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Past Regulation Experiences vs. Contemporary Challenges in Resource-Based Industries and Technologies?

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Regulation on waterfalls, water resources and hydro-electric power production has evolved over 100 years to reduce negative externalities and secure future generation's control of these important resources. The heritage of this tradition was also considered when establishing the regulations on petroleum exploration over five decades later. Therefore, in the petroleum offshore industry a holistic regulatory system was established concerning ownership, control and management of development and comprehensive safety regulations. This framework has continuously developed based upon experiences from industry developments and accidents. In contrast, today industries like fish farming and wind farms evolve and expand without a holistic, subsequent control, security and safety regulatory schema. Lack of proper regulation has given us security and safety challenges as, lack of control, loss of jurisdiction, and negative externalities on workforce and environment. How did our predecessors regulate resource-based industries, and to what extent have we achieved similar regulatory control over emerging industries today? What insights do past regulatory experiences offer for addressing today's challenges? How do global threats to power supply and infrastructure, evolving security concerns, and digitalization-related vulnerabilities impact regulatory frameworks? This paper is inspired by four expert seminars that examined these issues. It introduces a timeline of key regulatory developments, explores the regulatory development process, and discusses potential barriers to effective regulation. Given that regulatory compliance is enforced through auditing and sanctions, this paper also examines the evolution of regulation and governmental supervision, particularly the role of internal control auditing. Additionally, it highlights the growing demand for advancements in auditing methodologies. To navigate an increasingly complex future, we propose a research program focused on safety and security regulation for resource-based industries. This initiative aims to serve as a foundational knowledge base for a long-awaited White Paper on regulation and governmental supervision.

Keywords: Regulation, safety, security, critical infrastructure, energy

1. Introduction

Regulations of waterfalls, water resources and hydro-electric power production have evolved over 100 years. The regulations aim to reduce negative externalities and secure future generation's control of these important energy resources. Security and safety regulations have been followed during periods of industry development, international conflicts and war. Also, within the petroleum offshore industry, regulation on resource ownership, management and comprehensive safety regulation framework followed industry developments and after major accidents.

In contrast, contemporary emerging industries like wind farms evolve and expand over years without subsequent security and safety regulation and authority control. Moreover, the development of the internet and the rise of cyberattacks show that regulatory requirements are lagging technological development. The first computer virus, the Morris worm, appeared in 1988, and since then cybercrime and cyberattacks have evolved together with increased level of digitalization. Today cyberattack is a serious threat towards security and safety of infrastructures, systems and individuals. An all-hazard and minimum requirements on digital security came into force last year in EU, 26 years after the first computer virus was born; the EU's "Network and Information Systems" NIS2 regulation (EU, 2022). As this paper is written, NIS2-regulation in Norway is still in a development process, expected to come into force this year.

In this paper, we discuss three questions.

- What did our predecessors do?
- To what extent have we achieved the same regulatory control of new industries?
- What insights can we gain from past regulatory developments, and which lessons are worth transferring?

The main goal of this paper is a first step to identify key research gaps and provide a foundation for further inquiry. We aim to establish the historical backdrop to better understand how functional regulations can be refined and adapted to address the industry's evolving challenges. Learning from past experiences requires however expanding the knowledge base—both theoretically and practically—through new research. Achieving this, demands further systematic evaluation of past experiences to determine which lessons are worth transferring and which can be set aside. By doing so, we can ensure that regulatory developments are informed by the most relevant and effective insights

2. Method

Based on available administrative and scientific literature, this paper presents the background for four expert seminars that addressed the questions above. Four seminars were arranged from 24. November 2023 to 8. November 2024 with experts on regulation, audit and with domain knowledge on renewable energy systems and petroleum.

The seminars were organized by the Norwegian Water Resources and Energy Directorate (NVE), Norwegian Ocean Industry Authority, (Havtil), University of Stavanger (UIS) and Western Norway University of Applied Science (HVL). The first seminar drew up the history of regulation on security and natural hazards on waterfalls, quarries and properties. The second seminar focused on the petroleum safety regulation development. The third seminar shed light on control and audits, and the last seminar discussed how safety and security should be developed on an institutional level and in practice. The seminars featured a combination of expert talks and plenary discussions. It is important to emphasize that while this paper is inspired by the seminar and serves as input for our analysis, we have not systematically organized or analyzed all the presentations and contributions

This paper introduces a rough timeline of selected regulations, presents the regulation development process and discusses potential barriers to rapid and adapted regulatory development. Furthermore, as regulatory compliances are enforced by auditing and sanctions, the paper draws also the line on how auditing schemas have evolved and stabilized on internal control auditing.

