SAFE ENERGY RELATIONS: UNFOLDING THE PRECAUTIONARY PRINCIPLE WITH THE ADVENT OF HYDROGEN TECHNOLOGIES

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ABSTRACT

SAFE ENERGY RELATIONS: UNFOLDING THE PRECAUTIONARY PRINCIPLE WITH THE ADVENT OF HYDROGEN TECHNOLOGIES

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Recently, the hydrogen economy has gained considerable momentum with the effects of the climate crisis and the COVID-19 pandemic. In this context, the primary purposes of this thesis are:

1. To examine the relationship between legal, political, economic, and technical dimensions of the European Union’s (EU) decarbonization with hydrogen agenda within the *precautionary principle* (PP) conceptual framework.
2. To explore spaces where precautionary thinking is relevant for the advent of hydrogen technologies in the EU.
3. To make concrete policy suggestions for the EU and Turkey accordingly.

The literature review’s first pillar is the EU and Turkish laws, official and strategic documents, directives, regulations, and project reports on energy, environment, and hydrogen. The second pillar includes academic and legal readings of PP. Legal doctrinal methodology and qualitative content analysis determine intersections between hydrogen and PP. Findings include the standardization of gas quality emerging as a precautionary matter in the EU, lack of consensus on hydrogen safety resulting in its non-presence in official EU documents, and legal scope and authority problems for Turkey.

As an overall finding, hydrogen risk chain - hydrogen value chain incompatibility is discussed. The 'innovation principle' is also discussed. Its relationship with the precautionary principle as non-competing elements is debated regarding PP's non-presence in the EU hydrogen law and policies. Finally, precautionary policy suggestions for the European Union are presented and a preliminary regulatory analysis is made for Turkey to prepare herself to host the hydrogen economy.

Keywords: Hydrogen, Decarbonization, Risk, Precautionary Principle, Environmental Law and Policy.

ÖZ

GÜVENLİ ENERJİ İLİŞKİLERİ: AVRUPA BİRLİĞİ’NDEKİ HİDROJEN GELİŞMELERİNİN İHTİYAT İLKESİ ÇERÇEVESİNDE DEĞERLENDİRİLMESİ

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Bir enerji taşıyıcısı olarak hidrojenin geniş ölçekli enerji sosyo-teknik sistemine eklemlenmesi, iklim krizinin ve KOVİD-19 salgınının etkileriyle beraber ivme kazanmıştır. Bu bağlamda, bu tezin temel amaçları şunlardır:

1. Avrupa Birliği'nin (AB) hidrojen ile karbonsuzlaştırma gündeminin hukuki, siyasi, ekonomik ve teknik boyutları arasındaki ilişkiyi ihtiyat ilkesi kavramsal çerçevesi içinde incelemek
2. AB hidrojen teknolojilerinin gelişimiyle ihtiyat teorisinin ilgili olduğu alanları keşfetmek.
3. AB için somut politika önerilerinde bulunmak.

Literatür taramasının ilk ayağı hidrojenle ilgili AB ve Türk yasaları, resmi ve stratejik belgeler, direktifler, yönetmelikleri proje raporları ve ilgili enerji ve çevre mevzuatıdır. İkinci ayak ise ihtiyat ilkesinin akademik ve hukuki okumalarını içerir. Hukuki doktriner metodoloji ve nitel içerik analizi, hidrojen ve ihtiyat ilkesi arasındaki kesişimleri belirler. Genel bulgular şunları içerir: AB'de ihtiyati bir mesele olarak ortaya çıkan gaz kalitesinin standardizasyonu, resmi AB belgelerindeki hidrojen güvenliği yoksunluğu ve Türkiye için kapsam ve yetki sorunları.

Ana bir tartışma konusu olarak hidrojen risk zinciri- hidrojen değer zinciri uyumsuzluğu işlenmiştir. İnovasyon ilkesi tanıtılmış, ihtiyat ilkesi ile ilişkisi çalışılmıştır. Son olarak, hidrojen teknolojilerine yönelik Avrupa Birliği için ihtiyati politika önerileri yapılmış ve Türkiye'nin hidrojen ekonomisinde yer alabilmesi için gerekli olan düzenlemelere yönelik başlangıç niteliğinde bir analiz yapılmıştır.

Anahtar Kelimeler: Hidrojen, Karbonsuzlaştırma, Risk, İhtiyat İlkesi, Çevre Hukuku ve Politikaları

To My Parents and My Grandfather

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LIST OF ABBREVIATIONS

AA	Anadolu Agency
ACER	Agency for the Cooperation of Energy Regulators
AFID	Alternative Fuels Infrastructure Directive
BDDK	Turkish Banking Regulation and Supervision Authority
BOTAŞ	Petroleum Pipeline Corporation
CBAM	Carbon Border Adjustment Mechanism
CCUS	Carbon Capture, Utilization and Storage
CERN	The European Organization for Nuclear Research
CEN	The European Committee for Standardization
CEO	Chief Executive Offices
CFC	Chlorofluorocarbons
CFI	Court of First Instance
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COM	European Union Communiqué
COVID-19	Coronavirus Disease 2019
CO2	Carbon Dioxide
CRE	French Energy Regulation Commission
DG	Directorate-General
DP	Development Plan
EC	European Commission
EC JRC	European Commission Joint Research Center
EHSP	European Hydrogen Security Panel
EEA	European Environment Agency
EED	Energy Efficiency Directive
EIA	Environmental Impact Assessment
EMRA	Electricity Market Regulation Authority
EP	European Parliament

EPA	United States Environmental Protection Agency
EPBD	Energy Performance of Buildings Directive
EPP	European Public Party
EPRS	European Parliamentary Research Service
ERF	European Risk Forum
ERIF	European Regulation and Innovation Forum
ETD	Energy Taxation Directive
ETKB	Turkish Ministry of Energy and Natural Resources
ETS	Emissions Trading Scheme
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
FSR	Florence School of Regulation
GAZBİR	Association of Natural Gas Distributors of Turkey
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GW	Giga Watt
HC	Hydrogen Council
HCFC	Hydrochlorofluorocarbon
HDGMP	Hydrogen and Decarbonized Gas Markets Package
HIAD 2.0	European Hydrogen Incidents and Accidents Database
HFC	Hydrofluorocarbon
HSE	Health and Safety Executive
ICJ	International Court of Justice
ICHET	International Centre for Hydrogen Energy Technologies
IEA	International Energy Agency
IICEC	Sabancı University Istanbul International Center for Energy and Climate
IISD	International Institute for Sustainable Development
IP	Innovation Principle
İDDK	Plenary Session of Administrative Law Chambers

LPG	Liquidated Petroleum Gas
MEF	Turkish Ministry of Environment and Forestry
MENR	Turkish Ministry of Energy and Natural Resources
MEP	Member of European Parliament
METU	Middle East Technical University
MS	Member State
Mt	Million Tons
NASA	National Aeronautics and Space Administration
NGO	Non-governmental Organization
OECD	Organization for Economic Co-operation and Development
ODS	Ozone-depleting Substances
OPRC	Oil Pollution Preparedness, Response and Co-operation
ÖİK	Specialized Commission
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RED II	Renewable Energy Directive II
rGD	Recast Gas Directive
rGR	Recast Gas Regulation
rTPA	Regulated Third-party Access
R&D	Research and Development
SBB	Presidency of the Republic of Turkey Presidency of Strategy and Budget
SDG	Sustainable Development Goals
SRIP	Science, Research and Innovation Performance
STPS	Science and Technology Policy Studies
S&D	Socialists and Democrats
TEİAŞ	Turkish Electricity Transmission Corporation
TEKPOL	METU Technology Policies Center
TEN-E	The Trans-European Networks for Energy
TFEU	Treaty on the Functioning of the European Union
TÜBİTAK	Scientific and Technological Research Council of Turkey

TÜİK	Turkish Statistical Institute
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Program
UNDP MPU	UNDP Montreal Protocol and Chemical Unit
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCC	UN Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USA	United States of America
PP	Precautionary Principle
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

The COVID-19 pandemic triggered the already existing volatility in the world's energy policy regimes to the point that the processes of socio-technical change related to energy systems are more relevant than ever. Hydrogen is receiving unprecedented interest and investments as the post-fossil fuel world anticipates a CO_2-neutral energy system for mid-century (IEA, 2021b). This thesis examines the conflict between legal, political, economic, and technical dimensions of the European Union's (EU) decarbonization policy through the hydrogen path and its implications for Turkey within the conceptual framework of the precautionary principle (PP).

The EU is a pioneer in the promotion of a "hydrogen economy." The European Commission considers clean hydrogen as "a vital missing piece of the puzzle" to decarbonize carbon-intensive activities and help the EU achieve its 2050 carbon neutrality goals (EC, 2020). The 2020 EU Hydrogen Strategy flags up to €470 billion of investment (EC, 2020). The hydrogen lobby declared a €58.6 million expenditure in 2020 to influence Brussels policymaking (Kurmayer, 2021).

One of the reasons why hydrogen is hot on the agenda is that the Paris Climate Agreement's and net-zero carbon goals cannot be achieved with existing renewable energy sources, especially because of the intermittent nature of solar, wind and hydropower energy sources which prevents them to act as baseload power sources. For example, solar energy can only be used when the Sun reaches the Earth, but it does not exist at night. Wind power generation can be possible only if the wind blows. Although the global distribution of these energy sources is more balanced than fossil sources, their intermittent availability is problematic, and generates a storage problem for the electricity and heat generated from renewable energies (İ. Gökalp, personal communication, May 2021). The hydrogen factor precisely enters the stage here as a storable energy carrier. Many countries and investors deem the potential of hydrogen as capable of making a profound contribution to ensuring the continuity of renewable energies and take significant steps in this direction with the introduction of different types of green regulation such as carbon taxes, net-zero targets and hydrogen strategies (Hydrogen Council, 2021, p.8).

As the most common chemical substance in the universe, hydrogen is one of the primary substances in the cosmos, along with helium and lithium gases (NASA, 2019). It is about 13.7 billion years old (CERN, n.d.). Nine to ten percent of the human body consists of hydrogen (Zoroddu et al., 2019). Humans are now missioning this old atom/molecule with new tasks.

The main reason is that hydrogen is a clean fuel/energy carrier, depending on how it is produced. Water vapor is the only side product of converting hydrogen into heat by thermochemical processes (combustion). Similarly, the side product of converting hydrogen into electricity and heat by electrochemical processes (fuel cells) is only liquid water. In other words, hydrogen produces zero harmful pollutants when converted into useful energy: zero carbon monoxide, zero nitrogen oxides, zero sulfur dioxide, zero particulate matter and no carbon dioxide emissions[1].

Secondly, the new tasks attributed to hydrogen could be explained by the circular economy nature of its value chain. One cubic meter of water is 1000 kilograms, 111 kilograms of this amount is hydrogen, and the rest is oxygen. Therefore, in cases where hydrogen is produced cleanly from water by electrolysis and when hydrogen is converted into energy by combustion or fuel cells, hydrogen creates its own source, i.e. water. In addition, hydrogen may also be produced from organic wastes by using various technologies. Thus, hydrogen may contribute to solve environmental problems by eliminating wastes and contributing to the solution of the energy problem (İ.

[1] This and the following two paragraphs have been compiled from the seminar notes of Prof. Dr. İskender Gökalp under the STPS 545 course given in the 2020-2021 Spring Semester at METU Department of Science and Technology Policies.

Gökalp, personal communication, May 2021). Ultimately, hydrogen may potentially play a decarbonization role both for the energy sector and the transport and many industrial sectors (IEA, 2019).

In summary, hydrogen provides possible contributions and advantages in many aspects when being incorporated into the large-scale energy socio-technical system. The sources of hydrogen production are various (water, organic wastes, coal/lignite, and natural gas), and accessibility to these sources is high. Similarly, the production methods (electrolysis, solid fuel gasification, biomass fermentation, pyrolysis, and hydrothermal processes) are diverse. Therefore, it is suitable for regional/local, dispersed/multicenter energy systems. Hydrogen's transformation into usable energy is clean, and it re-produces its resource, setting an excellent example for the circular economy. Moreover, hydrogen production is still open to new technologies. Fuel cells and electrolyzers are science-based technologies that are still developing, while energy conversion technologies applied to fossil systems are almost ossified technologies. Hence, hardworking new players can enter the sector.

On the other side of the coin, the physical and chemical properties of hydrogen introduce many potential risks for humans and economic assets. From Hindenburg to Fukushima, accidents involving hydrogen have severe consequences for humans and the environment (EHSP, 2021). Risks of leakage, fires, and explosions are present in all segments of the hydrogen value chain: production, distribution, storage, and energy transformation. These risks are examined in Chapter 5.1.

This thesis employs qualitative content analysis of the latest hydrogen policy papers in the EU, revealing their perception of regulation as a "barrier" for the development of hydrogen strategies, and demonstrating the absence of serious considerations of "safety" issues, Therefore the incompatibility of the hydrogen risk chain with the hydrogen value chain is revealed as a significant finding. Finally, as one remedy to this incompatibility, the precautionary principle, its relation to science and technology policy studies (STPS), and its possible applications in the context of hydrogen technologies are discussed.

We approach hydrogen safety in a PP framework, propounding its significant place in just and safe energy relations. Next, we connect the normative underpinnings of PP with the governance of the advent of hydrogen technologies, asking how PP might illuminate good relations in uncertain worlds. Finally, we discuss how PP's implementation can help regulations balance the needs for safety and innovation and how it may tailor regulations to the needs of hydrogen technologies.

To contribute to the analysis of sustainable and safe energy transition policies, this thesis asks the following research question: How can the precautionary principle help to secure "the delicate balance between desires for a rapid advent of hydrogen energy technologies while keeping the highest safety level for the users?" (Kart & Gökalp, 2021).

This thesis is essentially devoted to analyzing the safety/innovation tension in the unfolding EU hydrogen strategies through the lens of the precautionary principle. By doing so, we also gathered substantial insight into the needed regulatory elements for developing countries such as Turkey to accompany the potential generalization of hydrogen technologies in those countries. Therefore, we formulated a preliminary research question for the Turkish case based on the precautionary principle cannons. This research question can be expressed as follows: "What are the preliminary regulatory analyses needed to be conducted for Turkey to prepare herself to host the hydrogen economy?" We briefly treated this question by analyzing the present status of natural gas regulations in Turkey, assessing the intensity of the modifications to be introduced to accommodate hydrogen or hydrogen-containing gases' arrival in the Turkish energy system and network. We, however, insist that this part of the thesis has a very preliminary nature waiting to be developed in future works.

1.1. Organization of the Thesis

The thesis is constructed on two main pillars: the precautionary principle and hydrogen. Both pillars are researched in the EU laws and regulations. Spaces of intersectionality where PP is relevant for hydrogen regulations are determined. Concurrently, precautionary policy suggestions for the EU are made for hydrogen where applicable.

In the Second Chapter, the EU laws, official and strategic EU documents, EU directives, EU regulations, and EU project reports on hydrogen, comprised the first part of the literature review. Relevant complementary literature such as energy and environmental regulations are also thoroughly examined. Turkish energy laws and regulations that may be impacted by the introduction of hydrogen as a new energy carrier are also studied.

The second part of the literature review includes the analysis of the precautionary principle literature and of the arguments of its critics and supporters, based on the studies of authors such as Sunstein with his "Laws of Fear" (2005), Parke & Bedau (2009); Sandin, Peterson, Hansson, Ruden, & Juthe (2002), Hartzell-Nichols (2013), Graham, Wiener, Marchant & Mossman. Main supporters include Sachs (2011), Fisher and Harding (2006), Som et al. (2009), Grant & Quiggin, Persson, Garnett & Parsons, Salzman & Kysar (2008). The legal readings of PP are done for legally binding international agreements and treaties, case law, legal doctrine, customary international law, and jurisprudence at the international level and state practice at the national level. As one very successful example of PP, the thesis focuses on the Montreal Protocol in detail. Examination of this Protocol contributes to understanding the delicate balance between innovation and regulation.

Original tables of PP in internationally binding agreements and PP in international policy instruments are made to support the quest for the answers to the research question. Interlinkages between precautionary measures and STPS studies are examined. Last but not least, the so-called 'innovation principle' is introduced as an obligatory dimension to be explored within the context of the thesis. An original table is prepared to reveal the evolution of the 'innovation principle.' This sub-section invokes future research topics opening the innovation-regulation tension in hydrogen technologies.

In the Third Chapter, how the thesis understands and uses legal doctrinal methodology and content analysis as a research tool are explained.

In the Fourth Chapter, Findings are presented in two main subchapters: the EU and Turkey. The findings on the EU's regulatory and policy framework are grouped under four main sections, and Turkey's findings consist of two main sections. These descriptive findings endeavor to find intersections between the two pillars of the thesis.

In the first section of the Fifth Chapter, firstly, the major issue, hydrogen risk chain - hydrogen value chain incompatibility, including the cost problem, is meticulously discussed. In the next subchapter, precautionary hydrogen considerations for the EU are provided. In the last subchapter, a recent development, the innovation principle's relationship with the precautionary principle as non-competing elements are discussed.

In the Sixth Chapter, a preliminary regulatory analysis for Turkey is made regarding the advent of hydrogen technologies. This Chapter also includes preliminary policy considerations for Turkey.

Concluding remarks are given in the Seventh Chapter. Concurrently, the limitations of this study and future research topics are discussed.

1.2. Significance and Objectives of the Thesis

The answers to the research question are significant as hydrogen can play a vital role in transitioning to a new global sustainable and decarbonized energy regime. The decarbonization potential of hydrogen concerns almost all the economic spheres from industry, transport, and services to household activities (Kart & Gökalp, 2021). PP can mobilize trans-disciplinary expertise needed for safe energy transitions in this context. PP requires a continuous and holistic audit, where information and knowledge are always prone to revision and change (Whiteside, 2006, p. 58). Therefore, it is crucial to policymaking, making it more reasonable, scientific, and accountable (Sachs, 2011; EPRS 2015; Whiteside, p. 48, 84-90, 147).

The first objective of the thesis is to examine the relationships between technical, economic, and legal aspects of the EU's decarbonization with hydrogen agenda while an integrated vision is in its infancy. The second objective of the thesis is to delve into the risk aspects of the hydrogen infrastructure for sound policymaking and regulation. This thesis's third objective is to contribute to designing hydrogen policies by offering additional transparency; and enabling more deliberative, participatory, and democratic decision-making processes. The fourth objective of the thesis is to reflect on the implications of the introduction of hydrogen into the Turkish energy system regulations.

In the next Chapter, a comprehensive literature review is conducted on the two central pillars of the thesis: PP and hydrogen regulations in the EU.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of the EU's Economics and Strategies of Decarbonization by Hydrogen

Sustainable energy systems are among the major objectives of countries and economic and political actors. In this context, countries and investors have paid increasing attention to hydrogen technologies, including resource and technology independence remedies and producing solutions to environmental and waste problems (IEA, 2020).

Hydrogen Council's Hydrogen Insights 2021 Report (from now on referred to as "the report") brings together a group of 123 companies in more than 20 countries. This report provides detailed analysis about the status of the hydrogen value chain.

The report (2021) identified 228 announced projects in the value chain as of 2021. Seventeen of these projects are at the Giga level ("Giga level: more than 1 GW of power for renewable hydrogen and over 200,000 tons per year for low-carbon hydrogen") (HC, p.6). Even though these projects are spread over six continents, the European continent leads with a prevailing rate of 55 percent. The report (2021) identified approximately US$ 80 billion in final investments, as well as US$ 262 billion in announced investments that are going to be made in hydrogen projects by 2030. There is also a comparison of clean hydrogen production capacities between 2019 and 2020. While this capacity was 2.3 million tons according to the 2019 projections, it was found to be 6.7 million tons according to 2020 projections. This nearly 300 percent leap over one year indicates that the hydrogen economy is accelerating greatly at least in intentions. It is estimated that hydrogen production costs will be 62 percent lower in 2030 compared to 2020 (HC, p. 6-9). As the costs decrease, production capacity will inevitably increase. Dozens of countries representing an essential part of the world's gross domestic product (GDP) determine and implement carbon prices, net-zero carbon targets, and hydrogen strategies (HC, p. 8) . As it can be seen in Figure 1 from the report, 31 countries representing 73 percent of the world's GDP have established national hydrogen strategies.

