigenous communities, who moved from harmonizing technology with nature through local knowledge to adopting technologies aimed at controlling and manipulating nature. The adoption of these new technologies by local populations was most likely mediated through mechanisms of control and domination commonly practiced in plantation industries, particularly through the functions of the *Administratuur* leader and the authority of the local elites (Nuralia, Sulistiyono, Imadudin, Budiman, & Marzuki, 2025).

The rationalization and modernization of water infrastructure in the Dutch East Indies unfolded through two critical conjunctures: first, the industrialization and the rise of modern science and technology stimulated by the Liberal Policy of 1870; and second, the formulation of the Ethical Policy in 1901 (Moon, 2007). While the liberal phase initially opened space for the expansion of private capital, the Ethical Policy introduced a civilizing mission framed as a "moral obligation" toward colonial subjects. One of its central programs was the development of peasant agriculture through modern irrigation systems, which subsequently became both a prerequisite and a technical foundation for the advancement of hydroelectric power in the Dutch East Indies.

In the history of electrification in the Dutch East Indies, hydroelectric power plants emerged in the early 20th century (Stibbe, 1939), following the initial reliance on steam power. Remarkably, as early as the 1890s, entrepreneurs in the colony had already established local electricity networks in various parts of Java and actively lobbied the government for concessions to advance electrical infrastructure. Formal regulations on electricity were introduced through *Staatsblad* No. 190 of 1890 (Stibbe, 1939). Surabaya, Semarang, and Batavia were among the first cities to benefit from electricity (Stibbe, 1939). The pioneering use of hydropower began with the *Bandung Waterkrachtwerk Pakar aan de Tjikapoendoeng bij Dago* in 1906, followed by another *waterkrachtwerk* in Tutang, Semarang, in 1911 (Groothoff, 1918).

Initially, hydroelectric power plants served as a backup energy source during failures of steam power. Greater attention to hydropower emerged around 1910 with the establishment of the *Waterkrachtbureau* (Hydropower Bureau), tasked with conducting systematic research on water potential throughout the Dutch East Indies. From then on, the government began to rationally consider the utilization of hydropower, engaging in exploration while granting electricity concessions to private companies. These concessions imposed a fee of 4 guilders per horsepower (745.7 watts), effective from the sixth year after the company's establishment (Groothoff, 1918, p. 28). Through early explorations and electricity management policies, the Dutch East Indies had produced 2,500 kW of electricity by 1910, of which 800 kW came from hydroelectric plants (Stibbe, 1939).

In the early 20th century, electricity in the Dutch East Indies was primarily developed to serve industrial needs. Companies relied on electricity – mostly generated from steam power – to support production activities, such as coal mining in Ombilin, tin mining in Bangka, gold and silver extraction in Rejang Lebong, and sugar factories in East Java that utilized steam from bagasse combustion (Stibbe, 1939). In West Java, however, electrification was the most advanced in the colony, mainly due to the extensive development of hydroelectric power plants by the *Landswaterkrachtbedrijf* and private enterprises. Major hydroelectric plants operated in Bogor (Ubrog, Kracak), Batavia (Weltevreden), Bandung and its surroundings (Bengkok, Dago, Plengan, Lamajang), extending further to Garut, Tasikmalaya, Sumedang, and Banten. Electricity from these facilities supported various needs, including the electrification of major cities and railway lines, private plantation industries, manufacturing, and the Malabar Radio Station in Bandung. The Pamanoekan and Tjiasemlanden region played a significant role, as it managed its own network of private hydroelectric stations (Cijambe, Gunungtua, and Cinangling), supplying power to plantations and local distribution networks in Subang, Segalaherang, and Kalijati (Stibbe, 1939).

The global political-economic context also shaped the development of hydroelectric power in the Dutch East Indies before and during World War I. Rising energy demands drove significant growth in hydroelectric technology, particularly during the war (Ley, 1924). Countries facing coal shortages, such as France and Switzerland, have returned to hydropower to meet their industrial and transportation energy needs. The scarcity of fossil fuels accelerated large-scale investments in hydroelectric plants as a more sustainable and economically efficient alternative (Ley, 1924). This global shift also influenced energy strategies in the Dutch East Indies, which began to adopt similar approaches in expanding electrification.