As a result of the discussions at the four seminars, we present some hypotheses and suggest a research program for safety and security regulation and control in contemporary emerging industries.

3. Regulation developments

3.1. *Hydro-electric power production and waterfalls regulation*

The Norwegian law on acquisition of waterfalls, quarries and properties from 1917 demanded that the licence holder of said natural resources was obliged to allocate money for the support of the

construction workers and their families (MoJ, 1917). The licence holder should also ensure medical services and fund extra police resources to safeguard the work if necessary (Tangeraas, 2024). This shows that already in 1917 safety and security was part of the licence holder's obligations and regulations to reduce negative externalities for the workers and their families. The legal regulation of the industry made a mutual responsibility relationship between the industry, the workforce, the local community and the national authorities.

The Water Resources Act, originally from 1940, but revised in 2000 (MoE, 2000) regulates ownership, licences, security of water magazines, emergency preparedness, environmental protection and conservation. Auditing of water resources has long tradition back to 1909, while environmental oversight and audit goes back to 1963. This demonstrates that the implemented water resources regulations were supplemented by a targeted supervisory system.

The Act on Securing the Power Supply was enforced in 1948 (MoE 1948), three years after WW2. Attention was on physical security and emergency preparedness. In 1991, after decades with peace and an international development towards growing market economy thinking also in public sector, the 1948 Act was replaced with the 1991 Energy Act (MoE, 1991). The security regulation was now included in the new law's chapter 9, and the law extended its focus to ensure that production, transmission, distribution and use of energy was carried out in a way that was regarded as rational for the whole society. The law also regulated a power market. Moving on, environmental protection got increasingly more attention from 1975. Later, there were regulations and guidelines on safeguarding the environment and wildlife (fish) production impacted by the construction of water magazines and operations of hydro-electric power plants.

More detailed sector security regulations on hydro-electric power and district heating production and distribution followed with the emergency preparedness regulation from 2003, revised in 2011, 2019 and 2025. The contingency regulation is a comprehensive regulatory framework that from 2019 also included obligations on securing digital systems in general in the power sector (NVE, 2025).

The path established over 100 years back, focusing a holistic regulatory system, is still the preferred way followed by the national authorities. However, the relationship between the industry and the local communities is not that prominent than before because e.g. the welfare and health care obligations are transferred to the municipalities.

Now, in 2025, there is on-going work going on regulating renewable energy production like wind farms and solar power plants. Regulating cybersecurity in cross-country digital operation control systems is an important problem to address. But at this moment, wind farms have already existed for many years, with complex management systems, digital technology, and ownership, and huge nature interventions.

Industrial fish farming, relying upon available water resources, has been an increasingly important economic factor in Norway since the 1970s. It is interesting to note that still there is no holistic regulatory system for this business which may be compared to what we have for the hydro-electric power production.

3.2. *Safety regulations of the petroleum production*

The Norwegian history of the petroleum industry goes back to 1960s, and production started at Ekofisk in 1971 (MoE, 2021). The Norwegian petroleum industry underwent significant reorganising, downsizing, and merges during the late 1990s, which, according to some, affected the safety level of the industry. The introduction of the "internal control system" in the 1980s, based on the philosophy of enforced self-regulation and goalsetting (function-based) legislation, strengthened the robustness of the Norwegian regulatory system. The tripartite collaboration among the regulatory authorities, trade unions, and employers' federations is a key feature of the Norwegian Regulatory Regime. When self-regulation is used to ensure safety, enterprises are obliged to identify and assess risks and hazards embedded in their operations. Internal control gives companies a personal responsibility to monitor and implement an updated safety management system.

Assessing the regulator-regulatee relationship in high-hazard industries, the regulatory bodies develop a learning mechanism to be integrated into their regulatory systems by investing in

monitoring and data analysis and evaluating performance with involvement of the stakeholders. The regime has thus developed its capacity to enrol new actors and to redefine their roles and behaviour in the face of internal disturbance, new technology and changes in the socio-economic environment. However, a regulatory approach based on internal control also induces challenges. The function-based regulatory regime creates a hierarchy of overlapping norms, which has developed into a complex system of rules and regulations, legal standards, risk assessment criteria, industrial standards, internal company standards, and codified best practices.