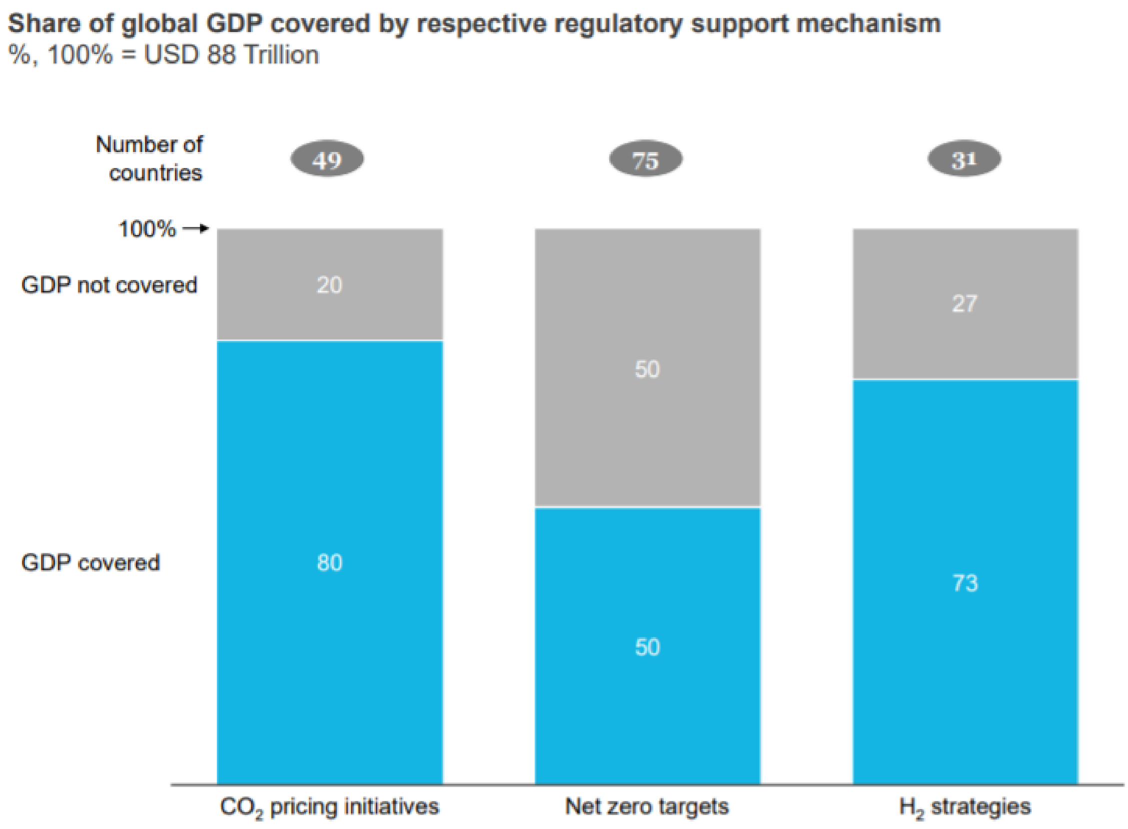

Figure 1: Hydrogen and Green Regulation

Source: Hydrogen Insights Report 2021, Hydrogen Council, McKinsey & Company, p.8

Figure 1 shows that even though there are a relatively limited number of countries developing a national hydrogen strategy -compared to net-zero targets and carbon pricing initiatives-, the economic power of these countries increases the significance of hydrogen in the upcoming period. The report (2021) states that 75 countries have set a net-zero carbon goal. Furthermore, many regulations and emission targets at the sectoral and provincial levels, especially in transportation, augment the need for clean hydrogen. In addition, advanced studies on hydrogen quota policies for maritime transport and aviation fuels are carried out in France, Germany, Portugal, and Spain (HC, p.8-9).

In the Hydrogen Study of the Joint Research Center (JRC) of the European Commission (public version), decarbonization scenarios of various EU institutions and organizations have been evaluated together (European Commission Joint Research Center, 2019). According to the findings, in most scenarios, hydrogen and its derivative fuels account for 10% to 23% of EU final energy consumption by 2050.

The European Hydrogen Roadmap is another significant document predicting that 5.4 million hydrogen-related jobs could be created by 2050 (European Hydrogen Roadmap, 2019). This number is equivalent to three times the number of jobs in the EU chemical industry today (Fernandez, 2022).

According to Global Hydrogen Review 2021 by the International Energy Agency (IEA), national hydrogen strategies of the countries in terms of their use of area are listed as follows: Buildings, electricity, industry (chemistry, steel, and other), mining, refineries, maritime, land transportation, and aviation (IEA, 2021). It has been determined that the majority of the investments by most countries are made for electrolyzer technologies. The second most common method is natural gas reformation, carried out with carbon capture technologies. By 2030, France has committed public investments of €7.2 billion, Germany €9 billion, Spain €1.6 billion, and Portugal €900 million. In addition to national commitments, the EU Hydrogen Strategy has committed €3.77 billion of public investment across the Union by 2030. €1 billion of this investment is allocated to R&D studies (IEA, 2021, p. 27-29).

2.2 A Brief Genealogy of Legal Protection of the Environment

Legal protection of the environment is a historical subject. Environmental regulations date way back to ancient civilizations such as Mesopotamia, Egypt, Anatolian civilizations, and Ancient Greece (Kloepfer, 1981, p.73). Roman Empire held several means to regulate the environment, having detailed rules on water, dirty smell, and neighborhood responsibilities (Söğüt, 2014). Even though these dispersed and unconnected regulations served their communities well, fulfilling their intended functions, it would be implausible to define these attempts as the formation of the discipline of environmental law, as they did not consist of a systematic approach to the environment (Güneş, 2020, p. 41).

The formation of environmental law can be traced back to the second half of the twentieth century (Rockwood et al., 2008). With two world wars being over, the accelerated economic growth of Europe and the US inevitably drove severe environmental problems, creating pressure on ecosystems. National responses (i.e., the 1956 UK Clean Air Act, 1961 Finland Water Act, 1964 Sweden Environment Protection Law) and international responses such as 1948 Universal Declaration of Human Rights, 1950 European Convention on Human Rights, 1969 American Convention on Human Rights, 1972 Stockholm Declaration, 1981 The African Charter on Human and Peoples' Rights, 1982 UN World Charter for Nature, 1983 Declaration of the Basic Duties of ASEAN Peoples and Governments, 1989 Convention on the Rights of the Child, 1992 Rio Declaration, 2002 Johannesburg and 2012 Rio Sustainable Development Conferences emerged (Güneş, 2020, p. 42-46). Philosophical approaches such as the anthropocentric, conservationist, preservationist, and deep ecological approaches evolved parallel to the political scene developments (Yokuş Sevük, 2017, p.10-12). These developments led to the formation of environmental law and its characteristic principles, which contributed to this discipline's independence. Prevention and precaution, the no-harm rule generally expressed by the maxim *sic utere tuo ut alienum nonlaedas* ("use your own property in such a way that you do not injure other people's") (Law & Martin, 2009), polluter pays, sustainable development, integration, cooperation, and intergenerational equity are among the main principles borne out of this multi-decade process (Van Dyke, 2006; s2). It is crucial that all these principles should be understood and implemented indivisibly, interconnectedly, and complementarily. They operate in a web structure, reinforcing each other's presence.

2.3 Precautionary Principle

2.3.1 Origins

Some authors connect PP's roots to the good old maxim "sic utere tuo ut alienum nonlaedes" (use your own property in such a way that you do not injure other people's) (Law & Martin, 2009) in Roman Law (Subramanya & Sarker, 2017). As the scope of our study focuses on the modern PP concept, we prefer to begin with the formation of this political, ethical, and legal principle in Europe in the 20th century; as the idea came to the fore with international discussions on environmental policies in the 1970s (Hansson, 2020).

The modern precautionary principle materialized in the Federal Republic of Germany in the early 1970s during the legislation processes regarding acid rain and air and sea pollution (EPRS, 2015; WHO, 2004, pg.33). German legislators aimed to encourage private companies to take preventative action before factually proven environmental damage (Bourg and Schlegel, 2001, p. 140; Carvalho, 2010). It is a consolidation of three German environmental law principles: "the prevention principle (Vorsorgeprinzip), the polluter pays or accountability principle (Verursacherprinzip), and the principle of cooperation/participation (Kooperationsprinzip)" (Bourg and Schlegel, 2001, p. 140). During this decade, Swedish and Swiss law discussed similar doctrines (Wiener, 2007, p. 599). For instance, in 1969, the reversal of the burden of proof was enacted as a legal mechanism regarding risky activities in the Swedish Environmental Protection Act (IISD, 2020, p.3).

The current understanding of PP can dominantly be connected to the first principle above, Vorsorgeprinzip. Even though most sources translate the concept into English as "foresight" (EPRS, 2015; p.4), a literal translation is fore care (Read & Tim O'Riordan), which connects to the "duty of care" in modern environmental law. PP is the regulatory framework where this duty is embodied. Furthermore, it is the only principle regarding implementing "planetary care" for the future globally and intergenerational (Read & O'Riordan, 2017, p.5, 8).

After the emergence of Vorsorgeprinzip, PP was referenced in international treaties during the 1980s and "enjoyed transatlantic recognition" during the 1990s (Fitzmaurice, 2013, p.7). As a result, PP was incorporated in almost all international environmental treaties/declarations, beginning with the 1982 World Charter for Nature (European Commission, 2000; EPRS, 2015). These treaties include (but not limited to) 1985 Vienna Convention for the Protection of the Ozone Layer, 1987 Ministerial Declaration of the Second International Conference on the Protection of the North Sea, 1990 Ministerial Declaration of the Third International Conference on the Protection of the North Sea, 1990 Bergen Declaration, 1990 OPRC Convention, 1991 Convention on the Ban of Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, 1992 Treaty of Maastricht on European Union, 1992 OSPAR Convention, 1992 Helsinki Conventions, 1992 Baltic Sea Convention, 1992 UN Framework Convention on Climate Change (UNFCCC), 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic, 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes, 1992 Bamako Convention, 1992 Convention on Biological Diversity, 1994 Sofia Convention, 1994 Fort Lauderdale Resolution, 1998 Wingspread Declaration, 2000 Cartagena Protocol on Biosafety (Jörgens et al., 2014, p. 213-217).

Many of these documents refer to or expound on the principle but do not define it. Some of them refer to the definition made in the 1992 Rio Declaration. There are numerous interpretations of the principle in the documents explaining it. To this date, there is no unified interpretation of PP. It is probably one of the most vexed subjects of environmental law, vehemently disputed in academia and beyond (Hansson, 2020, p.245).

The principle is based on the following idea: Measures taken after an activity or substance is proven harmful/risky will often result in delay. Hence, they will not be efficient enough, and even irreversible damages may occur. Consequently, PP warrants preventive and precautionary measures to be taken without waiting for scientific evidence if there is reasonable doubt that a substance or activity will have negative consequences for the environment.

PP is a legal mechanism that aims to accommodate two needs: Ecological limits and the demands of the industry (Sachs, 2011, p. 1310). The principle accomplishes it by "putting government in a risk gatekeeping role" (Sachs, p. 1310), safeguarding that the undertaker of a seriously dangerous activity is competent by the legal mechanism for the reversal of the burden of proof. This mechanism is explicitly enshrined in the 1998 Wingspread Conference:

> Where an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public bears the burden of proof. The process of applying the Precautionary Principle must be open, informed and democratic, and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action. (GDRC, n.d., p.1)

This version of PP is considered to be "strong precaution" in the existing literature (Sachs, p. 1313). The reversal of proof PP invokes is "only a possible consequence" of it, as also supported by the 2000 EC Communication (EC, 2000). On the other hand, examples of "weak precaution", characterized by Article 15 of the 1992 Rio Declaration do not explicitly state such a mechanism:

> In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (UN, 1992, p.2)

The weak-strong binarism will not be dealt with in detail as it is not a primary focus of this thesis. Furthermore, this distinction is made only by the authors of the relevant literature. It has never been made by the legal and policy texts listed in Tables 1 and 2 in this Chapter. We thereby reveal that the protection level is not always correlated with the exact wording of the principle in the respective text. We accept the reversal of the burden of proof as a principal interpretation of PP, as it works to “counterbalance certain perceived structural asymmetries of the unregulated market” and “actively deploys private actors in service of the public’s informational needs” (Kysar & Salzman, 2008). The standard of proof and the reversal of the burden of proof are technical legal topics out of the scope of this thesis.

Although there is no consensus on its definition and content, PP is included in many national, regional and international legal texts. Thus, it is also recognized that PP has become a universal principle. In addition to environmental protection, PP has taken place in international binding conventions in various fields such as chemical policy, marine protection, oil pollution, climate change, clean air policy, acid rain, ecosystems resilience, floods, nuclear accidents, genetically modifies organisms, nano-technologies, ozone depleting substances, protection of transboundary watercourses, food safety, conservation of fish stocks, biological safety, global warming, persistent organic polluters, sulfur emissions, radioactive discharges, sustainable development, protection of the North Sea, public health, endangered species, responsible fisheries and biodiversity (Jörgens et al., p. 214).

In the following tables, international documents incorporating the precautionary principle are listed chronologically according to their genres and the wording included in their respective texts. Table 1 examines legally binding international treaties and agreements, and Table 2 lists the international and regional policy instruments that are not legally binding but rather soft law instruments. Overall, Tables 1 and 2 present the paradigm shift from” a posteriori control” of risks “to a priori control” (De Sadeleer, 2005) in the late 20^{th} and early 21^{st} centuries. In addition, they exemplify in detail the variety of the contextual incorporation of the principle in official documents and the wide range of implementation of PP in public health and safety matters.

Table 1: Legally Binding International Treaties and Agreements Incorporating the Precautionary Principle According to Their Wording and Genres

Legal Instrument	Wording	Genre
1985 Vienna Convention for the Protection of the Ozone Layer	Prevention, precautionary measures	Chemicals and clean air policy
1987 Montreal Protocol	Prevention, precautionary measures	Chemicals and clean air policy
1990 London Amendments to the 1987 Montreal Protocol	Prevention, precautionary measures	Chemicals and clean air policy
1990 OPRC Convention	Prevention, precautionary measures	Oil pollution
1992 OSPAR Convention	PP	Protection of the marine environment of the North-East Atlantic
1992 Helsinki Conventions	PP	Protection and use of transboundary watercourses and international lakes
1992 Convention on Biological Diversity	Prevention	Biological diversity
1992 UN Framework Convention on Climate Change	Prevention, precautionary measures	Climate change

Table 1 (cont'd)

1994 UN Protocol to the 1979 Convention	Precautionary measures, no reference to Rio D. Art. 15 but the same framing	Long-range transboundary air pollution, on further reduction of sulfur emissions
1995 UN Agreement for The Implementation of UN Convention of 10 December 1982	Precautionary approach, precautionary reference points	Conservation and management of straddling fish stocks
1996 London Protocol to the 1972 Convention	Prevention, precautionary approach	Marine pollution
1997 Kyoto Protocol	No explicit mention	Climate change and global warming Elongates Montreal Protocol's protection to gases not covered there
1998 Rotterdam Convention on Hazardous Chemicals	Precautionary measures	Chemicals
2000 Cartagena Protocol	Precautionary approach, reference to Rio Declaration Art. 15	Biological safety
2001 Stockholm Convention	Precaution, precautionary manner, reference to Rio Declaration Art. 15	Chemicals, on persistent organic polluters
2018 Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean	Prevention principle, PP	Environmental protection with a human rights dimension

Note. Adapted from "Converging ideas about risk regulation? The precautionary principle in national legal systems", by Dieter Pesendorfer, 2014, in Understanding Environmental Policy Convergence The power of Words, Rules and Money, 2014, Cambridge University Press.

Table 2: International and Regional Policy Instruments Incorporating the Precautionary Principle

Policy Instrument	Wording	Genre
1982 World Charter for Nature	Precautions	nature conservation
1984 Bremen Declaration	Precautionary measures	Protection of the North Sea
1987 London Declaration	The principle of precautionary action	Protection of the North Sea
1987 Brundtland Report	Precautionary measures	Sustainable Development
1990 UNECE Bergen Declaration	PP	Sustainable Development
1990 OECD Recommendation	Prevention Precautionary action	Integrated Pollution Prevention and Control
1990 Ministerial Declaration on The Second World Climate Conference	Precautionary measure	Climate Change
1990 Hague Declaration	PP	Protection of the North Sea
1992 UN Rio Declaration	Precautionary approach	Environment and Development
Agenda 21	Precautionary approach, measures	Sustainable Development
1993 Joint meeting of the Oslo and Paris Commissions	PP	Radioactive discharges
1994 CITES Resolution	Precautions	Endangered Species
1995 Esbjerg Declaration	PP, Precautionary approach	Protection of the North Sea
1996 FAO Technical Guidelines	Precautionary approach	responsible fisheries
1998 Wingspread Conference	PP, Precautionary approach	Precautionary Principle
2002 Bergen Declaration	Prevention, PP, Precautionary approach	Protection of the North Sea
2015 Oslo Principles, Principle 1	PP	Global Climate Change Obligations

Note. Adapted from "Converging ideas about risk regulation? The precautionary principle in national legal systems", by Dieter Pesendorfer, 2014, in Understanding Environmental Policy Convergence The power of Words, Rules and Money, 2014, Cambridge University Press.

Pesendorfer's list was used as primary resource in the preparation of Tables 1 and 2 (Pesendorfer, 2014). The list is updated with the latest regulatory and policy documents. In addition, the wording and policy approaches on how the PP is incorporated into these texts is determined via textual analyses. As can be observed from Tables 1 and 2, PP "enjoyed transatlantic recognition" (Fitzmaurice, 2013, p.7) in the 1980s and 1990s and started a decline beginning in 2000s. Only at the end of the 2010s, PP found its place in international documents in the 2015 Oslo Principles and 2018 Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean. The Oslo Principles are quite significant as they place PP as the first principle for the states' obligations to restrain climate change. This document is prepared by legal experts from around the world, such as the U.S, Brazil, the Netherlands, Australia, India, the U.K, China, and South Africa. There are barristers, advocate-generals, a European Court of Human Rights Judge, retired Judges of High Courts, and law professors from Columbia, Yale, George Washington, Maastricht, Wuhan, and Stellenbosch Law Schools (Yale University, 2015). The text designates clearly the precautionary principle as a state obligation and delineates the means for the fulfillment of this obligation (Yale University, 2015). It is rather a recent document that outlines the primordial part that PP has in climate change mitigation.

A total examination of the wording columns reveals that the level of protection of the document is not necessarily correlated with the level of precaution (weak/strong) present in the wording of the texts. In this context, this thesis agrees with the general consensus of the formulations of weak and strong precaution, the former as seen in the Rio Declaration's Article 15 and the latter as in the Wingspread Conference. The Montreal Protocol is one prominent example of this situation. According to the weak/strong categorization, the wording of the Protocol can be determined as weak as it does not mention the mechanism of the reversal of the burden of proof in its text. However, the measures of the Protocol are so strong that they ban the production, use, and commerce of nearly 100 ozone-depleting substances. The same situation applies to all the documents present in Tables 1 and 2 on the protection of the North Sea, 1992 UNFCC, Agenda 21, and the 2000 Cartagena Protocol.

2.3.2 Critics and Supporters

Prominent scholars such as Sunstein with his "Laws of Fear" (2005), Parke & Bedau (2009); Sandin, Peterson, Hansson, Ruden, & Juthe (2002), Hartzell-Nichols (2013), Graham, Wiener, Marchant & Mossman have generously attacked the precautionary principle. Main supporters including Sachs (2011), Fisher and Harding (2006), Som et al. (2009), Grant & Quiggin, Persson, Garnett & Parsons, Salzman & Kysar (2008) responded to these critiques. There is a voluminous literature on this debate built up over decades. This thesis does not have an objective making an original contribution to this debate. Instead, as an original contribution to the literature, the thesis grouped the main arguments of critics and supporters of PP under ten themes: Utility, generality, applicability, flexibility, cost-benefit analysis, effect on innovation, relation with risk assessment, science-policy interface, protectionism, and cost-effectiveness. Table 3 provides a general representation of the arguments around these ten themes. In the preparation of this table, first we gathered comprehensive information on the arguments of critics and supporters of PP from the relevant literature. Then, we grouped them according to the themes these arguments revolve around. After the themes crystallized, we placed the relevant arguments within the respective thematic groups. In the table, the exact wording of the arguments is tried to be preserved as to provide a clear understanding of the underpinnings of the intense debate around PP.

Table 3: Thematic Representation of the Main Arguments of Critics and Supporters of the Precautionary Principle

Theme	Critics	Supporters
Utility	Imprecise, vague Senseless Irrational Conflicting definitions	Principles of international customary law always generally expressed No major conflicts among varying definitions Preserves "free space for decisions and activities of future generations."

Table 3 (cont'd)

Generality	Overly broad High level of discretion for lawmakers Arbitrary	No vacuity A concrete legal architecture establishing the reversal of the burden of proof Specific enough plausibility thresholds Detailed frameworks systematize the application process
Applicability	No clear action guidance Excessively risk-averse Ignores "risk-risk tradeoffs" Impractical- every technology is risky Unpredictable applications	Contextual Dynamic Pragmatic Assesses the seriousness of risks scientifically
Flexibility	Inflexible Extreme (ban or no-ban)	Shifting the burden of proof leaves the determination of the level of standard of proof "open-ended" Mostly is about non-binary applications such as restrictions, warnings
Cost-benefit analysis	Antithetical	Can include cost-benefit analysis A more qualitative response than cost-benefit analysis
Effect on innovation	Stifles innovation Paralysis of development Anti-growth Anti-technology Favors banning	Calls for monitoring of existing technologies and adoption of safer technologies. Does not impose banning necessarily. Fosters innovation of safer technologies A comprehensive approach to sustainable decision-making

Table 3 (cont'd)

Relation with risk assessment	PP as a tool of risk assessment	Risk assessment as only one aspect of PP Examines a wider range of harms Misleading certainty of narrow risk assessment Manages risk rather than preventing it Assumptions behind are open to manipulation
Science-policy interface	Not scientifically sound Based on fear Speculative science Judicial decisions without adequate scientific justification	Accounts for complex interactions Involves the possibility of ignorance in decision-making Deals with Type II policy errors Can prevent technological lock-ins Acknowledges knowledge always prone to change Takes scientific uncertainty seriously Enables transparent, accountable, informed decision-making
Protectionism	Open to opportunistic misuse by rent-seekers	Elements include proportional, fair, and non-discriminatory application Sovereignty of nations
Cost-effectiveness	Not economically viable	Protection of health takes precedence over economic considerations Accounts for environmental and health costs intergenerationally

Note The data for the critiques are compiled from Sandin, Peterson, Hansson, Rudén, & Juthe, 2002; Sunstein, 2005; Parke & Bedau, 2009; Hartzell-Nichols, 2013; Sandin & Peterson, 2019. The data for the supporters are compiled from and Som et al. 2009 and Sachs, 2011.