In the Dutch East Indies, although not directly affected by World War I, figures such as Ir. P. A. Roelofsen had already recognized the importance of hydropower before the war. He advocated for establishing a water and electricity authority in 1917 to systematically explore the potential of this energy source. Despite post-war budget constraints slowing development, the government and the private sector began to show a gradual commitment to advancing hydroelectric power stations (Ley, 1924, p. 2). Ley (1924) estimated that the Dutch East Indies possessed a hydropower potential of 6,600,000 horsepower – equivalent to approximately 4,848 megawatts (MW) – or nearly one-fifth of global hydropower capacity. The island of Java contributed about 600,000 horsepower (±441 MW), significantly less than other islands, despite having a population of nearly 40 million. The availability of hydropower per capita in Java was only around 70 horsepower (±51 kW), far lower than that of industrialized nations. Until the 1920s, the use of hydropower in Java remained extremely limited, with approximately 1/2000 horsepower per person, and was primarily concentrated in major cities. At the same time, the rest of the island still relied on steam-based (thermal) power plants. Nevertheless, from an industrial perspective, hydropower was seen as an efficient means to continue productive land exploitation, even amid difficult economic conditions (Roelofsen, 1916).

According to Stibbe (1939), tea-producing companies in mountainous areas were among the earliest adopters of electricity, primarily sourced from hydropower. In the Pamanoekan and Tjiasemlanden region, the Cijambe, Gunungtua, and Cinangling hydroelectric stations played a crucial role in supplying electricity to support the plantation industry operated by *N. V. Maatschappij tot Exploitatie der Pamanoekan en Tjiasemlanden*. By 1945, hydroelectric power had become the dominant energy source in West Java, surpassing thermal energy. West Java had ten hydroelectric power stations – three generating between 10,000 and 25,000 kW, while the remaining seven produced less than 5,000 kW. In contrast, thermal power plants comprised only three major stations, each with an output of 5,000–10,000 kW (Allied Geographical Section, 1945).

Dutch engineers viewed hydroelectric power stations (*waterkrachtwerk*) in the early 20th century as having the potential to drive the development of both large and small-scale industries in the Dutch East Indies. Ir. A. Groothoff, in his article *"Eenige mededeelingen over de waterkrachtindustrie in Scandinavië en over het waterkrachtvraagstuk in Nederlandsch-Indië"* ("Some Notes on the Hydropower Industry in Scandinavia and the Hydropower Issue in the Dutch East Indies"), emphasized that water resources, unlike mineral resources, were virtually inexhaustible, making their exploitation a rational and sustainable choice. Groothoff stressed that hydroelectric stations could serve dual purposes: electricity generation and irrigation, citing a planned project for the Bengawan Solo River. He believed that realizing such projects would promote the growth of Dutch engineering and industry while enhancing the prosperity of the Dutch East Indies (Groothoff, 1918, p. 29).

**Conclusion.**

This study reveals that the transformation of water engineering technology at the Pamanoekan and Tjiasemlanden Plantation was characterized by a shift from vernacular irrigation systems to modern technical irrigation. The modernization of irrigation and the application of more scientific methods of water management enabled the construction of three hydroelectric power stations: Cijambe (1912), Gunungtua (1922), and Cinangling (1936). This technological evolution occurred alongside the rationalization and modernization of the colonial plantation system. It formed part of the broader infrastructure development driven by colonial technocratic interests in the early 20th century.

The construction of hydroelectric power plants in Subang exemplifies how colonial authority was materialized through water engineering. The three hydroelectric stations – Cijambe, Gunungtua, and Cinangling – operated as run-of-river systems, converting natural flows into quantifiable energy without the need for large dams. Their relatively small scale and reliance on the region's hydrological stability reflected a technical rationality grounded in efficiency, predictability, and control – principles that mirrored the administrative logic of colonial technocracy. Through these infrastructures, water was transformed from a communal and ecological resource into a regulated force serving the economic interests of the plantation regime.