4. Enforcing compliance

4.1. *Internal control, supervision and audit*

Supervision at national level was last investigated and discussed on a general basis over twenty years ago, in St. meld. no. 17 (2002-2003) (MoLA, 2002). The white paper presented to the Parliament describes recommended supervision methodology, assesses the methodology's place in a function-based regulatory framework and the role of trust in government supervision.

The internal control auditing method has been the standard method used by governmental supervisory agencies since then. The methodology assumes that businesses must be able to document that there is "sufficient certainty for the authorities' regulations to be respected". Internal control is thus a duty for businesses to ensure that the requirements are met and that the business has established systematic measures.

The National Audit Office of Norway (NAO Norway) is an audit agency of the Norwegian parliament (the Storting) that has questioned the need for improving auditing and supervisory methods (NAO, 2023).

4.2. *Sectorial approaches to internal control*

Governmental bodies like NVE and Havtil have several tools to enforce compliance with the security and safety regulations of the energy sector. The two bodies apply different strategies to ensure that companies comply with security and safety requirements.

NVE supervises the management systems and preparedness procedures and performs audits and inspections. While inspections are more used for control with environmental conservations and physical security, control with emergency preparedness and digital security is conducted by reviewing management documents in combination with interviews of company experts and discussion in physical meetings. After an audit, a report is produced, and the auditee are given a deadline to fix the identified problems and mis-compliances. Audits are usually announced weeks beforehand, and companies prepare well and aims to mitigate expected deviations before the auditors from NVE arrive at the company's facility. NVE also shares the questionnaire they use before the audit starts. This gives auditee good opportunities to prepare for the audit. NVE's audit reports on security are not available to the public, but NVE provides fact sheets and reports that shows the general status.

Havtil's supervision covers all the activities that allow assessment of whether the companies are pursuing their operations prudently and in accordance with the regulations, and to follow this up. The supervision covers all players in the industry, including operators, contractors and vessel owners involved in the sector. With most attention to the companies acting as operators, as they have an overarching responsibility to ensure that all suppliers and sub-suppliers comply with the regulations. The supervision takes mainly form as audits and verifications on facilities, at land-based plants and at construction sites, but also consent for given activities applications, applications of consent for mobile facilities, and operator assessments and licence awards. The audits are based on spot checks and with a focus on the management system and governing documents. Audit reports are published on the Havtil's homepage for industry wide learning.

4.3. *Do audits and inspections have any impact and improve security and safety?*

Regulation encompasses various concepts and notions, each with slightly different connotations. Supervision refers to the process of overseeing and guiding the work or activities of individuals, teams, or systems to ensure tasks are performed effectively and objectives are achieved. Auditing involves a systematic, independent examination of processes, systems, or compliance with policies, laws, or standards to evaluate accuracy, reliability, and adherence. Inspection, on the other hand, is a

detailed evaluation of specific items, processes, or systems to verify that they meet predefined standards or criteria.

The concepts of supervision, audits and regulation provide us with certain sets of lenses that extract and focus on these properties, sometimes to the effect of reconceptualizing those more particular and context specific. In the case of audit, in theory as well as in practice, applications are directed at all types of activities and organizations; it has even been argued that the logic of auditability constitutes a meta-logic which continuously expand its range of applicability (Power, 1997). In the case of risk, in different respects embodying supervision, inspection and auditing, it has been argued that it has become a "new lens through which to view the world" (Hutter, 2006, p. 202). Power (2007, p. 1-2) likewise observes how otherwise distinctive activities and organizations become subject to discourses about risk and its management.

Within a regulatory context we also operate with two distinct conceptions: safety and security. The two concepts share commonalities in contemporary approaches to risk management, control, and professional practice. Although their methodologies may differ, risk management processes typically include similar procedures, such as screening, appraisal, characterization, and management. Furthermore, major organizational accidents involve similar technical, organizational, and human factors, where individuals play critical roles in detecting, managing, and mitigating the severity and impact of incidents or accidents (Jore, 2019).

While risk management in safety focuses on managing dangers, security risks are managed focusing on malicious threats, i.e., their intentions and capacities. For the control of such risks the spotlight in security is aimed at controlling measures related to physical hardening and deterrence in combination with technology to detect and ensure human response to incidents. Within safety, there is significantly less emphasis on intention, while the control measures seek to avoid human error and ensure compliance (Jore, 2019).