2.3.3 Precautionary Principle in EU Law

As a fundamental element of environmental decision-making, the precautionary principle was first enshrined at the Union level in Maastricht Treaty Article 130r(2) in 1992, formally entering the *acquis communautaire* (EPRS, 2015; Dinan, 2000). It is now incorporated into Article 191(2) of the Treaty on the Functioning of the European Union (TFEU) among the keystone principles of EU environmental policy like prevention, polluter pays, and rectification at source (Carvalho, 2010). The treaty stipulates that environmental policy “shall be based on the precautionary principle,” without making a concrete definition of the principle, a feature not specific to PP only but to all principles present in TFEU (EPRS, 2015; Sachs, 2011).

This does not mean PP is undefined, untreated, or a vague concept in the EU. On the contrary, the principle was elaborated in many institutions in the upcoming years. The Commission, the Parliament, the Council, European Environment Agency contributed to these interpretations. The legal status of PP was elevated into a being “general principle of EU law” by EU courts in the upcoming years (*Artegodan v. Commission* (T-74/00), 2002, prg. 184).

In 2000, the European Commission adopted a Communiqué on PP (EC, 2000), presenting a shared understanding of and a guideline for applying the principle. The communiqué stipulates that the scope of PP “is much wider” than sheer protection of the environment. According to the Commission, “human, animal and plant health” are also elements protected by the PP (EC, 2000, p. 2).

The European Parliament and the European Council endorsed the Communiqué, respectively, in Resolution dated December 14th, 2000, and Conclusion dated December 10th, 2000. They underlined the need for more multi-disciplinarity, transparency, and independence in risk assessments. Proportionality, non-discrimination, and information constantly subject to review were also elements stated in the Communiqué. Most importantly, the Communiqué explicitly stated that the “protection of health takes precedence over economic considerations” (EC, 2000, p.4).

This statement is primordial as the recent dichotomy created by the "innovation principle" suggests otherwise. This issue will be discussed further in Chapters 2.5 and 5.4.

The European Environment Agency's (EEA) definition in its 2013 report on the precautionary principle is far more comprehensive compared to that of the Rio Declaration:

> The precautionary principle justifies public policy and other actions in situations of scientific complexity, uncertainty, and ignorance, where there may be a need to act in order to avoid, or reduce, potentially serious or irreversible threats to health and/or the environment, using an appropriate strength of scientific evidence, and taking into account the pros and cons of action and inaction and their distribution. (EPRS, 2015, p. 10)

EEA also marks the capacity of PP to promote better and safer technologies.

In September 2017, The Commission published a future brief called "Science for Environment Policy The precautionary principle: decision-making under uncertainty," responding to criticisms and further delving into applying the principle with case studies, acknowledging the principle's function in high-stakes decision making (EC, 2017).

The mad cow (BSE) case regarding the validity of the Commission's export ban of beef from the UK laid the groundwork for the respect of the principle as one famous decision by the EU Court of Justice (Case C–180/96 UK v Commission (1998) ECR I–2265). This decision explicitly supported the extension of precautionary measures (WHO, 2004, p. 40). The CFI, in its seminal judgments, namely Pfizer (T-13/99, 2002, prg. 444) and Artegodan (T-74/00, 2002, prg. 183-184), concluded in clear terms that PP should be considered "a general principle of Community law". The case law was built upon the Treaty Articles and prior case law; for instance, the CFI referenced previous ECJ decisions recognizing the principle, creating consistency and legal certainty among the Union. Thus, the authorities' requirement to prioritize public health and environmental interests over economic interests was affirmed (T-74/00).

The principle is also represented in Secondary EU law. The Directive 2001/18/EC on genetically modified organisms; the Regulation (EC) 178/2002 establishing the European Food Safety Authority; or the Regulation on Plant Protection Products. One of the most prominent examples where PP is incorporated in the EU chemical legislation, Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), giving more duties to the industry by implementing the concept of "No Data, No Market," strengthening the precautionary approach. It changed the whole practice of registering chemicals by transferring the risk responsibility to companies and shifting the burden of proof onto the undertakers of technological activity (Richter et al., 2006, p. 70).

In 2018, the General Court of the European Union also confirmed that the PP is a general principle of EU law creating liability for relevant authorities (General Court of the European Union, 2018).

2.3.4 PP in International Court of Justice Jurisdiction on Energy Cases

Several judges in the International Court of Justice (ICJ) have recognized PP as an developing notion in international law in energy cases such as the 1995 Nuclear Tests Case (ICJ, 1995) and the 1996 Nuclear Weapons Case (ICJ, 1996). For example, in the 1995 case on the nuclear tests run by France in the Pacific, Australia and New Zealand complained under ICJ twice about the legality of French nuclear tests. Judge Weeramantry stated the following in his dissenting opinion: "The law cannot function in the protection of the environment unless a legal principle is evolved to meet this evidentiary difficulty, and environmental law has responded with what has come to be described as the precautionary principle" (ICJ, prg. 342). Judge Palmer also underlined in his dissenting opinion the following: "The norm involved in the precautionary principle has developed rapidly and may now be a principle of customary international law relating to the environment" (Van Dyke, 2006, p.20).

These are eminent representations of PP in case law. In the 1996 case, PP manifested once more in the dissenting opinion of Judge Weeramantry: "Principles of environmental law, which this Request enables the Court to recognize and use in reaching its conclusions, [include] the precautionary principle" (Ambrus, 2012, p. 264). These ICJ Judges' opinions are critical takes on PP by the Court, propounding its significant place in energy cases on the environment, paving the way for PP to be acknowledged as customary international law.

2.3.5 The Montreal Protocol

The Montreal Protocol, which is considered the most successful multilateral agreement on the environment and is the only agreement all UN member states are parties to, might be shown as a concrete example. It is the first Multilateral Environmental Agreement to establish targets and timetables for the phase-out of environmentally damaging chemicals, especially for the atmosphere. It is designed to address the concerns of producers, "preventing high price inflation or overproduction during the phase-out period of the targeted gases" (IISD, 2015). For the first time in history, The Montreal Protocol suggested an international intervention on the production, sale, and use of substances- nearly 100 ozone-depleting substances. Some of them ought to be banned, although the damage of these substances was not scientifically proven yet (ozone-depleting substances, from now on referred to as "ODS." For example, HCFC (Hydrochlorofluorocarbon) gases in refrigerators, air conditioners).

If this Protocol had not been signed, the depletion of the ozone layer would have increased tenfold by 2050. Signatories have phased out the use of 98% of ODSs worldwide compared to the 1990s. On the other hand, the Protocol has made significant contributions to health and prevented in the USA 46 million cataracts and "283 million cases of skin cancer, 8.3 million" of which were melanomas, by 2015 (EPA, 2015). A legal text based on PP may have a remarkable impact. According to the analysis prepared by Jacques Van Engel for the United Nations Development

Program (UNDP) in 2017, this 1987 Protocol covers 15 of the 17 Sustainable Development Goals and 39 of 169 sub-goals implemented in 2015 (UNDP MPU, 2017). The 28 years in this duration of time reveals the Protocol's vision, integrity, inclusiveness, relevance, and, therefore, the precautionary principle.

It is necessary to emphasize again that the discussions and practices of hydrogen decarbonization have gained such importance, especially today, due to environmental concerns. These developments are triggered by similar concerns as in the Montreal Protocol. Figure 2 is the outline of the Kigali Amendment, signed as an Amendment to the Montreal Protocol (UNEP, n.d.).

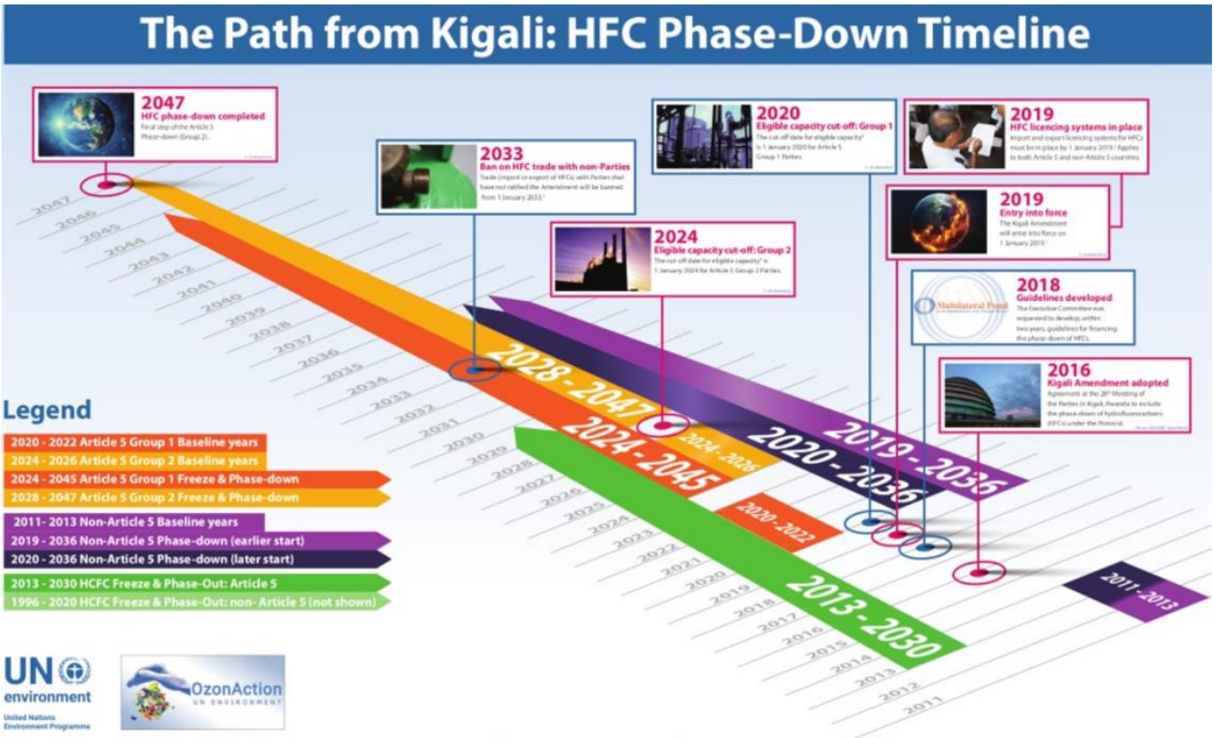

Figure 2: Kigali Amendment's HFC Phase-Down Timeline

Source: UN

The Kigali Amendment is the exit plan from the HFC (hydrofluorocarbon) gas that replaces the CFC (chlorofluorocarbons) prohibited in the Montreal Protocol. It entered into force in 2019, and the validity period lasts until 2047. The Amendment is expected to gradually reduce the use of HFCs, avoiding a 0.5°C increase in atmospheric temperature by the end of the century (UNIDO, n.d.). It has been demonstrated above that the achievements of the Montreal Protocol are of crucial importance. However, as seen in the Kigali Amendment, some remedies bring about their problems.

The use of CFCs and HCFCs (hydrochlorofluorocarbons) declined, thanks to the Protocol dramatically. Thus, HFCS use has significantly increased, especially in the refrigeration sector. HCFCs do not intervene with the ozone layer but have a high potential for global warming. Until the Amendment, the Montreal Protocol provided control only for the substances that damage the ozone layer. The Kigali Agreement implies further intervention in this sector. The impacts of the initiation and implementation of the measures of the Montreal Protocol required this intervention. As it can be seen, first-generation solutions may cause further problems. For this reason, it is necessary to be in a constant state of vigilance. It is also critical that the precautionary principle constantly allows information to update itself.

Eventually, an unprecedented success was achieved in the Montreal Protocol. However, it should be noted that the economic impacts of the prohibited gases are limited to specific manufacturers. The result was conducted in a short time. In this regard, the agreement reached in Kigali represents a milestone in the commitment of the international community to combat climate change. This Amendment is the first significant step toward a deal on limiting global warming after the 2015 Paris Agreement. However, today's situation is quite different, and the problem is highly complicated.

For this reason, the world public opinion predicts achieving the climate goals only between the years 2050 to 2060. Furthermore, hydrogen offered to remedy the climate crisis brings its own problems. The implications of PP for the hydrogen case is much nuanced than that of the Montreal Protocol. However, these problems do not have as linear and straightforward solutions as the Montreal Protocol. Nevertheless, it seems possible to eliminate at least some of the issues and resolve the issue's complexity in the context of PP. At this point, several study fields emerge for STPS studies and their intersections with law.

2.3.6 Precaution Safeguards Against Type II Errors

Two hypotheses are needed when performing hypothesis testing. The null hypothesis states that there is no relationship between the predictor and the population's outcome variables. The null hypothesis is the formal basis for testing the statistical significance (Banerjee et al., 2009). A null hypothesis or a hypothesis that is believed to be true. The alternative hypothesis is what would happen if the null hypothesis were incorrect. For example, a cleaning company can publish information proving that its cleaning product kills 99% of all germs if it conducts a hypothesis test with data to support its hypothesis. Two types of errors can occur when interpreting the results.

A Type I error transpires when the researcher declines a null hypothesis that is true in the population. This type of error is called a false positive. A Type II error transpires When the researcher neglects to decline a null hypothesis that is false in the population. This type of error is called a false negative. These two types of errors can never be circumvented completely, yet the researcher can diminish their likelihood by for instance raising the sample size (Banerjee, Amitav, et al., 2009).

Table 4: Type I and Type II Errors

Type of Errors	H_0 Rejected	Fail to Reject H_0
Type I	Correct	Type II Error
Type II	Type I Error	Correct

Alpha (α) = Probability (Type I Error)

Beta (β) = Probability (Type II Error)

Power = 1- β

The table above illustrates the four possible outcomes of hypothesis testing, which primarily depend on the consequence of H_0 after testing. When H_0 is true, one's decision must be failing to reject, whereas accepting to reject is valid when H_0 is true. Type II error happens if the null hypothesis is incorrect, resulting in failing to reject.

The illustration of β resembles the probability of the occurrence a Type II error, and its magnitude has a positive causality relationship with the power of the test.

In the last decades, environmental decision-making has been increasingly scrutinized through the precautionary principle (Underwood, 1997, p.1). According to PP, ambiguity and doubt make it hard to make a near-perfect decision. Any mistakes must favor the long-term sustainability of the environment. Although there are issues in implementing PP in a practical manner, it provides accurate means and value decision-making in risky situations. In the context of the environmental, those can regularly be rendered as Type I error which occurs when it is asserted that there may be an environmental effect when there is none. A Type II error could constitute failing to hit upon an impact even though one has occurred. The majority of environmental studies are geared to look for Type I errors. Usually, Type II errors are not a major source of concern.

However, PP prescribes that Type II errors are an extreme difficulty for environmental decision-making and are plenty greater in effect and volume than Type I errors. Thus, identifying the effects of Type II errors is crucial to sound and informed policy-making.

Type II errors, on the other hand, can lead allowing a hazardous activity to continue and are unavoidable effect of a constant bias against Type I errors.

People are autonomous individuals who are free to pursue their dreams and do their own thing as long as they do not damage others, according to popular belief that has gained traction. Unfortunately, this approach has created a conflict between the individual and society regarding defining tolerance and harm.

John Stuart Mill (1859) investigated “the nature and limits of power” that society can lawfully exercise over the individual (Mill, 1978; WHO, 2004, p.72). He figured that the only legitimate reason for just exercise of power on a person “against his or her will, is to prevent harm to others” (Warnock, 2003; WHO, p.72). Mill was worried that, “in a democratic society, the majority would” establish the boundaries of tolerance, impeding “the creative individual’s” desire to experiment and expand, and explore new horizons (WHO, p.72).

He was also concerned that the majority would interpret “harm” and use erroneous accusations of “hurt” as a roadblock to development (WHO, p.72). In a nutshell, Mill dreaded majority dictatorship; and their proclivity to maintain the status quo. Many of today’s policy disputes revolve around this tension. Harm must be defined, but people must also decide how to behave or use legitimate power with uncertain situations regarding risk. There is a risk of failure in thwarting damage if evidence of harm is demanded before restricting an activity or picking an alternative. It is simple to see how Mill’s anxieties are reflected in today’s environmental policies. In principle, the burden of proof is on the public or individuals who claim to have been damaged. “High standards of proof” make the situation worse for these individuals, even when the evidence implies that harm has happened or is anticipated (WHO, p.72). Thus, “a bias toward Type II errors”, which has been “established by convention in interpreting scientific data- has also crept into social, political, and judicial policy” (WHO, p.72). It's perfectly reasonable to wonder if such a bias is suitable for averting harm or selecting “among optional human activities” (WHO, p.72). Furthermore, it is reasonable to wonder how such a bias may affect the way human activities modify “complex ecological systems that define the world” to be bequeathed intergenerationally- a matter at the heart of sustainability (WHO, p.73).

2.3.7 Precautionary Measures

There is a wide range of policy tools for a concrete implementation of PP. The stringency level of these measures differs varying on the weightiness of the anticipated risk and the level of scientific evidence (Applegate, p. 23-24; Hansson, p.224). These complex measures should not be appealed for frivolous risks as they can be expensive and challenging to implement (Sachs, p.47). This flexibility assists the appropriate treatment of different levels of risk and scientific evidence of it. Methods and tools such as prohibition, permissibility, planning, environmental impact assessment, notification obligations, and the best available technology are considered the common tools of the prevention principle and precautionary principle (Trouwborst, 2009). These policies include establishing more significant safety boundaries, developing backup safety systems, implementing emergency plans, and education and training activities. The policies listed so far can potentially make a profound contribution to minimizing operator/user-related accidents detected by EHSP Task Force TF3, discussed in Chapter 5.1.

There are also some tools and methods specific to the precautionary principle for reversing the burden of proof, changing permit systems, changing decision-making procedures, and tightening environmental standards. Alternatives assessment, as another method, provides a holistic perspective since it also includes the alternative of "no action." PP may be implemented by establishing research programs to collect more information about the risk and test relevant successive assumptions (Kourilsky, 2002; Ewald et al., 2001). PP systematically requires opting for "clean" technologies in the environmental aspect. Such an approach is called an assessment of alternatives. The assessment process must also take the "no action" alternative seriously by asking whether an activity is too dangerous or unnecessary (Tickner, Raffensperger, and Myers, 1999).

In the context of public law, PP refers to the establishment of long-term environmental and health monitoring systems (European Environment Agency, 2001, 170–173), strengthening the independence of regulatory agencies and regularly informing the public about the activities of government agencies, manufacturers and users on ongoing experiments, safety protocols, observed anomalies, accidents, and safety violations (O'Brien 2000; Lascoumes 1997; Noiville 2002).

2.4 Innovation Principle

Numerous food safety, environmental, and health crises led to the adoption of PP by the EC in 2000 in its Communication. Since then, PP has provoked controversial debates among various stakeholders. In the coming years, polarized views on PP directed on the course to the invention and advocation of the ‘innovation principle’ (IP) by industry stakeholders with mainly economic concerns.

European Regulation and Innovation Forum, known as European Risk Forum until 2021, is a not-for-profit think tank organization based in Belgium. The founding objective for ERF was to discuss “new developments to the use of cost-benefit analysis.” These developments were probably the growing influence domain of PP, as the Forum described the Union’s approach to risk management functions as far-reaching. It is financed by its members who are fierce representatives of the industry from various sectors such as pharmaceuticals, sectors, including food and drink, chemicals, energy, building materials, oil and gas, biotechnology, and medical devices. Company members of the Forum by June 2021 are as follows: Companies BASF Bayer Burson Cohn & Wolfe Dow Europe Fipra International Henkel AG & Co MSD Animal Health Norilsk Nickel Ltd Syngenta AG Unilever plc (ERIF, 2021a).

ERF’s history is symbolic of the so-called IP/PP dichotomy. Initially a European Policy Center working group, it involved several tobacco companies like British American Tobacco and Philip Morris *fighting against* smoking bans (Smith et al., 2010). The tobacco industry’s membership in the ERF last for 13 years until their lobbying capacities were efficiently impeded by Art. 5.3 of UN Tobacco Framework Convention (Corporate Europe, 2018). These companies, along with pharmaceutical and fossil fuel companies, tried to shape regulation according to their interests. Garnett et al. examine these efforts in a meticulous paper, revealing these corporations’ involvement in influencing regulatory reforms (Garnett et al., 2018).