This technological reorganization of water did not occur in isolation but was embedded within the broader economic and institutional structures of Dutch colonialism. The political-economic context of the Dutch East Indies – characterized by the convergence of liberal economic policies, private enterprise, and the colonial state's drive for modernization – facilitated the circulation of technology and expertise across the empire. Technology transfer occurred, as formal distribution channels, such as Heemaf in Surabaya, underscored the dependence on European standards. Meanwhile, the introduction of Francis turbines, Bell Maschinenfabrik generators, and Willem Smit & Co. transformers highlighted the colony's integration into international supply chains. The resulting electrical infrastructure supported the expansion of the plantation industry, while the Ethical Policy provided moral legitimacy by framing electrification and irrigation as part of a colonial welfare project. Yet, behind this narrative, hydroelectric power plants – such as those in Pamanoekan and Tjiasemlanden – ultimately functioned as instruments of colonial control over natural resources.

Colonial engineers drove the construction of hydropower plants in Pamanoekan and Tjiasem, led by C. W. Weys and his assistant, F. A. Janssen van Raay, was tasked with modernizing the plantation lands. Weys, a graduate of the Technische

Hoogeschool Delft, played a key role in the modernization of Pamanoekan and Tjiasemlanden. He was actively involved in developing dams, tramlines, factories, and irrigation systems. His role illustrates the involvement of engineers in ethical and technocratic colonial projects. It highlights the strong influence of the colonial engineering community in shaping private industrial development in the Indies.

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**Conflicts of interest.**

The authors declare no conflict of interest.

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## Колоніальна технополітика в Нідерландській Ост-Індії: Дослідження колоніальної гідроелектроенергетики на плантації Паманоекан та Чіасемланден

***Анотація.*** *Це дослідження присвячене історичному розвитку технологій гідроелектроенергетики в Нідерландській Ост-Індії на початку XX століття, з* *особливим акцентом на плантацію Паманоекан та Чіасемланден, нині частини плантацій регіону VIII Тамбаксарі-Сіатер у Субанзі, Західна Ява. Метою є дослідження трансформації водної інженерії – від традиційних місцевих зрошувальних систем до сучасних зрошувальних мереж і, зрештою, до гідроелектростанцій. Дослідження також розглядає процес технологічної адаптації, роль колоніальних інженерів, походження технічних компонентів та механізми роботи гідроелектростанцій у ширшому контексті політики етичності та колоніальної технократії. Використано метод історичної археології, поєднуючи текстові архіви та матеріальні залишки для інтерпретативного наративу. Приватні колоніальні плантації розглядаються як простори, де реалізовувалось домінування над природними ресурсами. Польові дослідження охоплювали три гідроелектростанції – Чіямбе, Ґунунгтуа та Чінанглінг, доповнені різноманітними текстовими джерелами: газетами, інженерними журналами, промовами та протоколами нідерландських інженерів, колоніальними водними нормативами, буклетами компаній, геологічними дослідженнями та картами плантацій. Аналіз застосовує концепцію технополітики, розглядаючи технологію не як нейтральний інструмент, а як невід'ємну частину політико-економічних стратегій колоніального правління. Виявлено, що три гідроелектростанції розширили колоніальну інфраструктурну мережу після реалізації зрошувальних проектів на Паманоекан ен Чіасемланден. Політика Етичності забезпечила «цивілізаційний» наратив, що легітимізував технічну раціоналізацію. Через інженерне регулювання водних потоків колоніальні адміністрації та приватні підприємства, за посередництвом інженерів, зробили річки вимірюваними та контрольованими, підтримуючи промислове виробництво на базі плантацій, одночасно зберігаючи традиційне місцеве вирощування рису для самозабезпечення. Отже, розвиток гідроелектричних технологій на Паманоекан ен Чіасемланден був не лише технічним досягненням, а й технополітичним проєктом, який мобілізував водні ресурси для консолідації економічної продуктивності через мережі приватних підприємств, технократичних агентств та міжнародних постачальників обладнання.*

***Ключові слова:*** *гідроелектростанція; технополітика; технократія; політика етичності; колоніалізм; Паманоекан ен Чіасемланден*

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