Two studies of NVEs supervision give conflicting answers to the effect of supervision. One study is about the effect of NVE's environmental supervision (L'Abée-Lund, Braut, & Brittain, 2022). The study examined 113 businesses in hydropower production and aquaculture. 20 of the businesses were checked 2-12 times in the period. The researchers concluded that supervision had no effect on quality and security. In the article, the authors point out that other considerations, e.g. financial, receive more attention from businesses than operating in accordance with the legal requirements. A study on audits of cybersecurity controls in the energy sector (Storm, et al, 2023) investigated the effect of controls at 30 large enterprises, and concluded that the controls had had effect, and that regulation without supervision does not have effect. In the field of ICT security, however, technical tools are necessary to be able to control software and configurations that are not directly visible to human insight. In 2020, NVE conducted a study of selected supervisory authorities' use of digital tools such as vulnerability scanning and security testing. The study showed that document control, interviews and physical meetings were still the main form of work at the supervisory authorities, but that although the use of digital technology in the work of control was little used, such tools could become more relevant in future audits and supervision of ICT security (Svensen, Kallseter, & Husabø, 2020).

Havtil experienced that effect, and improvements were best achieved when Havtil standardized the controls with same review topics towards several companies and over time. Havtil experienced that it is important that the controls are perceived as relevant to achieve safety and security objectives. Havtil emphasizes also the contribution of checking the implementation and functioning of required measures. This extra level of control improves the business processes and enhances the security and safety level. Havtil distributes surveys and evaluates the effect of the audit two weeks after the audit is completed. They run also a yearly survey to study the relationship between Havtil's actions and the companies' mitigations, how identified compliance issues are solved, and the industry's attitude towards the regulations.

5. A lack of a broad and holistic regulatory approach

It appears that the way an emerging industry is regulated, or not regulated, ab initio has great impact on the further development of the relation between the industry and the society. This is also what to be expected based upon theories on path

dependency (Mahoney, 2000; Pierson, 2000). A broad and strong engagement from the authorities in the first phase, as we saw when establishing the hydro-electric power industry in the early 1900s and the petroleum activities from the 1960s, leads to a continuing strong relationship between industry and society.

A lack of a broad and holistic regulatory approach, as still seen related to new energy producing industries and fish farming, appears not to give the same mutual responsibility relationship between industry and society. A contemporary example on the tensions this may lead to may be the ongoing political discussions on lant rent tax on fish farming.

6. Need for research on regulation development

In this paper we have discussed the regulation of water resources, petroleum and the lack of similar holistic regulation of new industries like fish farms and wind farms. Fish farming and wind farms are however not the only industries that have lagged a holistic regulatory framework. We observe similar development in the all-industry cybersecurity regulation.

Digitalization has been a political ambition for many decades, and with the increased penetration of digitalization in businesses and society, crime has moved and expanded to the internet. Næringslivets sikkerhetsråd (NSR) has since 2006 (NSR, 2006) published bi-annual studies on cybercrime in Norwegian businesses. The studies document the development of hacking, internet fraud, data theft and sabotage, and that the applied cybersecurity practices have not been sufficient. Economic losses related to global cybercrime has continued to rise over years, and World Economic Forum states that cybercrime is big business. One estimate of economic losses worldwide shows that damages incurred by all forms of cybercrime, including the cost of recovery and remediation, totalled $3 trillion in 2015, $6 trillion in 2021, and could reach $10.5 trillion annually by 2025 (Mugga and Margolis, 2023). WEF states that one problem has been a lack of mandatory reporting of cyber incidents applicable to all-industries.

Therefore, we lack information about cybercrime and its consequences, but last year EUs NIS2-legislation came into force. With the NIS2 regulations follows also a regime for reporting of incidents. In Norway, the digital security act and related regulation is expected to come into force in 2025. NIS2 covers more businesses compared to the current regulation on contingency and cybersecurity in the Norwegian Power system. Revised requirements on securing digital systems (Hagen et al, 2017) came into force in 2019, but now NVE is again revising those requirements and their coverage. The problem is not just the slow development of regulatory regimes, but also the legal requirements and how regulations are developed. A newly published phd-dissertation revealed weaknesses in the cybersecurity regulatory frameworks that are developed by EU and pointed among other things towards lack of cybersecurity regulation on operational technology and automation systems. The weakness could be traced to lack of relevant technical competence of the experts in the working groups that took part in the regulation development processes (Toftegaard, 2024).