The forum always kept its distance from PP, the most possible reason why these powerful industry leaders came together in the first place. Yet, after the establishment of the ERIF Innovation Task Force in 2014 (ERIF, 2021b), it leveled up this distance by inventing an “innovation principle”, promoting innovation as an “equally important objective (as PP) for the EU” (ERIF, 2021c). The Forum continually expressed discontent with PP in its Monographs, Highlight Notes, and Communications between 2014-2022. ERIF aims to make the Innovation Principle a European policy framework over time (ERIF, 2021c). Recently, a major step has been taken in the fulfillment of this aim. The ‘innovation principle’ entered into EU law in 2021 in the Recital 6 of Regulation (EU) 2021/695 with the exact same content that ERF proposed and promoted. It concerns the introduction of IP in Horizon Europe -terms for the next 160-billion-euro EU research funding.

This is a huge development for PP that necessitates further inquiry. The chronological and genealogical study carried out in Table 5 aims to foster a deeper understanding of the underpinnings of the entrance of IP into EU law.

Table 5 provides detailed information on the anatomy of the innovation principle. The idea for the principle was born in 2013 by a group of CEOs of multinational companies with an ambitious open letter addressed to the then three Presidents of EU institutions (ERIF, 2021). From then on, with the formation of the European Risk Forum by these CEOs, a strong campaign for the promotion of IP and critique of PP began. This campaign accelerated with the participation of other multinational CEOs, BUSINESSEUROPE, and the European Round Table of Industrialists. The first time IP entered the EU jargon was in 2015 in a speech made by the then Commissioner for Research, Science and Innovation, praising IP and offering a dichotomy between IP and PP just as proposed by the formulators of IP (EC, 2015). The presence of IP continues in the upcoming years, finding its place in a Commission Staff Working Document in 2015, in EU Dutch, Slovak, and Finnish Presidencies’ agendas, in the Conclusions of the Competitiveness Council in May 2016, in a Commission Communication in 2017, in a funding and tender call for Horizon Europe 2020 Framework Program in 2017, in an Independent Expert Report published by the EC Directorate-General (DG) for Research and Innovation in 2019 and the 2020 Science, Research and Innovation Performance (SRIP) report by DG. These were all policy developments which led to a major legal development of the official entrance of IP to EU legislation on April 28th, 2021, with Regulation 2021/695. This Regulation establishes Horizon Europe, the Framework Program for Research and Innovation between 2021-2027, and sets the terms for the 95.5-billion-euro EU research funding (EC DG, 2021). Recital 6 of 2021/695 enacts that activities under Horizon Europe should be “in line with the innovation principle.”

The most important finding that the table puts forth is that the context of the innovation principle never changed throughout the 8-year-period it was born till its enactment in EU legislation. The third column of Table 5 serves to reveal this finding. Whereas PP has been a concept of vehement contestation for decades, IP was adopted as it was first presented by the representatives of industry. The EU never discussed the concept with the relevant stakeholders. In 2019, 75 civil society organizations wrote an open letter to the Council and the Parliament, urging them to "completely remove all references" to IP in EU policy and law, warning that the inclusion of IP in Horizon Europe is "extremely dangerous" (Global Health Advocates, 2019). This letter was not reciprocated by European bodies, and IP became a reference point for all the activities supported under Horizon Europe.

The dramatic entrance of IP to EU legislation set out an unbalanced situation with the existing EU laws and policies. ERF and ERIF lobby performed a strategic plan for the acknowledgement of IP by EU bodies beginning in 2005 and flourishing from 2013. For instance, they majorly targeted chemicals regulations, namely REACH, as presented in Corporate Europe Observatory's documents (Corporate Europe, 2018). Industries subject to strict regulation due to their dangerous nature for humans or the environment such as pharmaceuticals, chemicals, tobacco, plastics and fossil fuels industries form the majority of ERF and later ERIF.

The Table 5 is prepared from ERF and ERIF Highlights Notes, Monographs, 2014-2021, European Union's official website for the study of the relevant official texts of the EU, websites of stakeholders where communication is made such as BUSINESSEUROPE website and the websites where civil society open letters are published, and the Corporate Europe Observatory, The Innovation Principle Trap article dated December 5th, 2018.

Table 5: Chronological and Genealogical Examination of the 'Innovation Principle'

Institution	Date	Exact Wording of the Innovation Principle	Document Niche and Title	Content
12 CEOs of multinational companies	October 2013	Whenever policy or regulatory decisions are under consideration the impact on innovation as a driver for jobs and growth should be assessed and addressed.2	Open letter addressed to the then three Presidents of the EU institutions, José Manuel Barroso, Herman Van Rompuy and Martin Schulz	expressing their deep concern about "the negative impact of recent developments in risk management and regulatory policy on the innovation environment in Europe"
European Risk Forum	2013	"Whenever policy or regulatory decisions are under consideration, the impact on innovation should be fully assessed and addressed."	-	-
22 CEOs of multinational companies from in and out of ERF	November 2014	-	Open letter	demanding the adoption of IP from freshly installed Commission President Jean-Claude Juncker
BUSINESSEUROPE, ERF and the European Round Table of Industrialists	June 22nd, 2015	"Whenever EU institutions consider policy or regulatory proposals, impact on innovation should be fully assessed and addressed".	Joint Position Better Framework for Innovation Fueling EU policies with an Innovation Principle	"The EU is lagging behind major competitors in its ability to invest in research and turn these investments into marketable products and services."

Table 5 (cont'd)

Carlos Moedas – Commissioner for Research, Science and Innovation	June 22nd, 2015	No definitions. IP praise and	SPEECH/15/5243 Open Innovation, Open Science, Open to the World at 'A new start for Europe: Opening up to an ERA of Innovation' BUSINESSEUROPE Conference	How do we make sure that regulation is based on an innovation principle as well as a precautionary principle?
European Commission	December 16th, 2015	States that: IP "anticipates impacts on innovation to be assessed and addressed in policy or regulatory proposals."	COMMISSION STAFF WORKING DOCUMENT Better regulations for innovation-driven investment at EU level	Better Regulation Agenda and the REFIT program, Mentions the existence of "regulatory burdens, inefficiencies and obstacles". 'Research and Innovation Tool' evaluate the positive and negative innovation implications of options for new legislative proposals.
Dutch Prime Minister Rutte (During Dutch Presidency of the EU)	March 3rd, 2016	-	-	Declaring innovation a top priority for the Presidency
Competitiveness Council	May 26-27 2016	"…the application of the innovation principle, whereby policy and regulatory measures are evaluated in terms of their impact on research and innovation."	*Outcome Of the Council Meeting (#3470)* Conclusions Competitiveness (Internal Market, Industry, Research and Space)	Adopts IP, official recognition Invites the Commission and MS to "further develop and implement a pilot on Innovation Deals"

Table 5 (cont'd)

European Political Strategy Center*	June 2016	"An innovation principle means ensuring that whenever policy is developed, the impact on innovation is fully assessed."	Strategic Note "Towards an Innovation Principle Endorsed by Better Regulation"	Efforts to legally justify an implicit reference to IP in EU law Suggests the inclusion of an explicit IP in EU Treaty
European Economic and Social Committee	Sept 21st, 2016	"The 'Innovation Principle' should be applied, which entails taking into account the impact on research and innovation in the process of developing and reviewing regulation in all policy domains"	Exploratory opinion from the Slovak presidency Future proof legislation	Advice for IP to have the same weight as PP and other principles Observes IP becoming a priority for the Council.
BUSINESS EUROPE	December 2016	Inside lobby note to emphasize balancing IP with PP rather than overplaying PP	Briefing to the Advisory and Support Group of Business Europe for the CEO Event in EC European Commission in Berlaymont Building 3 December 2015, Brussels with EC President, two Vice-Presidents, two Commissioners and the Secretary-General	Notes on IP addressed at Carlos Moedas, European Commissioner for Research, Science and Innovation and Günther Oettinger, European Commissioner for the Digital Economy & Society
European Commission	Sept 13th, 2017	"The innovation principle entails taking into account the impact on research and innovation in the process of developing and reviewing regulation in all policy domains, i.a. to ensure that EU regulation allows companies to enter markets more easily."	Communication "Investing in a smart, innovative and sustainable industry A renewed EU Industrial Policy Strategy" ***	Introduction of IP in EU regulation to be implemented by the EC Application of IP by the Commission through its Better Regulation Agenda.

Table 5 (cont'd)

DG Research	February 2017	-	'Taking stock of the application of the precautionary principle in Research & Innovation'	Screening "future initiatives to identify where IP could be implemented.
EC HORIZON EUROPE 2020 Framework Programme	December 5th, 2017	"…Innovation Principle (IP), by which potential innovation benefits should be favoured when weighed against potential risks."	Funding and tender call Science with and for Society H2020-SwafS-2018-2020)	Call to proposes several scenarios for the future of the PP and IP and to develop new tools or approaches to PP or IP
75 Civil Society Organizations	March 11th, 2019	No definitions. Criticisms	Open Letter the European Council and European Parliament	Urges the Council and the Parliament to completely remove all references to IP in EU policy and law Warning that inclusion of IP in Horizon Europe is extremely dangerous
European Parliament	April 17th, 2019	No definitions. Reference made in Preamble "Innovation principle a key driver in turning faster and more intensively the Union's substantial knowledge assets into innovations."	Legislative Resolution on the proposal for a regulation of the European Parliament and of the Council establishing Horizon Europe	Sets out the need for IP to realize EU policy objectives

Table 5 (cont'd)

European Commission Directorate-General for Research and Innovation	November 2019	Acknowledges lack of a widely accepted definition considers it an issue to be improved	Independent Expert Report by CEPS Study supporting the interim evaluation of the innovation principle	Points out the need for improvement of the lack of a clear legal basis Advises to Commission to give prominence to IP with Horizon Europe
Finnish Presidency	November 2019	"IP can promote sustainable growth while offering a novel and important approach to addressing key socio-economic transitions."	"The IP – Developing an innovation-friendly legislative culture" High-level conference in Helsinki	The Independent Expert Report by CEPS discussed
EEB, Corporate Europe, IFOAM EU Group, Slow Food Europe	December 10th, 2019	No definitions. Criticisms	Letter to EU Commissioners	Warning on the use of IP in new technique GMOs, underlining lobbying attempts of industry Urges to right the wrong of putting IP in European Green Deal
European Commission Directorate-General for Research and Innovation	May 2020	A new explanatory dimension is added: "By applying (IP), the Commission can help ensure that innovative activities by European entrepreneurs, researchers, business and civil society are aligned with the broader social, environmental and economic objectives and that innovation realises these objectives better and more quickly"	SRIP 2020 Science, Research and Innovation Performance of the EU 2020 A fair, green and digital Europe	Calls for less traditional approaches to regulation and policy, such as regulatory sandboxes and policy experimentation
Regulation (EU) 2021/695	April 28th, 2021	Recital 6: "activities supported under this Programme should…(be) …in line with the innovation principle"	Regulation of the European Parliament and of the Council establishing Horizon Europe	Introduction of IP in Horizon Europe -terms for the next 95.5-billion-euro EU research funding

In this Chapter, a literature review on the two main pillars of the thesis is provided: the precautionary principle and hydrogen regulations. The research was conducted in the EU's and Turkey's regulatory and policy frameworks. After presenting an overview of national and regional strategies of decarbonization by hydrogen, a brief genealogy of legal protection of the environment is given to set the framework for PP. We studied relevant literature on the PP, its critics and supporters, its incorporation in international agreements and policy documents, its presence in EU case law, its protection against Type II policy errors and its specific concrete measures. In the next Chapter, the methodology and research tool used to answer the research question will be deliberated.

CHAPTER 3

METHODOLOGY

The strong interdisciplinary nature of this thesis lies in the interception of methodologies and tools it incorporates: qualitative research of a doctrinal nature as a hermeneutic discipline[2,3] and content analysis. Vick puts this almost binary opposition forth as follows: “Many interdisciplinarians perceive doctrinalists to be intellectually rigid, inflexible, and inward-looking; many doctrinalists regard interdisciplinary research as amateurish dabbling with theories and methods the researchers do not fully understand” (Vick, 2004, p. 164). This thesis aims to ease any rigidities due to the nature of doctrinal research with the help of content analysis, broadening legal doctrine in an interdisciplinary direction, and putting it systematically in context with science, economics, and policy science.

One prominent definition of *doctrinal research* is “a detailed and highly technical commentary upon, and systematic exposition of, the context of legal doctrine” (Salter and Mason, 2007, p. 49). In this respect, we conducted a qualitative, critical analysis of our main research objects: legal texts and policy documents. These two pillars of research objects characterize the thesis’s politico-legal approach, bringing an additional interdisciplinary perspective. We identified policies and legal rules,

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[2] This thesis considers legal doctrine mainly as a hermeneutic discipline as Hoecke deliberates.

[3] “L’oeuvre doctrinale, dans la tradition historique française et, plus largement, européenne, est au premier chef d’interprétation de « lois » écrites . . . Et à cela ne s’est pas borné son rôle. Face à des sources diverses et hétérogènes, elle s’est trouvé aussi pour fonction d’unifier, de créer un ordre juridique cohérent et même, à partir du XVIème siècle, systématique, préparant ainsi les voies de la codification.” See J-L Thireau, *La doctrine civiliste avant le Code civil*, 1993.

discussed their meanings, revealed underlying principles, ambiguities, and criticisms, and subsequently offered answers to our research question.

Our legal doctrine methodology has an interpretative and argumentative dimension, too. Hoecke rightfully claims that interpretation and argumentation are "roughly two sides of the same activity," as the latter will "almost always be based on interpreted texts" (Hoecke, 2011, p.5). We approach hydrogen safety from a broader perspective, using argumentation to support our interpretation. Our argumentative approach is sometimes a reinforcement of our interpretation (see Chapters 4.1 and 4.2) and sometimes loosely related to the objects of our research, such as statutory texts, as the discussion in Chapter 5.4 exemplifies. We use argumentation to sustain interpretation, the former being the means and the latter the objective. We also make explanations in service of our interpretations, not as the primary research objective (see Chapter 4.1.4). For instance, We explain PP by looking into its varying historical backgrounds, allowing us to better understand and implement it on a policy level.

According to Hans Albert, rules are not the sole object of an empirical legal doctrine; they also include the "influence of those rules on the members of the society in question" (Albert, 1976, p.183). Our research is aligned with this understanding in that it includes data from other disciplines, such as economics and policy science (see Chapters 2.1 2.2, 2.4.7, 2.4.8, 5.1.1). Firstly, we identified all valid legal and official documents; collected all relevant legal and official empirical data under two categories: normative sources and authoritative sources. Our normative sources include but are not limited to international treaties, agreements, statutory texts, general principles of law, and customary law. We also conducted research in authoritative sources such as case law and scholarly legal writings. I examined these resources in a *relevance* (Hoecke, p.14) context, creating an inherent internal logical coherence in the research activity. We searched for the relevant legal sources present in the legal system today, locating them in the hierarchy of norms. The comparison levels include conceptual framework, principles, rules, and cases. Law and economics, and legal history were helpful as supporting disciplines. The level of legal research is not systematization but interpretation. These interpretations are elaborated with policy suggestions.

PP is a vigorously contested conceptualization in the politico-legal scenery as there is no consensus on its meaning. Reasons vary as to why legal scholars have interpreted PP for decades. This thesis instead focuses on its evolutionary features for methodological concerns. The research object of the thesis, PP, stays the same while its meaning and presence evolve. We also pursue the search for this meaning in legal doctrine and valid policy texts from all relevant stakeholders. This choice conveys a large-scale socio-technical system understanding of hydrogen safety (Hughes, 1983). Hoecke states that this meaning is co-determined by "the normative context today and socially desirable result" (Hoecke, p.14). The social dimensions accessed by PP prove that it is an excellent politico-legal domain with evolving characteristics, paving the way for a more holistic approach to the emerging hydrogen economy. In this regard, a considerable number of hypotheses and frameworks have been designed in this evolutionary process to try to understand PP better while simultaneously contributing to the co-determination of its meaning. This evolving characteristic is core to our research methodology. We approach the "hydrogen economy" with an institutional economics understanding, taking into account the people factor as "makers of economic decisions" (Brittanica, 2016), who are "continually affected" (Brittanica, 2016) by changing laws and institutions. Institutional economics locates economic institutions in a more comprehensive "process of cultural development" (Brittanica, 2016). This approach aligns our evolutionary legal work with economics in the interdisciplinary space.

Our research is also evaluative in that it tests "whether rules work in practice, or whether they are in accordance with desirable moral, political, economical aims" (Hoecke, v). The thesis sets out the relationship between PP and hydrogen by examining the conflict between various dimensions of decarbonization with the hydrogen agenda within the conceptual framework of international environmental law and policies. General due diligence on hydrogen's technical, economic, and social aspects in Europe led the thesis to a multidimensional direction for understanding this hot button issue.

Content analysis is a "research tool used to quantify and analyze the presence, meanings, and relationships of (such) words and concepts" (Busch et al., 2005). Implicit and explicit data are two general contents of data used in this type of research (Busch et al.). We used the latter in our content analysis, as the former can introduce an element of bias and can instead be subjective, which could distort our results. From the two types of content analysis, relational and conceptual (Busch et al.), we used the latter to determine the existence and frequency of a concept occurring in our data sets. As our findings reveal in Chapter 4, the general lack of concepts we searched for in our research objects made a frequency analysis irrelevant. This thesis used deductive coding- pre-determined codes, as the objects of our research mainly consisted of statutory texts, which are usually crowded but clear. Deductive coding and explicit data were suitable tools in the context of our research question, which has normative roots. We identified patterns and found generalizations when analyzing our results.

Content analysis contributed to this thesis by adding a quantitative gusto via the determination of the number of times the codes occur in our sets of data. The explicitness and simplicity of our codes allow replicability of the research. However, this tool is sometimes criticized for being reductionist[4] (Thomas, 1994). We tried to overcome this limitation by making meaningful analyses that move beyond the "word count."

The thesis tried to encapsulate all notions related to PP while designing the four sets of codes related to our research question:

- Set 1: "safe," "safety," "security."
- Set 2: "caution," "precaution," "precautionary," "precautionary principle."
- Set 3: "prevent," "prevention," "preventative," "prevention principle."
- Set 4: "risk," "mitigation."

[4] Thomas argues that "these criticisms are ill-founded", stating that "In building and argument for the validity of content analysis, the general value of artifact or text study is first considered" (Thomas, 1994). Most of our research objects are legal texts with binding powers, and some soft law instruments with guiding powers.

These four sets of codes were categorized thematically. Not only did we trace PP in the data set, but we also traced any references made for safety and risk mitigation. Therefore, a complete survey of hydrogen safety in official EU documents was made. As detailed in Chapter 2, there is a consensus that PP encapsulates the prevention principle, as they have a mutual evolution process with common *ratios legis*. Sometimes the lawmaker is unwilling to express principles but implies them or softens them without explicit reference. Codes “prevent,” “preventative,” “caution,” and “security” were used to target these situations. “Safe” and “risk” codes are representative of the general theme of PP. We included “mitigation” to the codes to complement the code “risk.” The use of code “safety” helped focus code “safe” on hydrogen safety. The ‘innovation principle’ (IP) concept is also an important pillar of our content analysis both by itself by presenting a complete IP chronology that reveals the underpinning relations between various stakeholders and by cross-referencing it with PP to completely reveal the underlying multidimensions. All codes were used with a coherent, logical approach for rigorous qualitative content analysis in our research objects.

CHAPTER 4

FINDINGS

4.1 European Regulatory and Political Framework on Hydrogen

After its predecessors of 1998 and 2003, the third EU Energy Package adopted in 2009 introduced the current gas directive (2009/73/EC) in force. It was the golden age of natural gas. The focus was on the liberalization of the markets via unbundling, the creation of the Agency for the Cooperation of Energy Regulators (ACER), etc. Hydrogen was not on the table at all; topics of consideration such as power-to-gas or hydrogen storage were completely absent during this legislative process. 2009/73/EC "establishes common rules for the transmission, distribution, supply, and storage of natural gas." During the discussions of the 2003 Gas Directive (2003/55/EC), the European Parliament pushed for including biogas and other gases with clean energy concerns (EP, 2002). The European Commission (EU) approved of this proposal if a proper clause is added to accentuate that 2003/55/EC would "only apply to such gases insofar as they can be technically and safely injected into the natural gas system" (EC, 2002). Lastly, the European Council (EC) prompted that the scope of the Directive also applies to "other types of gases than natural gas and biomass-based gases" (EC, 2003). It cannot be extrapolated from the legislative history the particular "other types of gases" the Council proposed (Fleming, 2020, p. 10-11). A few years later, during the negotiations of 2009/73/EC, on the proposal of the Parliament, the notion of non-discrimination was included to the scope of Article 1(2), with the statement that "assuming the technical and chemical safety threshold for the different gases are met, the need for non-discrimination for access between the gases from different sources must be emphasized."

Considering these two normative elements of Article 1(2) and the obvious fact that hydrogen molecules naturally exist in gas form; it can be concluded that the Directive covers hydrogen as long as it can "technically and safely be injected into, and transported through, the natural gas system". Today, Directive 2009/73/EC remains the essential regulatory framework in Europe regarding hydrogen until Hydrogen and Decarbonised Gas Markets Package (HGMDP), the fourth gas package, is approved by the Parliament and the Council.

Ten years later, the Commission came up with the famous Clean Energy Package, more than 8000 pages of regulation, including the recast of the Electricity Directive 2019/944. Most legal interpretations suggest that hydrogen "re-converted to electrical energy by a fuel cell or gas turbine" is covered by this legislation (Fleming, 2020, p.8) Still, there is no specific mention with regards to that. Neither hydrogen nor power-to-gas is explicitly mentioned in 2019/944. Furthermore, no legislation mirrors this new electricity package on the gas front, leaving many open questions about the old linkage between the natural gas system and any kind of hydrogen penetration.

In the Clean Energy Package, the modifications in RED II (revised version) offer only indirect legal classification/categorization of hydrogen. Article 7(1) indirectly partly covers hydrogen, and Recital 59 analogs the term "renewable gas" implies "hydrogen from renewable energy sources". However, these interpretations are far from solid. These definitions are not clear enough to build up support schemes for hydrogen as provided by the RED II. Therefore, the scenery is patchy and blurry regarding the regulatory framework. Recognizing this, the Commission came up with a strategy, namely the 2020 EU Hydrogen Strategy, which is not a turning point but an important starting point to assess what is missing.

Nevertheless, it does not make any regulatory changes. It was highly anticipated that the necessary regulations clarifying the blurriness and reorganizing the patchiness would be developed in the upcoming gas package, which was expected to be published in 2020 and was finally published in the last quarter of 2021. This new Package, HDGMP, is explored in detail in the next subchapter.

In terms of standards for gas quality, the blending rates are historically heterogeneous among member states. Directive 2009/73/EC does not provide a maximum value for blending. The CEN standards and their famous Annex E are only informative, limited to particular situations, and outdated. In the absence of a standard at the EU level, MS "have discretion to set the hydrogen limit at the national level, including for gas interconnection points" (Fleming, 2020, p.19). Some examples of the maximum hydrogen concentration allowed in the gas grid, according to the countries, are (in terms of volume %): UK 0.1%, Netherlands 0.02%, Spain 5%, France 6%, Germany <10% (<2% for CNG tanks), Italy <2-3% (Dolci, 2019). Such a standard is difficult or perhaps impossible to establish given the diversity of conditions concerning the use of hydrogen and the resistance uncertainty of the pipelines to embrittlement. The upcoming gas package was expected to deal with this issue to benefit from the trade of hydrogen-enriched gas streams and, ultimately, create the long-promised internal gas market in the EU. HGMDP establishes an obligation for transmissions system operators to accept cross-border blended streams with up to 5% hydrogen content from 1 October 2025. There might be severe repercussions considering the variety of energy systems in the different Member States, with additional storage facilities and pipelines that cannot tolerate that amount of hydrogen.

4.1.1 Hydrogen and Decarbonized Gas Markets Package

On December 15th, 2021, the EC published the Hydrogen and Decarbonized Gas Markets Package (HDGMP), providing a concrete legislative implementation for the Fit for 55 Package proposals. Fit for 55, launched in July 2021, is the collective of EU green policies with its short and long-term climate targets "to deliver a 55% reduction in greenhouse gas emissions by 2030, relative to 1990 levels" (EC, 2021). HDGMP includes legislation on methane emissions, legislation on the energy performance of buildings, a Communication on sustainable carbon cycles, the recast of Regulation 715/2009 on conditions for access to the natural gas transmission networks COM(2021) 804 ("Recast Gas Regulation"- rGR from now on), and the recast of Directive 2009/73 on standard rules for the internal market of natural gas

COM(2021) 803 final ("recast Gas Directive"- rGD from now on), and their corresponding Annexes. These proposals made by European Commission Executive Vice President and Commissioner for Energy are under scrutiny by the European Parliament and European Council (EP, 2022). Therefore, modifications can be made to the Proposals in this procedure. This new gas package is the first significant overhaul in gas market legislation after the adoption of the 3rd gas package in 2009. Challenges of energy security supply and decarbonization of energy made this fourth iteration inevitable.

The main goal of the Proposals is to ascertain grounds for an open and competitive hydrogen market. There are detailed rules on dedicated hydrogen networks, gas quality parameters, repurposing of pipelines transmitting natural gas, incentives to promote hydrogen uptake as an energy vector, and enhanced consumer engagement rules. However, EU legislative machinery's formal processes of approval at the Parliament and the Council and then the transposition by 27 Member States can take several years before the requisite legislation is in place, as mentioned in the panel organized by the Florence School of Regulation on HGDMP in February 2022 (FSR, 2022). The prolonged process of the fourth gas package can endanger the fulfillment of the 2030 goals of the Union.

4.1.1.1 Main HDGMP regulations

4.1.1.1.1 Scope and Definitions

The controversial scope debate about the explicit inclusion of hydrogen in the rGD is addressed by Articles 2 (1) and (3) rGD, differentiating natural gas and hydrogen. This explicitness is a positive development for sure, but the applicability of hydrogen to the third gas package was not an unanswered question, as mentioned earlier in Chapter 4.1. Another issue cleared by the Proposals is the distinction between hydrogen from renewables and non-renewables, which does not exist in the present regulatory framework. As one of the most contested provisions in the proposal, the usage of the terminology of "low-carbon hydrogen" (Art 2(10) rGD) as one form of low-carbon gases (Art 2(11) rGD) ends this legal uncertainty in favor of blue hydrogen. The proposal uses the term for describing hydrogen produced "from non-renewable sources, which meet a greenhouse gas emission reduction threshold of 70%" (Baker & McKenzie, 2022). *Renewable hydrogen* is the other category that corresponds to green hydrogen. This use of fuzzy words is a deliberate choice by the Commission to leave using the color code (blue, green, grey, brown, etc.). A definition of "clean hydrogen," a term pushed by the Commission before (Fleming, 2020), is not included in the Proposals. If the Proposals are approved, renewable hydrogen will be certified according to RED II, and low-carbon hydrogen will be certified according to rGD. This controversial provision is a topic of hot debate among the public, as "low-carbon" gas can risks becoming a blanket term for hydrogen produced from fossil fuels and nuclear. Recital 9 rGD expresses that this threshold "should become more stringent for hydrogen produced in installations starting operations from 1 January 2031". Thus, it can be inferred that the %70 thresholds will become more demanding progressively.

4.1.1.1.2 Unbundling

Equal ownership unbundling rules in the third gas package for electricity and gas networks will also apply to hydrogen infrastructures, separating transport and production activities (Art. 62-64 rGD and recital 9 rGD). This provision prevents an initial position of advantage for a market planned to have several players competing on a level playing field.

The commission is proposing a stricter approach than for natural gas when it comes to unbundling for hydrogen transport. The independent transmission operator model will no longer be used. Instead, it allows a vertically integrated firm to continue to own transmission assets but keep them in a separate entity subject to independent transmission operator rules (Bergen, 2022). This stricter unbundling would only be introduced along with the third-party regulatory access and tariff methodology control after 2030. This flexibility indeed ensures easier regulatory oversight.

Diagonal unbundling is a new question the regulatory framework did not have before in the gas sector. The most concrete example is the treatment of the question "Could a gas TSO be involved in the production of hydrogen?" as a diagonal unbundling issue (Bergen, 2022). The Commission's Proposals adequately cover these issues.

4.1.1.1.3 Flexibilities until 2030 are primarily in favor of the gas sector

Non-discriminatory network access, unbundling of other functions, and ex-ante regulatory supervision are among the current regulatory principles governing gas networks that will be gradually transferred to the hydrogen sector (White & Case, 2022). In addition to third-party access and separation of the regulated asset base, these provisions will enjoy a so-called "regulatory holiday" until January 1st, 2031. This date marks the end of the transition period, after when all the relevant provisions in rGD and rGR will be enforced fully. This regulatory choice supports projects like the hydrogen valley or dedicated hydrogen pipelines.

The proposal offers a negotiated regime as a possibility until 2030, and from 2031 onwards, all have to move towards regulated third-party access (rTPA). Overall, the idea is having flexibility in the beginning when there is a need to mobilize financial resources for the investments. The legislation already clarifies from the beginning that rTPA will kick in after a decade, and they can take it into account in the way they set up their business case (Baker Botts, 2022). However, it is uncertain if 2030 is the correct date or not. Regulated third-party access has proven to work well to ensure and enable competition. However, it is a long time until 2030 to wait for the EU to move toward a more integrated network system to install rTPA (FSR, 2022).

Many companies now have operating hydrogen transportation pipelines in countries like Belgium (FSR, 2022). There are extensive exemption possibilities for these existing hydrogen undertakings before 2030. These already existing pipelines will have the opportunity to be derogated from the new rules, at least until 2030. That is quite a long time which should ensure sufficient flexibility (FSR). After 2030 there are derogations for geographically confined hydrogen networks which again provides a flexible approach. However, it is not sure 2030 as a single date for the whole EU will work, given widely varying conditions and investment plans in MS. It might be beneficial to adopt a more gradual approach (FSR, 2022).

The market ramp-up of hydrogen must take place under close and strict regulatory scrutiny. Some of these flexibilities, especially the duration of regulatory holidays, seem to disturb the necessary balance between market and public concerns to the advantage of the gas industry.

4.1.2 Criticisms

In her presentation in the digital seminar organized by Bergen Research Group Climate & Energy Law on March 17th, 2022, Leigh Hancher categorized three types of stakeholder criticisms (Bergen). First, the Gas Sector criticizes the absence of clear definitions and clear targets just as renewable electricity, which would help them get subsidies (Bergen). The second group of critics is the regulators, who are not very keen on tariff exemptions and cross-subsidization. Regulators would like to see more precise rules on horizontal unbundling, making sure a gas network operator is separated from a hydrogen network operator in a horizontal construction (Bergen).

The last set of criticisms of HGMDP is from NGOs and climate activists. Even though they are very vocal in the field, an open letter written to the Commission by 19 NGOs before publishing the Package was not reciprocated. Joint NGO letter: The hydrogen and gas decarbonization package under publication needs to improve (Ecostandard, 2022). Climate activists are not convinced that this Package is enough to phase out fossil fuels by 2035, claiming that allowing so-called low carbon gases will prolong the use of fossil fuels. Other criticisms include the risk of oversizing future hydrogen grids. They also counter the 5% cap for blending hydrogen as a commercial practice (Bergen).

The Commission seems to postpone the transition to green hydrogen until 2031 to facilitate energy transition, allowing low-carbon hydrogen to play a role in decarbonization. Unfortunately, this choice opens the door for massive subsidies for technologies that will perpetuate dependence on fossil fuels and nuclear power, resulting in some unsustainable gas production routes being considered low carbon.

Regarding just transitions, Clean Energy Package provisions on energy poverty and vulnerable customers have not been mirrored in HGMDP. Though they are explicitly mentioned in the Clean Energy Package, having them in HGMDP makes sure that gas consumers also will benefit from protection when it comes to energy poverty and vulnerable consumers.

The jargon “recast regulation” and “recast directive” means that the Commission has kept much of the old measures but amended and supplemented them. These old measures will no longer have legal value after adopting the Package but confirm the continuity of the system’s core features. Here, the intrinsic regulatory dependence on the existing gas system comes into question with the risk of gas devouring hydrogen, mainly green hydrogen. Rules including renewable and low carbon gas and low carbon hydrogen are essentially carried over from the third gas package. However, these provisions focus on conventional gas and are not entirely on renewable and low-carbon gas.

It is perplexing that there are no rigid definitions of what is renewable and what is low carbon gases in HGMDP. When what is renewable is not clear, certification and issuance of guarantees of origin will be problematic until the methodology to define them comes in 2024 as Delegated Act (Baker Botts). However, the idea with HGMDP was to make sure that the EU harbors a level playing field so that consumers also can assess their total greenhouse gas emission footprint of what they are consuming (White & Case, 2022).

With the move towards more decarbonization, the energy system gets more complicated. These developments show that while addressing some issues, the Proposals failed to address many others, which creates the risk of more complications, confusion, and stranding of billions of euros of investment. Therefore, the Parliament's and the Council's takes on the Proposals now are critical regarding these risks.

4.1.3 Standardization of Gas Quality Emerging as a Precautionary Matter

In Chapter 4.1, we explained that currently, MS "have discretion to set the hydrogen limit at the national level" (Fleming, 2020, p.19). The European lawmaker deals with the critical question of standardization of gas quality among the Union in HGMDP. Cross-border hydrogen interconnectors are discussed in Article 53 rGD, and the cross-border flow of blended gas/hydrogen streams is enacted in Article 20 rGR. HGMDP creates an obligation for transmissions system operators to accept cross-border blended streams with up to 5% hydrogen content from 1 October 2025. There might be severe repercussions considering the variety of energy systems in the different MS, with various storage facilities and pipelines that cannot tolerate that amount of hydrogen.

There is an important safety issue with piping. Polyethylene pipes widely used in low-pressure distribution grids are generally considered compatible with all hydrogen blending rates. However, there is a severe risk of deterioration of the steel pipelines resulting from a reaction called hydrogen embrittlement (GRTgaz et al., 2019). Research conducted in 2020 by the gas industry confirms the need for additional research "to assess the precise influence of hydrogen embrittlement on the lifespan of steel pipelines and the system-wide impact and costs of modifying the steel pipeline infrastructure" (Enagás et al., 2020). The study foresees higher costs for higher blending rates (Enagás et al., 2020, p.425-426).

In the non-binding nonrepresentative EC Final Report on "assistance in assessing options for improving market conditions for bio-methane and gas market rules", it is acknowledged that mandatory EU-level gas quality standards would lead to "unreasonable costs for adapting gas infrastructure and end-user equipment, appliances and processes." (EC, 2021, p. 164). However, the same report advises that future EU gas quality standards should balance end-user application safety and minimal modification costs for "infrastructure and end-user equipment, appliances, and processes" while delivering maximal flexibility for producers (EC, 2021, p. 165). This advice is precautionary, suggesting precautionary action without any reference to it.

ACER thinks that, in principle, the blending cap at a five percent level is quite a good way of ensuring sufficient harmonization at the European level. Moreover, there is also the possibility of derogating from this provision between neighboring MS if they agree on a higher cap. This vast flexibility is also welcomed by ACER (Florence School of Regulation, 2002). On the other hand, French Energy Regulation Commission (Commission de Régulation de l'Energie-CRE) very recently published its "response to the public consultation" on HGMDP on April 12th, 2022 (CRE, 2022). In this comprehensive and meticulous response, CRE clarifies that it does not favor blending hydrogen in natural gas networks, even on a transitory basis, due to safety and economic reasons (CRE, 2022).

The Commission believes that the 5% blending cap would reduce the value of both hydrogen and natural gas to a great extent. In addition, the Commission concedes that the higher the proportion of blending, the greater the adaptations needed to the facilities and the more costly for both infrastructure operators and consumers. Therefore, CRE does not recommend blending at all, offering a more "technologically and economically coherent" approach, preferring dedicated networks only (CRE, 2022, p.3). CRE proposes a maximum blending rate of 2% to balance risks and costs, referring to the Macrogaz Association Study (CRE, p.4). It is fair to say that this is the only document the ere hydrogen safety issue is taken seriously. The proposal of CRE tries to minimize both risks and costs with a precautionary approach. Precautionary principle repercuss the blending problem characterized by uncertainty and risk. Hydrogen embrittlement is an open subject with insufficient scientific data to confirm implications, especially in the long run. There emerges a relevant space for PP to intervene.

4.1.4 A Regulatory Patchwork

The proposals do not offer an exhaustive take on hydrogen in Europe. Instead, they add new pieces to a broad set of legislation puzzles, including but not limited to the Renewable Energy Directive II, Energy Efficiency Directive (EED) and Emissions Trading Scheme (ETS), the proposal of the Carbon Border Adjustment Mechanism, the revised Climate, Energy and Environmental State Aid Guidelines, etc. By looking at the interlinkages between all relevant normative and authoritative sources, one can argue that the regulatory patchwork problem is not solved since it will still take a multitude of legal acts to govern hydrogen. Another essential criticism is that HGMDP does not effectively address that crucial question of separate packages, one for gas and one for electricity. They are not dealt with together, which is key to promoting sector coupling and system integration.

In December 2019, European Green Deal was published. It mentions hydrogen only three times, briefly in the context of decarbonization. On July 14th, 2021, the European Commission published the Fit for 55 Package, which involves thirteen regulatory "proposals to reduce net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels" (EC, 2021). Hydrogen has a dominant presence in Fit for 55, making it an integral element of the Package. In the next subchapter, we briefly assess interlinkages between HGMDP and relevant Fit-for-55 proposals in a general policy context.

4.1.4.1 Renewable Energy Directive (Recast) 2018 (RED II)

Originally, RED II defined and imposed targets for hydrogen in the transport sector. It has a strict sustainability criterion for green hydrogen production (ECHA, 2022). Fit for 55 proposes the extension of RED II applications to steel, iron, aluminum, fertilizer, ammonia, chemicals, cement, and construction industries, imposing a 50 percent green hydrogen use limit. HGMDP will further enable the deployment of green hydrogen technologies with its provisions that support the formation of a hydrogen infrastructure. An important note is that RED II certification schemes will apply to renewable fuels and gases, whereas HGMDP will govern certification schemes for "low-carbon gas and its derivatives" (EC, 2021). The Proposals created another level of a regulatory patchwork for the public and investors.

4.1.4.2 European Emissions Trading System (ETS)

The proposals made by EC have the objective of gradually increasing the cost of GHG emissions to foster demands for renewable and low-carbon gases. In particular, it includes all hydrogen production in the ETS scheme beginning from 2026. HGMDP is in line with ETS, assisting green hydrogen to be marketable and eligible for free allowances.

4.1.4.3 Carbon Border Adjustment Mechanism (CBAM)

To counteract carbon leakage, CBAM imposes a carbon price for certain imports such as iron, steel, cement, aluminum, ammonia, and fertilizers at the European border. It is not yet definitive if the CBAM will extend RED II's requirement to use 50 percent green hydrogen to non-European producers. Assessment criteria for emissions and methodology are yet to be determined by EC.

4.1.4.4 Alternative Fuels Infrastructure Directive (AFID)

AFID sets out minimum requirements for publicly available hydrogen refueling stations to boost investments. AFID requirements ensure that Member States make an appropriate number of refueling/recharging stations (including hydrogen-powered motor vehicles and fuel cell vehicles) available to the public by December 31st, 2025 within networks determined by those MS (ECHA, 2022). There is no focus on the connection between infrastructure and network operators. With its emphasis on network infrastructure, HGMDP can help ease the accommodation of hydrogen supply for refuel/recharging points.

4.1.4.5 The Trans-European Networks for Energy (TEN-E) Regulation

Hydrogen was introduced "as a new infrastructure category for European Network Development" (ECHA, 2022). HGMDP complements TEN-E with its provisions that align national plans with the END.

4.1.4.6 Energy Taxation Directive (ETD)

This Directive ranks energy products and electricity groups according to their energy content and environmental performance, ensuring that the most polluting fuels are taxed the highest (ECHA, 2022). ETD aligns with HGMDP's aim "to create a level playing field" between natural gas, renewable and low-carbon fuels (ECHA, 2022). Furthermore, HGMDP treats consumer empowerment and protection as separate pillars, enabling active customers' participation and complementing ETD's objectives.

4.1.4.7 Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBD)

EED's and EPBD's *ratio legis* is the principle of energy efficiency first. Therefore, HGMDP is coherent with the Directives, prioritizing hydrogen deployment in hard-to-abate sectors (ECHA, 2022).

This regulatory patchwork was one of the main reasons for the nearly two-year delay of the fourth gas package, HGMDP, as an integrated and coherent regulation necessitated a very complex regulatory action. It is unusual for the European Union to fall behind the official legislative schedule, and this was one prominent example of such delay. Due to the tight agenda and complexity, HGMDP brought up its own questions, such as the lack of clear definitions for renewable and low-carbon gases or the criteria for the determination of the 70% threshold for greenhouse gas emissions reduction. The urgent policy agenda pushes for fast regulation, and regulation tries to keep up with the ambitious policy demands. However, as elaborated in this Chapter, the extensive regulatory corpus of the EU creates difficulties for a completely integrated framework. It is possible that this regulatory patchwork can result in missing carbon targets until 2035 due to this complexity and lengthy national transposition processes.

4.1.5 Hydrogen Safety in European Official Documents

I conducted qualitative content analysis on all the official EU documents referring to hydrogen to find out and evaluate the reflection of the hydrogen risk chain in the legal field. In this research, we have searched for the words "safe," "safety," "security," "caution," "precaution," "precautionary," "precautionary principle," "prevent," "prevention," "preventative," "prevention principle," "risk," and "mitigation" in the texts. We have found that almost no measures have been envisaged for hydrogen safety; the concept has been used in a very narrow scope in only a few points where the safety concept is included.

"The Role of Hydrogen in National Energy and Climate Plans" by FCH JU, dated 31/08/2020, identifies and highlights the possibilities of hydrogen technologies to "contribute to the achievement" of the EU's 2030 climate and energy goals and its MS, including the United Kingdom (FCH JU, 2020). In this comprehensive 144-page study, hydrogen safety was mentioned only once. Except for the sentence in Hungary's national plan in which it is stated that it plans to "…create favorable conditions (including safety) and incentives", it is seen that the safety issue has not been thoroughly evaluated in the plan of any Member State.