Furthermore, how does the growing influence of the security affect the regulatory regimes? The expanding coverage and scope of the Security Act, affect the regulatory authorities also to emphasize the need for an integrated perspective on the overall risk landscape, ensuring that both individual and comprehensive risk assessments are consistently conducted. A governance model, with its multiple decision-making authorities, poses challenges for coordination and consensus-building, particularly within the framework of tripartite traditions. This complexity highlights the importance of structuring key decision-making centers to facilitate effective engagement and the integration of safety and security measures across diverse organizations and industries.

However, sustaining a culture of transparency presents difficulties. For example, during the summer of 2023, following incidents involving drones, the war in Ukraine, and the sabotage of the North Stream II pipeline in the Baltic Sea, trade unions expressed frustration over information-sharing barriers. They argued that certain oil companies and Havtil withheld critical information from tripartite forums, creating obstacles to effective dialogue in arenas like the Safety Forums. These challenges highlight the need for stakeholders involved in both safety and security to engage in open discussions. From a

security perspective, sharing relevant, albeit classified, information with trade unions could be valuable. Workers at the operational level, particularly those offshore, serve as critical "eyes and ears" during security incidents and are often the first to observe unfolding events. Balancing the system of safety and security requires finding ways to share essential information while safeguarding classified details.

As new industries evolve the question of side effects and consequences for third parties also arise. It is the government or the politicians' responsibility to manage the resources to the best for the society and its population. Regulation is one way to control or reduce consequences of unwanted externalities. We realize that is it difficult in an early phase of new industry development to design and decide on regulation, but we would recommend that industry development is followed by research also on regulation and control with the industry development. Cross-industry comparisons in the petroleum have been widely explored, particularly in studies comparing the Norway UK and US (Renn et al 2014). Further studies could significantly enhance knowledge about regulatory effectiveness and how to avoid externalities.

Historically, there has been no systematic effort to facilitate sector-wide learning in Norway. From a policy perspective, the structure of public administration may be one explanatory factor. This issue is often referred to as "silo thinking" in Norwegian public administration—a work culture where different sectors, agencies, or departments operate in isolation, with limited collaboration and information sharing. The consequences include reduced innovation, weaker decision-making, and a lack of holistic governance. Despite ongoing challenges, addressing silo thinking requires continuous commitment and strong political will to foster a more integrated and efficient public administration. Hence a research program on evolution on regulatory regulation in nature-based industries should also challenge how the administration could facilitate better information flow and systematically lessons learned to improve regulation in new industries.

6. Conclusive remarks

In this paper we have examined the evolution of regulations in nature resource-based industries in Norway. The historical development of regulations for hydro-electric power and petroleum industries demonstrates how public based, active governance can foster mutual responsibility between industries, society, and authorities.

Contemporary industries like wind farms, fish farming, and digital infrastructure have shown delays in developing similar holistic regulatory frameworks. This lag in regulation often results in missed opportunities to establish strong foundational relationships between industry and society, as well as vulnerabilities to externalities and risks. For instance, the slow adaptation of cybersecurity regulations underscores the need for expert-led, future-oriented governance models that prioritize technical competence and risk integration. By contrasting these with the fragmented and delayed regulatory approaches proposes a research agenda for future safety and security frameworks.

This was one of the topics on the seminar and particularly highlighted by Fløysvik Nordrum. Fløysvik Nordrum (2019) has written and researched better regulation, focusing on how regulatory development can be made more efficient, knowledge-based, and balanced. His work highlights the importance of evidence-based regulation, balancing flexibility with predictability, adopting an interdisciplinary approach, fostering collaboration between the public and private sectors, and ensuring effective enforcement and supervision. He also addresses challenges related to regulatory complexity and how to avoid overregulation while still safeguarding essential societal interests.

Hence to advance regulatory effectiveness, it is imperative to draw such lessons from past successes and challenges. Key strategies include fostering early stakeholder engagement, integrating safety and security measures, and embracing transparency to build trust among regulators, industries, and workers. Moreover, investing in research and monitoring of regulatory impacts can guide continuous improvements and ensure alignment with technological and societal developments.

Before actionable recommendations can be made, thorough preparatory work is required. It is important to build on past experiences, but directly transferring previous solutions can lead to unintended consequences. While we have a

historical foundation to learn from, the approach should focus on learning rather than mere replication. To address the challenges of the future, a knowledge-based White Paper on safety, security regulations, and governmental supervision for natural resource-based industries will be both essential and highly welcomed.

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