In the "EU Hydrogen Strategy" dated July 8th, 2020, numbered COM/2020/301 (European Commission, 2020), consisting of 24 pages, the safety issue was mentioned three times in single sentence forms. The first sentence noted the contribution of open and competitive markets to clean and safe hydrogen production. The second sentence said that the safety aspect should be added to the research activities before establishing standards. Finally, the third sentence mentioned the need to create improved and harmonized standards as a research activity. In this context, it is observed that hydrogen safety is only included as a research subject in the EU's primary strategy document on hydrogen.

Hydrogen safety is also never mentioned in the European Commission Communiqué (European Commission, 2020) COM/2020/299 titled "Powering a Climate Neutral Economy: An EU Strategy for Energy System Integration." Nevertheless, one of the most important contributions of incorporating hydrogen into a large-scale energy socio-technical system is the hydrogen's capability of accessing and integrating into every sector of the energy system.

In another official document of the European Commission, the study of 45 pages titled "Hydrogen Production in Europe - Overview of Costs and Key Benefits" dated July 2020 (European Commission, 2020), the issue of hydrogen safety was utterly ignored.

The concept of safety is not included in the text even once. However, as mentioned in Chapter 5.1.1, safety and cost are directly associated.

Similarly, in the document titled "The role of hydrogen in achieving our climate and energy goals for 2030," dated July 14th, 2021, safe hydrogen was not mentioned (European Commission, 2021).

Hydrogen safety was never mentioned in the Declaration of the European Clean Hydrogen Alliance, an official initiative of the EU, bringing together industry, "public authorities, civil society, and other stakeholders" (European Clean Hydrogen Alliance, 2020). The alliance has other studies on the issues, such as competition and industrial strategies, but it does not have any surveys on safety.

Even though it is not a strategic document to clarify the EU's approach to the issue, it is noteworthy to mention the HyLaw Project, which was carried out with 23 Member States in 2017-2018. The project approaches law as an "obstacle" and aims to "remove legal obstacles to deploying fuel cells and hydrogen applications." However, as pointedly mentioned in the "Better Regulation" Agenda, which establishes the principles followed by the Commission "when preparing new initiatives and proposals, as well as when managing and evaluating existing legislation" (European Commission, n.d.); the innovation principle and the precautionary principle are not competing, but complementing, supporting and strengthening each other. However, it is observed that the EU's "Better Regulation" approach is not applied in the context of the hydrogen economy, or even an opposite direction can be observed.

HGMDP regulations do not stress precaution anywhere. Only preventative measures which concern definite risks are foreseen[5] (COM/2021/803 final Art. 3). These measures do not contribute to additional safety. They are the continuance of former

[5] Proposed Article 5/3 is as follows: "Public service obligations related to the security of gas supply shall not go beyond what is necessary to ensure compliance with the gas supply standards pursuant to Article 6 of Regulation (EU) 2017/1938 and shall be coherent with the results of the national risk assessments carried out pursuant to Article 7(3), as detailed in the Preventive Action Plans prepared pursuant to Article 9(1), points (c),(d) and (k) of the same Regulation."

regulations on standards and technical specificities. The HGMDP is far from having a precautionary approach, let alone imposing the PP.

The detailed text analysis summarized above demonstrates an incompatibility between the hydrogen risk chain and the hydrogen value chain. It may be considered that this incompatibility might be eliminated by correctly applying the prevention and precautionary principles, basic principles of international environmental law. However, these two chains may only be harmonized in this way. For this reason, addressing the precautionary principle as a solution proposal and developing policy proposals based on this principle constitutes the main point of this study.

CHAPTER 5

DISCUSSIONS

5.1 Hydrogen Risk Chain- Hydrogen Value Chain Incompatibility

The hydrogen value chain is more dynamic today than ever before, and based on the data provided by the European Commission Joint Research Center Technical Report "Towards net-zero emissions in the EU energy system by 2050", which compares 24 energy scenarios for 2050, it might be safely said that this mobility will increasingly continue (EC JRC, 2020). Hydrogen has the potential to reduce global and trans-national energy disputes, solve environmental pollution and health problems, and minimize colossal infrastructure requirements. However, there is a balance of blessing and burden here, as in law. Hydrogen is a hazardous gas because it is a tasteless, odorless, colorless, and very easily flammable substance. In the words of scientists, this "naughty gas" must be used to reduce the risk potential arising from its physical and chemical properties.

In this thesis, which employs an STPS (Science and technology policy studies) approach, the possible risks of hydrogen are evaluated by making a simple comparison with methane gas, the densest component of the natural gas (85-98%), without providing the technical details. The minimum flare energy is less hydrogen than methane, and this property indicates that the gas may inflame at the slightest trigger. Also, the inflammation-combustion limits in the air are vast for hydrogen. The inflammation rate is almost ten times higher than methane so that the flame may progress rapidly once inflamed. The backfire risk is relatively high, therefore significantly increasing fire risk. In addition, the risk of penetration-embrittlement of all materials, including metals, is also relatively high. Thus, difficulties arise in the transport of hydrogen.

The EC considers clean hydrogen as “a vital missing piece of the puzzle” to decarbonize hard-to-abate industries such as steel and “help the EU achieve its 2050 climate neutrality” goals (EC, 2020). However, in terms of safety, the transportation and use of hydrogen must be subject to strict protocols. The high flammability of hydrogen, which is an odorless, tasteless and colorless gas, has urged EU legislators to make sure that the prospective safety problems of the gas do not impede hydrogen’s place on the market. Nevertheless, there are still significant disagreements among the legislators.

In her EURACTIVE interview, Angelika Niebler, a German MEP as a member of the European Public Party, the center-right group in the EP, stressed that it would be necessary to create high safety standards “for the successful development of the EU hydrogen economy”, and that “technologies must be safe first if they are to be trusted.” (Kurmayer, 2021). Niebler is one of the MEPs who prepared the EU parliament report related to the draft hydrogen strategy submitted by the EC in July 2020. In the description, appealing to the EU to take actions to foster a robust “safety culture in the hydrogen value chain”, it is stated that the EP firmly believes that “public acceptance is the key for creating the hydrogen economy successfully” (European Parliament, 2021). On the other hand, some other EU deputies seem less concerned. A German MEP from the Socialists and Democrats, and the lead author of the parliamentary report, Jens Geier, stated in his speech at EURACTIV, “The industry has been producing and processing hydrogen for decades. Therefore, there is already expertise in safety and security standards related to the use of hydrogen.” He indicated that there is no need to consider new and different precautions (Kurmayer, 2021).

The production and use of hydrogen is not a new technology, and its risks are also known. It suffers “from image problems due to its high flammability, hydrogen bomb,” and association with the Hindenburg disaster- the infamous airship spotted on camera exploding in fires “during an air show in Germany” in 1937 (Kurmayer, 2021). Moreover, the catastrophic explosion in Fukushima, Japan, in 2011 was set off by hydrogen. Three nuclear reactor buildings were damaged in the blast. However, in today's world, where the new function of hydrogen as an energy carrier comes forward, safety is a problem that needs to be addressed more holistically, going beyond "public acceptance," since there are risks of leakage, fire, and explosion in all the rings of the hydrogen value chain (Gökalp, 2021). The four main segments where these risks are present are presented below:

- Hydrogen production segment: Electrolyzers for green hydrogen, solid fuel/organic waste gasification with CCUS for natural gas reform and blue hydrogen, or natural gas pyrolysis for turquoise hydrogen

- Hydrogen transmission/distribution segment: Using the existing natural gas network or special hydrogen networks for the admixture of natural gas and hydrogen; road or sea transportation in the form of compressed or liquefied hydrogen

- Hydrogen storage segment: In emptied natural gas wells, salt caves, and tanks, added to the solid components

- Hydrogen energy transformation segment: burners, gas turbines, internal combustion engines, fuel cells, household appliances

These risks are not abstract. Although a common understanding of hydrogen safety is still being discussed in the European Parliament, considering the significance of hydrogen in the decarbonization of industry, EU policy-makers have started an initiative to guarantee keeping hydrogen production, transportation, and utilization as safe as possible. In this context, the European Commission has commissioned the Fuel Cell and Hydrogen Joint Undertaking (FCH JU), a public-private partnership for the management of hydrogen safety, to establish "an expert panel to ensure that hydrogen safety is adequately addressed and managed" (FCH JU, 2021). The European Hydrogen Security Panel (EHSP), established in 2017, has two main aims, (1) to address hydrogen safety and (2) to spread the culture of "knowledge and safety in the hydrogen value chain" (EHSP Task Force TF3, 2021). While large businesses generally have vigorous safety procedures in place, FCH JU has aimed to create safe use of procedures that are freely accessible by anyone working with hydrogen, involving small companies.

In this context, the European Commission's Joint Research Center (JRC) cooperated with FCH 2 JU to enlarge and enhance a database that records the events related to hydrogen even before 1990 (HYSAFE, 2018). As a result, the European Hydrogen Incidents and Accidents Database (HIAD 2.0) recorded 577 cases in its latest report on September 21st, 2021 (FCH 2 JU, 2021, p. 37). The report was prepared by EHSP under the mandate of FCH 2 JU. The causes and contexts of these accidents, on the other hand, require another in-depth analysis.

EHSP Task Force TF3 examined 485 cases in the database in July 2020 (FCH 2 JU, 2021, p. 37). The study contained "statistics, lessons learned, and recommendations" (FCH 2 JU). The statistics were collected in relation to industrial sectors, cause of the accident, systems (accident cases initiated by hydrogen or non-hydrogen systems), amount of hydrogen that caused the accident, and severity of damage to property and persons. The critical database and reviews provided by the report revealed valuable information. One of the necessary inferences is that improved education and training could prevent "more than a quarter of hydrogen-related accidents" (FCH 2 JU). The classification according to the case type is essential for the subject of this study.

Table 6: HIAD Cases Categorized by Their Causes

Cause	Number of causal cases
System design error	126
Material/manufacturing error	127
Installation errors	38
Job factors	98
Individual/human factors	94
Organization and management factors	158

Source: HIAD 2.0

In the reviews for lessons learned from former cases of operator errors, the classification recommended “by the Health and Safety Executive (HSE)” of the institution where the accident occurred has been adapted (FCH 2 JU, p.23). The category related to operator errors is further divided into three subcategories, namely “job factors, individual/human factors, and organizational and management factors” (FCH 2 JU) The HSE classification divides the dynamics affecting the probability of operator errors into subcategories.

- Business factors: improper design, errors in design, incomplete or imprecise instructions, inadequately preserved equipment, unbalanced workload, challenging working environments, continuous intrusions, etc.

- Individual/human factors: insufficient skills and competencies, fatigued workforce, discouraged team, health troubles, etc.

- Organization and management factors: insufficient business planning causing high pressure, absence of safety schemes and protective equipment, failure to take necessary lessons from earlier events, lack of coordination in management and unclear description of job duties, insufficient health and safety management, inadequate health, and safety culture.

HIAD 2.0 findings demonstrate the significance of thinking seriously on the experiences to be learned in these three categories to reduce the occurrence and impact of all kinds of human-caused errors. Moreover, many of these lessons are directly related to concrete applications of the prevention principle[6], an essential part of PP. The issue will be discussed in the following parts of this thesis.

[6] The principle of prevention has the same objective as PP, only that it concerns certain risks. In legal doctrine, the prevention principle and the precautionary principle are mostly accepted to complement each other, and this distinction will not be mentioned in this article due to the scope of the thesis. As Trouwborst argues, the conceptualization of PP covers the principles of prevention and precautionary measures together. PP is considered to be the “most developed form” of the prevention principle (Trouwborst, 2009).

5.1.1 The Cost Problem

When the formation of the hydrogen value chain is accelerating at an increasing rate, it is reasonable to estimate that the hydrogen risk chain will also gain momentum. The number of projects implemented in the hydrogen economy, whose impact is fueled by high externalities, will likely increase hydrogen accidents. Although education and training are also cost-effective solutions in discussions about safety and market viability, the impact of these activities remains limited.

“There is always a tradeoff between safety and cost,” says one Project Officer at FCH JU, stating that those who enforce the possible strictest safety rules will make hydrogen too expensive to commercialize (EURACTIV, 2021). A member of EHSP says that this is a “classic conflict of optimization” (EURACTIV). Stating that “preventing accidents at all costs is not an economically viable solution”, the member calls for a more efficient “safety first approach” (EURACTIV). There are disputes among experts regarding hydrogen safety. The social, environmental, and intergenerational dimensions of cost must also be included in the cost calculations. As the member of EHSP points out, this problem might be improved by implementing mechanisms in which the precautionary principle is applied.

There are vital points to be considered so that hydrogen does not accompany additional problems to the existing ones. Hydrogen, which has the simplest atomic structure known in the universe, is expected to simplify the existing complex energy system and energy/environmental interaction. It is also anticipated that hydrogen reduces uncertainty and instability in the energy sector as much as possible. A holistic approach to the safety of hydrogen technologies will be possible if these approaches are processed together, which means concrete applications of the precautionary principle.

5.2 Precautionary Policy Suggestions for Hydrogen in the European Union

Cost-benefit analysis cannot always fully reveal the “distributional and ethical implications” of policy initiatives (Renda, 2017, p. 6; Adler, 2012; Boadway; 2016). The current hydrogen policies are a contemporary example of this situation. In this context, concrete implementations of the precautionary principle will be able to provide practical solutions to this problem. As a result of our evaluation, we developed the following policy recommendations where PP is applied to hydrogen decarbonization.

As elaborated in Chapter 4.1.3, standardization for gas quality unravels as the most relevant issue to PP. The Union should involve as many stakeholders as possible in decision processes on blending. Standardization rates should pursue a maximum limit, not a minimum, considering infrastructures with varying vulnerability. Furthermore, nuanced policies should be developed for different uses, users, countries, and regions.

Regarding standards for gas quality, one solution is PP in its strong version: Limit storage or transportation of hydrogen in its most dangerous gaseous form because the risk is not in the energy conversion of hydrogen by combustion or by fuel cells in its storage and transport. Standards may then concern: (1) In situ on-demand generation (regulation: zero or minimal storage) (2) Transport of hydrogen in a different form than gaseous: liquid, ammoniac, adsorbed in solids (regulation: impose the different transport modes depending on distance, milieu, etc.). Financial and structural incentives for in-situ and on-demand applications would be beneficial to promote such technologies.

Incentivizing uses and users with already existing know-how on hydrogen safety to contribute to the development of precautionary measures would connect concrete experience with abstract principles. While lower precautionary levels for industrial uses and dedicated pipelines are preferable, higher precautionary levels for general public end-users are necessary. Public perception of risk is an essential factor, too, when it comes to determining costs.

Safety in line with the precautionary principle should be an issue of primary concern. Therefore, PP should be explicitly stated in HGMDP. Accelerating ongoing EU safety assessment processes and ensuring that the knowledge attained is constantly subject to change with communication and feedback mechanisms at every level.

Avoiding EU-level regulatory patchworking is an arduous job that should be meticulously studied with a strategy. For example, different packages for gas and electricity are severe obstacles to the EU's system integration goals. Instruments such as regulatory sandboxing for piloting strategic hydrogen initiatives could be considered. These regulatory sandboxes can impose varying precautionary levels, case by case.

5.3 Innovation Principle & Precautionary Principle as Non-Competing Elements

The anatomy of the innovation principle is studied in Chapter 2.5. Prior to declaring that IP is not opposed to PP, ERIF formulated the "very simple" main aim of the innovation principle as "making sure all new regulation takes account of the potential impact on innovation – but does not set out to position any particular innovation as being good or bad" (ERIF, 2021b) This formulation is perplexing in the way that its vulgarly expressed second part, seem to achieve (1) creating a rival element to PP (2) devoid PP of its powers.

ERIF aims to make the 'innovation principle' a European policy framework over time (ERIF, 2021c, n.d.). One huge step was taken with Regulation 2021/695 on the way to the achievement of this ambitious goal. The Precautionary Principle as a regulatory approach that guides decision-making under uncertainty and risk has emerged and evolved as a dire need of the society. What the IP offers is also a response to a significant need of society. Nonetheless, the binary positioning of PP and IP by ERIF seems problematic. PP is an established meta norm with roots in decades-long political and legal history. IP on the other hand is a recent formulation made by only one group of stakeholders: the industry. The EU should openly discuss IP in multilevel stakeholder gatherings, in connection to PP and beyond. PP itself being a tool for democratic deliberation, such a democratic foyer where these ideas are shared transparently. Civil society is a main part of this discussion, too. In 2019, 75 civil society organizations from all over Europe voiced dissent in an open letter in this regard (see Table 5). The political rationale behind all relevant stakeholders should be well understood via cellularization of the elements in the relevant networks. The findings should guide policy and regulation with balance and diligence. The legal rationale and positioning should be clarified by EU governing bodies before IP is incorporated into other EU legislations.

The underpinnings are very unclear as to how ERIF thinks that both principles are "essential". With no intent of marginalization, recognizing the need to balance innovation and regulation; this thesis perceives the so-called IP as complementary to PP. This complementarity means regulatory action should consider its impact on innovation, too, and vice versa. Yet an economic impact cannot and should not compete with environmental or health harm.

This conceptualization attempt reflects a perfect evasion of the environmental law corpus. PP already imposes broadened cost-benefit analyses, taking into account both economic and environmental elements. If the industry is insistent on normative protection of innovation, it is possible. The name innovation principle can even be discussed. Nonetheless, it just cannot overrule everything that PP stood for decades. Public interests are already outweighed by private interests by far. PP is one lonely but beautiful example of resetting that balance if applied properly. The claim that IP can balance PP is absurd.

PP continues to be attacked in today's pro-growth political atmosphere. The reason why PP evolved in the first place was the need for a broader approach than evidence-based methodologies to risk management. In the following years, an intentional dichotomy was created by proponents of IP (Read & O'Riordan, 2017). Thus, a pendulum began to swing from PP to IP.

Recently, Garnett et al. proposed a critical bur peace-making view of IP, offering a "qualified innovation principle", that is the reformation of IP with a deeper comprehension of PP (Garnett et al., 2018). The scope of their study does not include the design of that quality. Yet, the idea is valid considering the recent developments in EU law and policy. This proposal can be valuable to release the tension between precaution and innovation.

The formation of a legal principle is almost always bottom-up, as seen in the brief environmental law genealogy presented in Chapter 2.3. In our opinion, creating a top-down non-legal principle to compete with a bottom-up legal principle does not fit any legal approach within the hierarchy of norms. Legally speaking, these two elements cannot compete as they exist on different ontological levels.

Chapter 4.1.5 revealed the non-presence of hydrogen safety in official European documents. This finding also pointed out the necessity for precautionary regulations. Now that the activities supported under Horizon Europe 2021-2027 will be in line with IP according to Regulation 2021/695; the PP/IP dichotomy becomes more relevant than ever for research and innovation on hydrogen technologies. Metaphorically, the pendulum was never on the side of PP regarding hydrogen regulations. Now that the IP is a legal reference point for Horizon Europe, it can be assumed that the pendulum will swing fast in the direction of IP.

CHAPTER 6

A PRELIMINARY REGULATORY ANAYLSIS OF TURKISH POLICY AND REGULATORY FRAMEWORKS FOR HYDROGEN

This thesis is essentially devoted to the analysis of the safety/innovation tension in the unfolding EU hydrogen strategies through the lens of the precautionary principle. By doing so, we also gathered substantial insight on the needed regulation aspects for developing countries such as Turkey, to accompany the potential generalization of hydrogen technologies in those countries. In this Chapter, we try to answer the following research question: "What are the preliminary regulatory analyses needed to be conducted for Turkey to prepare herself to host the hydrogen economy?" We briefly treated this question by analyzing the geopolitical implications of the recent hydrogen developments for Turkey, the Turkish political and regulatory frameworks for hydrogen, and Turkish law including the present status of natural gas regulations in Turkey; trying to assess the intensity of the modifications to be introduced to accommodate hydrogen or hydrogen containing gases arrival in the Turkish energy system and network. We however insist that this part of the thesis has a very preliminary nature waiting to be developed in future works.

Even though the Turkish regulatory framework for hydrogen is not ripe enough to make fruitful discussions on the areas of intersectionality between hydrogen and the precautionary principle; this Chapter begins with the introduction of prevention and precaution in Turkish law to make the necessary connection with the rest of the thesis and to provide precautionary insights for policymakers on future hydrogen legislation.

6.1 Prevention and Precaution in Turkish Law

In this subchapter, we provide a normative analysis of prevention and precaution in Turkish law according to the hierarchy of norms, beginning with the Turkish Constitution at the top of the hierarchical triangle, continuing with relevant laws, regulations, by-laws, and ending with court decisions incorporating PP.

Article 56 of the Turkish Constitution guarantees every Turkish citizen's "right to live in a healthy and balanced environment," endorsing the constitutional duty to "prevent environmental pollution." Although PP is not explicitly mentioned in the Constitution, it is not a foreign concept to Turkish law, recognized multiple times in the below-stated High Court decisions.

Even though PP is not explicitly stated in Law of Environment Article 3, which defines the principles, Articles 2, 3/1-f, 8/2, and 11 adopt the principle either implicitly or by reinforcing preventative and precautionary measures. In addition, there are also various preventive and precautionary measures enshrined in 5977 Biosafety Law and 5403 Law of Soil Protection and Land Use.

Environmental Impact Assessment (EIA) By-law is one prominent example of a preventative approach in Turkish law. It aims to determine the effects of certain activities that may hurt the environment before allowing them to be carried out. The relevant activities are permitted if appropriate measures are taken to eliminate these negative impacts or reduce them to a minimum. It also makes an alternatives assessment obligatory pursuant to Article 4/1-c. Many by-laws, including Water Pollution Control By-law, Air Quality Assessment and Management By-Law, Soil Pollution Control and Contaminated Sites of Point Origin By-law, Genetically Modified Organisms By-law, include provisions based on the prevention principle. Waste Management Regulation Article 22, Water Pollution Control By-Law Articles 4 And 36, Genetically Modified organisms By-Law Articles 1,5,6, By-Law on the Implementation of the Convention on International Trade of Endangered Wild Animals and Plant Species, and By-Law on Registration, Evaluation, Authorization and Shortening of Chemicals on are all reflections of the precautionary principle (Güneş, 2020). The spectrum of presence on prevention and precaution in Turkish law is further consolidated by Court decisions acknowledging the principle. On May 30th, 2012, the Supreme Court of Assembly of Civil Chambers adjudicated that if the base station is likely to pose a danger to human life, human life and health should be given precedence. It decided on the relocation of the base station even though the measurements of the base station do not exceed the limit values, considering the notion of *uncertainty* (emphasis added) (E:2012/4-147, K:2012/327). This decision's uniqueness is at its core which is based on the PP, yet no reference is made to the principle anywhere in it.

Following this decision, the Council of State's 13th Chamber elevated the principle in a decision dated June 16th, 2020, canceling security certificates issued to the base stations located on the real estate across the residence of the plaintiff and abrogating the article of the Regulation subject to litigation (E:2014/2281, K:2020/1403). This ruling is a landmark decision regarding PP in Turkish law as the decision frequently references PP, precisely 21 times, strictly interpreting it as a normative ground of national law. There are also references to EU law, international case law, and the Rio Declaration in the decision. The Plenary Session of Administrative Law Divisions (İDDK) of the Council of State decided to approve this appealed Decision of the 13th Chamber, emphasizing the necessity to respect PP, and moving beyond, stipulating that Article 56 of the Constitution contains PP within itself, positioning PP as an organic part of Turkish law (İDDK., E. 2020/2637 K. 2021/1095). This ruling is a powerful representation for PP at the Highest Chamber of the Council of State, one of Turkey's four Supreme Courts (Constitutional Court, Council of State, Court of Jurisdictional Disputes, Court of Cassation).

Another striking decision made on PP in the context of energy and the environment is about Ordu Hydroelectric Power Plant, Power Transmission Line and Material Ovens Project. An administrative fine of two percent of the project price was imposed as the construction was started before starting or completing the environmental impact assessment process under the project. However, Ankara 2nd Administrative Court annulled the fine on March 17th, 2011 (E:2010/1303, K:2011/363).

The Council of State 14th Chamber reversed the decision of the local court. It ruled that not engaging in construction activities before the EIA process required in the legislation is completed has been violated, that is, before the plaintiff company has completed the EIA process. In this case, the local Court states that there was no breach of the law in the fine imposed on the plaintiff company. No legal accuracy was observed in the Decision of the local Court that appealed otherwise. The decision explicitly states that PP has been adopted in regulations contained in Turkish legislation (E: 2011/13577 K: 2013/2594 T: 10.4.2013).

An unusual reference is made to the precautionary principle in a BDDK (Banking Regulation and Supervision Authority) Guide. Here the notion is used in a banking law context. Even though the notion is borne out of environmental law, it became a general rule of EU law as presented in Chapter 2.4.3. Thus, when risk is in question, prevention and sometimes precaution come naturally, not limiting but necessary and comprehensive approaches to regulations.

The BDDK Guide on the Management of the Country's Risk, dated 31.3.2016, numbered 6827, prepared according to Banking Law No. 5411, describes the best practices expected from banks regarding managing the country's risk (BDDK, 2016). Article 37 of the Guide is about country limits, a system for controlling the country's risk, based at a minimum on establishing and monitoring country limits. In this context, all banks should have a limit set for the countries in which they take risks and an information system that allows these limits to be maintained and reviewed constantly. This is precisely where the PP comes into question with its feedback systems and information renewal methods and requirements. "The established limits should be designed according to the precautionary principle rather than marketing purposes." This is an incredible public take on a banking law regulation underlining the dichotomy weighing into the advantage of precaution in the face of marketing purposes. These two underpinnings are characteristic of PP as a general principle of law. Furthermore, the Guide imposes that the unit establishing the limit and the unit responsible for marketing should be clearly separated, and exceptional cases/rules/applications that may allow limit overruns should be clearly recorded.

Overall, this exciting implementation of PP broadens its scope beyond environmental law and exhibits the need for precaution in any type of risk, not only public health or ecological ones.

6.2 Geopolitical Implications of the Recent Hydrogen Developments for Turkey

One of the main goals of the Turkish energy policy is to prioritize utilizing local energy sources (MENR, 2021). According to TEİAŞ data presented in Figure 2, the "share of renewable resources, including hydroelectric, wind, solar, geothermal, and biomass," reached 53% of Turkey's "total installed capacity" (IICEC).

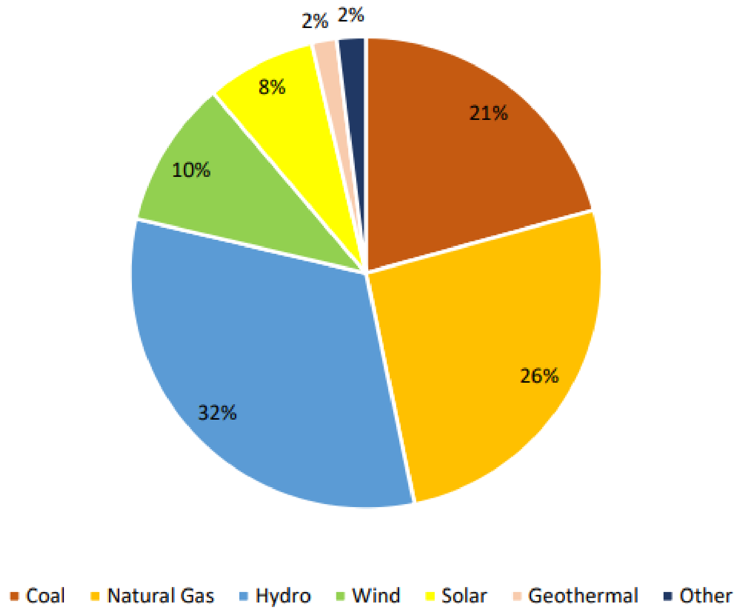

Figure 3: Installed Capacity by the End of July 2021
Source: TEİAŞ

Fossil fuels amount to "83% of the total primary energy supply" in 2019 (IEA, 2020). Turkey meets its energy needs based on fossil fuels with a substantial proportion of imports. Turkey's total imports increased by 17.7 percent in 2017 and amounted to 233.7 billion dollars (AA, 2018). Turkey imported US$ 37.2 billion worth of energy in 2017 (AA, 2018). The share of energy in imports is about 7 percent. The increase in energy imports is a negative data even though the ratio of energy in Turkish imports seems low, as the energy item is vital in terms of the current account balance based on the import/export balance. Energy equals US$ 37.2 billion in the 2017 account deficit of 47.4 billion $ (AA, 2018; Duvar, 2017). In other words, the share of energy in Turkey's 2017 account deficit is over 90 percent, and it is an immense burden (TÜİK, 2017; Duvar, 2017). The account deficit is significant for macroeconomic balances. The fact that energy has the lion's share here is unfavorable in terms of the overall outlook for the economy. Green hydrogen can play a game-changer role in the Turkish energy system. This issue will be further examined in Chapter 5.3.

At the beginning of March 2002, the EU Commission published a joint action plan called "REPowerEU." Currently, 5.6 million tons (Mt) of green hydrogen production are projected to be produced by 2030 under the EU's 'Fit for 55' agreement (EC, 2020). In addition to this target, the EU recently declared its urgent action plan to produce 15 million tons of green hydrogen within the scope of the REPowerEu action plan (EC, 2022). Thus, "25 to 50 billion cubic meters of natural gas per year from Russia" will be replaced (EC, 2022). These new goals go beyond the purposes set out in the EU hydrogen strategy in the run-up to the Ukraine crisis with Russia.

Five million tons of the 15 million tons of green hydrogen will be produced within Europe, while the remaining 10 million tons will be imported from other 'neighboring' countries (EC, 2022). After the Russia-Ukraine tension, the EU's efforts to improve energy efficiency and security, invest more in renewable energy and create a hydrogen market have accelerated (EC, 2022). Turkey is a region with a high level of renewable energy resources such as solar and wind, considering renewable energy sources' promising potential to produce hydrogen. Moreover, Turkey can produce clean energy more competitively than other Europe regions in terms of cost (SHURA, 2021). Therefore, Turkey can meet a particular part of the EU's green hydrogen needs.

As discussed in Chapter 4.1, the EU's regulatory and policy frameworks for hydrogen continue to develop with numerous legal and political initiatives. These new developments will continue regarding the urgent characteristic of the EU's decarbonization by hydrogen agenda. For instance, HGMDP is still on scrutiny by the Council and the Parliament. Their take on the Package is extremely influential as to the implications for Turkey. In addition, recent policy initiatives such as REPowerEU present great trade opportunities for Turkey if she can be an importer of green hydrogen. Therefore, all of these novel regulations and policies on hydrogen in Europe should be carefully understood, analyzed, and considered in policymaking.

The central role attributed to the future mass use of green hydrogen seems to be the complete decarbonization of the EU. The CBAM, as an upcoming European policy tool, aims to control CO_2 emissions globally and is memorizing measures. With CBAM, EU climate policy is going global. The EU is home to the world's largest market as a regulatory superpower (Bradford, 2012, p. 66; EC, 2008). CBAM is an excellent policy tool to prevent carbon leakage, which is the shift of activities of EU-based manufacturers of a selection of products to regions with fewer carbon costs. This tool is designed due to the increase in production costs in the EU with CO_2 taxation policies. Today, carbon leakage is dealt with through the system of free allotment of emission certificates. CBAM makes sure that "all CO_2 emissions, including those embedded in imports, can be priced according to the certification prices in the EU – ETS" (EC, 2021).

CBAM will create enormous costs for carbon-intensive sectors such as cement, steel, iron, and gray hydrogen-intensive industries such as refineries, chemicals, fertilizers, and glass industries (gray hydrogen means hydrogen produced from fossil fuels, especially CO2 emitted by natural gas reforming) (COM/2021/550 final). Turkey, the United Kingdom, China, and Russia are expected to be affected by CBAM the most as these countries are the largest suppliers of the products specified in CBAM (IICEC, 2021, p.12). Therefore, green hydrogen could have strategic importance for Turkey in this dramatically changing and challenging arena.

6.3 Turkish Political and Regulatory Framework for Hydrogen

In October 2003, the Turkish Ministry of Energy and Natural Resources (MENR) "signed an agreement with UNIDO" (United Nations Industrial Development Organization) to establish the "International Centre for Hydrogen Energy Technologies" (ICHET) in Istanbul (MEF, 2007, p.11). Beyond helping Turkey increase the amount of energy produced from non-fossil fuels, the mission of UNIDO-ICHET was to link developed and developing countries in hydrogen technologies and innovations. ICHET's objective was to "respond to demands from developing countries for energy services by promoting the development, acceptance, and use of hydrogen energy technologies, which are economically, technically and environmentally appropriate." Pilot projects were used to demonstrate these technologies' applicability and viability. The Turkish government contributed $40,000,000 to UNIDO in the form of a Trust Fund (MEF, 2007, p.21).

According to the final report of project SHEL, "Sustainable Hydrogen Evaluation in Logistics," which was a "collaborative demonstration project" funded by the FCH JU; at the end of 2012; CIDETEC as SHEL coordinator, was informed by ICHET that MENR contacted UNIDO to notify about the shutdown of ICHET on midnight, December 31st, 2012 (CORDIS-SHEL, 2018). All ICHET operations were ceased from then on (CORDIS-SHEL, 2018; CORDIS-FITUP, 2015), and to this date, there is still a lack of information on the details of the shutdown process. The reasons still being opaque, it should be acknowledged that Turkey missed an excellent opportunity to be an early adopter, even an innovator of green hydrogen technologies, and a green hydrogen exporter to Europe.

Hydrogen, which briefly found its place in national program documents at the beginning of the 2000s, was not considered part of energy policies in the following decade. On January 15th, 2020, MENR communicated with the public after this long break by organizing a "Hydrogen Exploration Conference" (ETKB, 2020). MENR Minister Fatih Dönmez, who delivered a speech at the online meeting, noted that the Ministry aims to handle hydrogen in four main foci: including more renewable energy in the system, decarbonizing the "heat sector, producing hydrogen from domestic coal, increasing the use of boron" as hydrogen storage and holder (ICCI, 2020). Referring to the need to use storage technologies to stabilize electricity production from renewable energy sources, Minister Dönmez highlighted the method of mixing 2% to 6% hydrogen into natural gas distribution lines. He noted that this corresponds to the delivery of 1 to 3 billion cubic meters of hydrogen to the system for Turkey. He added that the introduction of hydrogen into distribution lines is aimed at the end of 2021 at the latest in Turkey (ICCI, 2020). Concurrently GAZBIR-GAZMER conducted an admixture experiment in the R&D project detailed next paragraph.

The MENR assigned the Association of Natural Gas Distributors of Turkey (GAZBIR) to work on the accession and integration of hydrogen into natural gas pipelines. On April 2nd, 2021, GAZBIR's R&D center GAZBIR-GAZMER started operations in Konya, Turkey. 5% to 20% hydrogen and 95% to 80% natural gas were mixed in the laboratory, while the resulting mixture was burned for testing purposes. According to the initial results of this hydrogen admixture project conducted in Konya, it was concluded that hydrogen could be mixed with natural gas in distribution networks by up to 20% without the need for significant changes in natural gas internal installations and consumer devices (GAZBİR, 2022). This finding needs to be tested in more elaborate laboratories and extended experiments, as safety concerns regarding, for instance, hydrogen embrittlement emerge as serious risks. This view is supported in such and such studies. On this not yet hot-button but fundamental issue of safe energy transitions, French Energy Regulation Commission (CRE) very recently published its "response to the public consultation" on HGMDP on April 12th, 2022 (CRE, 2022). In this comprehensive and meticulous response, CRE clarifies that it does not favor blending hydrogen in natural gas networks for safety and economic reasons, even transitory. Relevant authorities should closely watch notable developments such as this one.

6.3.1 Hydrogen in Turkish National Strategic Documents

On the national hydrogen policy front in strategic documents, there are two single measures taken in the 9th (2007-2013) and 11th (2019-2023) Development Plans (DP). In the 9th DP, “Hydrogen and Fuel Cell Technology” has been supported as one of the priority areas. In the 11th DP paragraph 361.2., it was decided to carry out feasibility studies on lignite reserves to establish gasification reactors that allow the production of coal-derived chemicals (such as ammonia, methanol, monomer, synthetic natural gas, hydrogen, synthetic liquid diesel fuel) (SBB, 2019, p.86).

There are minimal observations on the upcoming hydrogen economy in the 9th DP Mining Specialized Commission (ÖİK-Özel İhtisas Komisyonu) Report, 9th DP Mining, Energy Raw Materials (lignite, coal, geothermal) Working Group Report and 10th DP Mining Policies ÖİK Report (SBB, n.d.). During the process leading to the 9th DP, there is awareness of the potential of hydrogen. In the last report listed, hydrogen is mentioned once in the limited context of clean coal technologies.

Hydrogen is not mentioned in Presidential Annual programs between 2011 and 2022 (SBB, n.d.). It is also not included in the 2019-2023 MENR Strategic Plan. However, I want to note that the goals and values – (Goals: Ensuring the security of sustainable energy supply, increasing regional and global market presence, technology development, and « Yerlilik »… Values: Efficiency, Reliability, Transparency, Participation, Sustainability, Innovation and Leadership, Consistency and Predictability, Sensitivity to Environment, « Millilik » …) (MENR, 2018) underlined in this Strategic Plan are well aligned with a potential national hydrogen strategy.

6.3.2 Hydrogen in Turkish Law

Hydrogen energy first entered into legislation in Turkey on May 2nd, 2007. In the “Energy Efficiency Law” published in the Official Gazette, hydrogen and biofuel have been determined as alternative fuels whose use should be encouraged. In addition, in 2011, a regulation on hydrogen-fueled vehicles was issued. This regulation on the type approval of hydrogen-powered vehicles was in line with the relevant EU regulations on transport (EU/168/2013, EU/134/2014). This lawmaker probably carried out this preliminary preparation expecting that these vehicles would be on the agenda after a while. It should be noted that most hydrogen standards and some regulations ought to have international characteristics. This example was an attempt by Turkey to adapt its national laws during the EU Accession process. These also include legislation on safety.

The Turkish regulatory landscape regarding hydrogen is still largely immature. Therefore, it necessitates the coordinated assessment of the issue by the relevant actors such as the Presidency, the Parliament, MENR, and other responsible Ministries.

6.3.2.1 Scope and Authority

The main legal instrument which is most relevant to approach the "hydrogen problem" in Turkish law per the hierarchy of norms is the Natural Gas Market Law numbered 4646. Article 2 about the scope of 4646 reads as follows: "The Law covers the import, transmission, distribution, storage, marketing, trade and export of *natural gas* and the rights and obligations of all real and legal persons relating to these activities" (emphasis added).

The definition of Natural Gas in Article 3/1/7 of Law 4646 reads as follows: "All natural hydrocarbons in the gaseous state, generated or can be generated from the ground and other states of gas been liquified and pressurized or physically processed by various methods (Liquidated Petroleum Gas - LPG) to present to the market." Since hydrogen does not technically meet this definition, when these two substances are evaluated together, it can be inferred that hydrogen is outside the scope of law 4646. Furthermore, unlike the above-mentioned related European Directive 2009/73/EC, current Turkish legislation on natural gas does not include "biogas and gas from biomass or other types of gas" in its scope. This situation is the most fundamental legal obstacle related to hydrogen injection into the existing natural gas system.

The deployment of hydrogen technologies in Turkey could be facilitated by an amendment to Article 2 that will broaden the scope of 4646. The amendment could be done by the General Assembly of the Turkish Parliament or by a statutory decree introduced by the President. Electricity Market Regulation Authority (EMRA), as an independent, autonomous authority, has a regulation function defined in the 2002/12 numbered Report of the State Supervisory Council (Devlet Denetleme Kurulu); yet until explicitly authorized by law by the legislator or until necessary amendments are made in the laws mentioned above, EMRA cannot introduce any direct regulations regarding hydrogen. Furthermore, law 4628 on EMRA Organization and Duties stipulates that the EMRA mandate is strictly limited by the powers invested in it by the Electricity Market Law, Natural Gas Market Law, Petroleum Market Law, and LPG Market Law. Therefore, EMRA's authority to regulate is derivative and can only be performed following the "administrative legality" principle (Article 123 of the Constitution).

6.3.2.2 Dispersed Regulations

Dispersed hydrogen regulations can be categorized under three titles: energy efficiency, transport, and safety. 5627 Energy Efficiency Law enacted in 2007 is the primary legal instrument represented on a "law" hierarchy. It mentions hydrogen only once in Article 7/1/e, which stipulates that the procedures and principles for encouraging alternative fuels such as biofuels and hydrogen in electric power generation facilities and transmission and distribution networks are to be determined by the MENR by-law. No new provisions about hydrogen have been made in Law 5627 by the lawmaker in four consecutive legal modifications made in the following years.

One specific note to make among these regulations is the EMRA Decision dated 18/06/2020 numbered 9394 (repealed on October 7th, 2021), and Decision dated 17/03/2022 numbered 10847-2 regarding pre-license and construction periods for renewable energy power plants. Both EMRA Decisions regulate the same issue with the same regulations on hydrogen. The former was repealed by the EMRA decision dated 30/09/2021 numbered 10442-1.

The legal rationale behind the wording of this Decision is unclear, treating "solar/hydrogen energy" in the same category. As seen in Table 1, solar and hydrogen energy (hydrogen does not take place anywhere else in Turkish law as renewable energy, only as "alternative fuel" in Energy Efficiency Law) are regulated to have the same installed power range (MWm) and construction periods that will be referenced in determining the completion date of the facility and pre-license periods. The reasons for this duo usage remain vague. Solar and hydrogen have very different characteristics. The former is an energy source and the latter an energy carrier. Hydrogen is entirely different from other renewable resources when it comes to safety. It should be regulated according to its unique requirements. These dispersed, unclear usages create blurriness and legal uncertainty for investments. EMRA can be more explicatory as to which context and with what underlying rationale it ruled this particular provision. Comprehensive, rational, innovative political strategies should be designed and implemented. EMRA, as one of the main actors in this ecosystem, can be more proactive in adopting the Turkish energy system to the current and future necessities of the energy transition.

Table 7: Construction periods that will be referenced in determining the completion date of the facility and pre-license periods

Production Facility Type	Installed Power (P) Range (MWm)	Construction Time (month)
Solar/Hydrogen Energy	$10<P\leq 50$	30
	$50<P$	36
	$P<10$	18

Source: EMRA Decision #9394 (repealed) and EMRA Decision #10847-2

A very recent hydrogen regulation is made in the Amendment to 2014/6124 EMRA Organization By-law published in the Official Gazette dated 06.04.2022, numbered 31801. It is not an exclusive hydrogen regulation by a general clause that considers hydrogen with a list of other fuels. In Additional Clause 3, a new body, Energy Transition Chamber, is instituted with the addition of Articles 15/A and 15/B. Article 15/B/1 describes the duties and authority of the Presidency of the Energy Transition Chamber. Recital ç entrusts power to the Presidency for conducting research, contributing to the development of new legislation, and the design and management of permit and monitoring processes related to the use of the following fuels: hydrogen, biofuels, synthetic and paraffin fuels, biomethane, and similar alternative fuels. While this very recent regulation adds dimension to the hydrogen regulation framework of Turkey, EMRA still needs to be delegated authority by the Turkish National Grand Assembly by law to be able to make secondary regulations on hydrogen in Turkish law. With this new regulation, The Presidency of the Energy Transition Chamber is only decorated with the power to contribute to legislation development, not to its making. Still, it is an essential step by the lawmaker to consider hydrogen on a by-law level.

In Table 8, most present regulations considering hydrogen in Turkey are listed under three categories. Regulations regarding hydrogen peroxide are excluded.

Table 8: Present Hydrogen Regulations in Turkey According to Their Regulatory Domains

Regulatory Domain	Present Hydrogen Regulations
Energy	Energy Efficiency Law No. 5627 By-law on Increasing Efficiency in the Use of Energy Resources and Energy EMRA Organization By-law

Table 8 (cont'd)

Energy (cont'd)	EMRA decision dated 18/06/2020 numbered 9394 (repealed as of October 7th, 2021) EMRA Decision dated 17/03/2022 numbered 10847-2 (under Electricity Market Licensing Regulation Articles 9/1 and 23)
Safety	By-law on Fire Protection of Buildings By-law on Electrical Internal Facilities Planned Areas Zoning Regulation Istanbul, Gaziantep, Bursa, and Ankara Zoning Regulations 305/2011/EU Construction Products Directive By-law on Fire Response Classes of Building Materials, Fire Resistance of Building Elements, External Fire Performance of Roofs and Roof Coverings (in the scope of MHG/2017-13 (305/2011/EU))
Transport	(By-law SGM-2013/21) on the Implementation Measures of the Type Approval By-law of Hydrogen-Powered Motor Vehicles (AT) 79/2009 Regulation AB/134/2014 on Environmental and Drive Unit Performance Requirements for Type Approval of Two-Wheeled, Three-Wheeled Vehicles, and Four-Wheeled Motorcycles By-law on the Procedures and Principles for Improving Energy Efficiency in Transport By-law on the Manufacture, Modification, and Installation of Vehicles By-law on the Repeal of the Communiqué (AT) 79/2009 The Regulation on the Type Approval of Hydrogen-Powered Motor Vehicles. To be revoked on Effective Date: 06.07.2022

In this subchapter, via examination of the Turkish political and regulatory frameworks for hydrogen, preliminary legal action points for Turkey to catch up with the EU's decarbonization by hydrogen agenda were determined. These points include the need for an amendment that will widen the scope of Law 4646 to include hydrogen and for EMRA to be authorized by the legislator to make explicit regulations on hydrogen. A study of present Turkish hydrogen regulations revealed that most of the regulations on transport were enacted in line with the relevant European regulations, most of them transposed directly in Turkish law. This finding reveals the international character of transport regulations. This case is also valid for some safety regulations such as the Construction Products Directive and the By-law on Fire Response Classes of Building Materials, Fire Resistance of Building Elements, External Fire Performance of Roofs and Roof Coverings. While regulations under the safety and transport categories are comprehensive and consistent with regional necessities, the regulations under the energy category seem to be dispersed and without focus. The study in Chapter 4.1 revealed that regulatory action on hydrogen as an energy carrier is quite complicated and should be managed with a planned strategy. A study on the Turkish energy regulations, including hydrogen, showed that dispersed regulations without a holistic regulatory take could bear risks of confusion and a patchwork situation. The EMRA Decisions' (#9394 and #10847-2) ambiguous wording is one example that paves the way for such risks. Policy suggestions for such risks are made in the next subchapter.

6.4 Policy Considerations for the Development of Hydrogen Technologies in Turkey

As the hydrogen technologies are still immature in Turkey, precautionary policy considerations would be devoid of essence. Instead, general policy suggestions for the deployment of these technologies will be made in this subchapter taking into consideration the geopolitical analysis of the current and future developments in the region. These implications are examined in detail in Chapter 6.2.

As in the rest of the world, Turkey has faced the dire consequences of global warming and increasing air pollution in recent years. In this regard, Turkey needs urgent adaptation to the measures taken worldwide by fulfilling her international commitments. In this context, with the ratification of the Paris Agreement on October 7th, 2021 (AA, 2021), Turkey will need a long-term energy transition strategy. The regional developments studied in Chapter 2 show that this strategy should include green hydrogen technologies as a main pillar. For this to happen, synergies between public bodies, universities, industry, NGOs, think tanks, and the innovation ecosystem should be heightened. The establishment of a Communication Committee between these stakeholders can help serve this policy aim. Such a committee would be a good starting point for planned, transparent and coordinated work in the light of a scientific vision.

Legal security and planning can play a crucial role in creating predictable and attractive markets for investors. This way, blurriness and irregularities in the legislation can be prevented. The legal authorization of EMRA by the legislator for the governance of hydrogen technologies is the first step in this direction. Following this step, EMRA can form an expert “Hydrogen Chamber” which can design regulations in alignment with the EU regulations.

Like Europe’s challenges, Turkey needs to avoid regulatory patchwork and multiple standards that would create distortions in the natural gas market, compromise its integrity, undermine potential strategies of repurposing, and indirectly delay the development of legal stability needed for large-scale investments. Turkey should give safety extra attention as a country without sufficient experience in these technologies. Safety considerations due to the generalized use of hydrogen should be primordial, in line with PP.

As the EU is a major trading partner for Turkey, the sectors that CBAM will be covering such as cement, iron & steel, refineries, and chemicals, fertilizers; “greening” these industries should be a priority. The deployment of green hydrogen technologies can help ease the potential financial burdens of CBAM. A 2021 SHURA report evaluating Turkey’s green hydrogen production and export potential from a technical and economic perspective finds out that Turkey can reach an annual output of 3.4 million tons of green hydrogen nationwide by 2050 if policies make cost-effective investments possible. This amount of production requires a yearly investment of between $3 and $4 billion by 2050 (SHURA, 2021, p.11).

In 2021, the Turkish Presidential Board of Science, Technology and Innovation Policies conducted studies on six strategic subjects, one of which is hydrogen technologies (Dünya, 2021; AA, 2021). The output of these Working Groups is not publicly available. Yet, it can be inferred that hydrogen is given specific importance by the Turkish Presidency. The implications of this study may reflect on the 2023 Annual Presidential Program. In this respect, a national hydrogen strategy/roadmap should include support and incentive mechanisms for accelerating and strengthening scientific, educational, technological, and commercialization efforts. R&D activities, pilot-scale, and demonstration projects are necessary to raise the technology readiness level of commercialization. Studies should also increase public awareness about hydrogen technologies' economic and environmental importance, regulations, measures, and standards.

MENR should provide legislative and consultancy support for the potential investors in hydrogen technologies. TÜBİTAK can open a thematic call for proposals to accelerate development of green hydrogen technologies and support knowledge accumulation. Organizing interdisciplinary conferences and meetings in this regard is also a helpful policy tool.

Salt caverns are artificially constructed cavities in underground salt formations. Turkey uses salt caverns to store natural gas. Salt Lake Natural Gas Underground Storage Project Stage I and II studies are carried out in Sultanhanı district of Aksaray Province, 40 km south of Salt Lake. Stage I has been completed as of the end of 2021, and the working gas capacity reached 1 billion Sm^3 (standard cubic meter), and the daily back production capacity reached 40 million Sm^3 (BOTAŞ, n.d.). Hydrogen has been successfully stored in salt caverns at four different facilities for decades "(Teesside, Great Britain (3 caverns, 70,000 m^3 each, 370 m); Clemens Dome, Texas (1 cavern, 580,000 m3, 1,000–1,300 m); and Moss Bluff, Texas (1 cavern, 566,000 m3, 335–1400 m), USA)” (U.S. Department of Energy, 2020, p.40). The technology is considered mature for hydrogen storage (EC, 2022, p.93). Therefore, Turkey should use its decade-long experience and storage potential already geographically available.

This Chapter provides a short snapshot of the ongoing task of investigating the Turkish legal landscape for hydrogen system deployment. Further research is needed to develop the current analysis to cover several important topics regarding the regulatory gaps and needs of the Turkish legal landscape for efficient, sustainable, and safe deployment of hydrogen technologies. The next Chapter is the Conclusions Chapter where we accentuate everything elaborated through the analysis, describe the novelty of the thesis, and discuss limitations and future study prospects.

CHAPTER 7

CONCLUSIONS

The type of risk subject to PP's protection springs up from change. As inevitable as change is, the immanent uncertainty within change. PP is a democratic, pluralist attempt for responsible and deliberative governance as the sole principle of its kind which enables and protects "social and ecological resilience" (Read & O'Riordan, 2017).

Ambitions of total prowess or mastery are incompatible with the uncertainty and ignorance the world harbors (Read & O'Riordan, 2017). Acknowledging the limits of our evidence models is critical when stakes are high. PP opens a space in law and policy for acceptance of ignorance, an ode to Socrates.

As Carvalho et al. elaborately put it, the prevalent application of PP "to energy choices does not seem to be taking place in the real world" (Carvalho et al., 2010). This thesis is an attempt for such a contribution. In that regard, we aligned the concepts of the precautionary theory with the hydrogen risk chain, designing policy-level research pursuing ecological complexity while analyzing the immature, complex, and differing nature of legal processes necessary for the deployment of hydrogen technologies. The thesis offers a preliminary precautionary approach to designing the main ingredients of hydrogen safety regulations. We also offered some policy suggestions for the safe and just deployment of hydrogen technologies.

PP's underlying goal is thermodynamic equilibrium. It preserves and sustains all forms of life. Its inherent objective is "to preserve thermodynamic conditions in the biosphere, amenable to the preservation of all forms of life, including social and historical constructions of humanity" (Bourgourg & Schlegel, 2001). No other regulatory framework reflects such a duty of care.

This thesis contributes to the existing literature by bringing together concrete policy recommendations with abstract politico-legal principles. The thesis is novel domain-wise regarding the intersection of hydrogen energy studies with the precautionary principle. Until now, hydrogen has not been the object of such research. It attempts to offer ways for precaution and innovation to coexist in hydrogen deployment. One of the most significant findings of the thesis reveals a hydrogen risk chain – hydrogen value chain incompatibility, an issue that is yet to be treated by the relevant literature. Finally, this thesis encircles its argumentation at the end by exhibiting a detailed politico-legal historical archive work on the 'innovation principle', weaving an interdisciplinary study.

The limitations of the thesis include the lack of extensive research on the politico-legal aspects of hydrogen technologies. Incommensurability is of concern due to the sui generis nature of cases. More detailed studies could have been conducted especially concerning the dynamics of multilateral negotiations, resolution of various positions between countries, and the role of international organizations. Some country case studies could have been deepened to model the pp/innovation dichotomy (i.e., France and the UK). Deepened philosophical studies that relate to sustainability science would be beneficial.

This study evokes future research topics such as developing a general precautionary framework applicable to emerging energy technologies, ex-ante and ex-post impact analysis of precautionary applications, searching for various ways to implement PP in environmental cases, and bibliometric studies on precaution, safety, and energy transitions, and various research on the tension and complementarity between the Precautionary Principle and the challenging "innovation principle."

The risk issue for hydrogen is not an environmental risk problem. Quite the contrary, green hydrogen is called for to solve the carbon emissions problem. Hydrogen risk is inherent to its use, it is a dangerous material that may explode and kill people, but there will be no lasting damage as in the case of a nuclear explosion where radioactivity will continue to kill people decades later, and also as the global warming issue as its effects will last for centuries. Therefore, hydrogen risk is local in time and space, but it can occur often and everywhere. Thus, its use should be regulated, from its production to transmission and storage.

Hydrogen risk is unique, yet the best comparison is natural gas, also a risky gas with the potential to cause fire and explosions. The natural gas risk may be considered lower than hydrogen because of its physical and chemical properties. However, the impact is also local in time and space and will not last like a nuclear explosion.

Although hydrogen risk is higher than natural gas risk, the best comparison of hydrogen risk would be with natural gas risk, as both risks are local in time and space. It took close to a century to master natural gas risks. There are, of course, still natural gas explosions and fires, but they happen very rarely. Therefore, the hydrogen regulation/precaution question is what to regulate in the hydrogen case to make it as safe as natural gas today. Therefore, it is imperative to review natural gas' regulatory and legislative histories; the legal steps are taken to master these risks and make parallels with hydrogen. These comparative dimensions are fruitful future study prospects to find out where the precautionary/preventive hydrogen regulation should target, also giving ideas on how to deal with the PP/IP dichotomy in the hydrogen case

REFERENCES

1996 Protocol To The Convention On The Prevention Of Marine Pollution By Dumping Of Wastes And Other Matter, 1972 (as amended in 2006) https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/PROTOCOLAmended2006.pdf

75 civil society organizations. (2019, March 11). *Open Letter for the removal of Innovation Principle* https://www.ghadvocates.eu/wp-content/uploads/11March-Last-chance-to-safeguard-citizens-protections-by-removing-Innovation-Principle-from-HorizonEurope-v8.pdf

Adler, J. H. (2000). More Sorry Than Safe: Assessing the Precautionary Principle and the Proposed International Biosafety Protocol. Faculty Publications 226. *Texas International Law Journal*. https://scholarlycommons.law.case.edu/faculty_publications/22635

Adler, M.D. (2012). *Well-Being and Fair Distribution*, Oxford: Oxford University Press.

Applegate, J. S. (2002). The Taming of the Precautionary Principle, 27 *WM. & MARY ENvTL. L. & POL'Y. REV*. 13.

Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea Of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks https://documents-dds-ny.un.org/doc/UNDOC/GEN/N95/274/67/PDF/N9527467.pdf

Alam, S., Atapattu, S., Gonzalez, C. G. & Razzaque, J. (Eds.). (2015). *International environmental law and the global south*. Cambridge University Press.

Albert, H. 'Kennis en Recht' in FD Heyt (ed), Rationaliteit in wetenschap en samenleving (Alphen aan de Rijn, Samsom, 1976)

Anadolu Agency. (2018, January 3). Turkey's exports cross $157 billion in 2017. Anadolu Agency https://www.aa.com.tr/en/economy/turkeys-exports-cross-157-billion-in-2017/1021346

Baker & Botts. (2022, January 13). The EU New Gas Package- Will it Prove Fit for Purpose? https://www.bakerbotts.com/thought-leadership/publications/2022/january/the-eu-new-gas-package-will-it-prove-fit-for-purpose

Boadway, N. (2016). “Cost-Benefit Analysis”, Chapter 3 in M.D. Adler and M. Fleurbaey (eds), The Oxford Handbook of Well-Being and Public Policy, Oxford: Oxford University Press.

Bodansky, D., Brunnée, J. & Rajamani, L. (2017). *International climate change law*. Oxford University Press.

Britannica, T. Editors of Encyclopaedia (2016, June 14). institutional economics. Encyclopedia Britannica. https://www.britannica.com/topic/institutional-economics

BOTAŞ. (n.d). Tuz Gölü Underground Natural Gas Storage. https://www.botas.gov.tr/Sayfa/tuz-golu-yer-alti-dogal-gaz-depolama/23

Bourgourg, D. & Schlegel, J.-L. (2001). Parer aux risques de demain. E´d. du Seuil, Paris.

Bradford, A. (2012). The Brussels Effect. Northwestern University Law Review, 107(1). https://scholarship.law. columbia.edu/faculty_scholarship/271

Busch, C., Maret, P. S. D., Flynn, T., Kellum, R., Le, S., Meyers, B. Saunders, M., White, R. & Palmquist, M. (2005). *Content Analysis*. Writing @CSU. Colorado State University. https://writing.colostate.edu/guides/guide.cfm?guideid=61

Carvalho, J. F., Seger, S., Mercedes, P. & Sauer, L. (2010). *Energy Policy* 38 5399–5402.

CERN Accelerating Science. (n.d.). The Big Bang. https://home.cern/science/physics/early-universe

Çetinkaya, Z. (2021, May 24). Bilim, Teknoloji ve Yenilik Politikaları Kurulu; öncül teknoloji çalışmalarına odaklandı. Anadolu Ajansı. https://www.aa.com.tr/tr/bilim-teknoloji/bilim-teknoloji-ve-yenilik-politikalari-kurulu-oncul-teknoloji-calismalarina-odaklandi/2252471

Chen, L. C. (2014). *An introduction to contemporary international law: a policy-oriented perspective*. Oxford University Press.

COM/2000/0001 final Communication from the Commission of 2 February 2000 on the Precautionary Principle.

COM/2002/304 final ‘Amended Proposal for a Directive of the European Parliament and of the Council Amending Directives 96/92/EC and 98/30/EC Concerning Rules for the Internal Markets in Electricity and Natural Gas’.

COM/2017/0479 final Communication from The Commission to The European Parliament, The European Council, The Council, The European Economic and Social Committee, The Committee Of The Regions and The European Investment Bank Investing In A Smart, Innovative And Sustainable Industry A Renewed EU Industrial Policy Strategy

COM/2018/0435 – C8-0252/2018 – 2018/0224(COD) European Parliament legislative resolution of 17 April 2019 on the proposal for a regulation of the European Parliament and of the Council establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination europarl.europa.eu/doceo/document/TA-8-2019-0395_EN.html

COM/2020/299 final Communication from The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Powering a climate-neutral economy: An EU Strategy for Energy System Integration. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2020:299: FIN

COM/2020/301 Communication from The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions A hydrogen strategy for a climate-neutral Europe. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0301

COM/2020/301 final Communication from the Commission to The European Parliament, The Council, The European Economic and Social Committee, And the Committee of The Regions A hydrogen strategy for a climate-neutral Europe

COM/2021/803 final 2021/0425(COD) Proposal for a Directive of The European Parliament and of the Council on common rules for the internal markets in renewable and natural gases and in hydrogen

COM/2021/803 final Proposal for A Directive of the European Parliament and of the Council on Common Rules for the internal markets in renewable and natural gases and in hydrogen

COM/2021/804 final Proposal for a Regulation of The European Parliament and of the Council on the internal markets for renewable and natural gases and for hydrogen (recast)

COM/2022/108 final Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, and The Committee of The Regions REPowerEU: Joint European Action for more affordable, secure, and sustainable energy

CORDIS. (2015). https://cordis.europa.eu/project/id/256766/reporting Record number: 169311

CORDIS. (2018). https://cordis.europa.eu/project/id/256837/reporting/pl Record number: 246933

Council of the European Union. (2003). Common Position Adopted by the Council on 3 February 2003 with a View to the Adoption of a Directive of the European Parliament and of the Council Concerning Common Rules for the Internal Market in Natural Gas and Repealing Directive 98/30/EC.

Court of the First Instance, Joined Cases T-74/00, 76/00, 83/00, 84/00, 85/00, 132/00, 137/00 and 141/00, Artegodan GmbH and others v Commission [2002] ECR II-4945.

Craig N. & de Búrca, G. (2011). *EU law. Text, cases, and materials*, 5th ed. Oxford University Press, Oxford.

Deville, A. & Harding, R. (1997). *Applying the Precautionary Principle*. Annandale, Australia: Federation Press.

Dünya. (2021, May 25). Bilim, Teknoloji ve Yenilik Politikaları Kurulu, çalışmalarını Cumhurbaşkanı Erdoğan'a sundu. https://www.dunya.com/sektorler/teknoloji/bilim-teknoloji-ve-yenilik-politikalari-kurulu-calismalarini-cumhurbaskani-erdogana-sundu -haberi-622363

Ecostandard. (2021). *Letter Improving Gas Package*. https://ecostandard.org/wp-content/uploads/2021/12/COM-Letter_improving-gas-package-1.pdf

EEB, IFOAM EU Group, Corporate Europe & Slow food Europe. (2019, December) *Open Letter* https://eeb.org/wp-content/uploads/2019/12/NGO-Letter-on-EU-Green-Deal-Innovation-principle-and-New-GM-1.pdf

EHSP Task Force TF3. (2021*). Statistics, lessons learned and recommendations from the analysis of the Hydrogen Incidents and Accidents Database* (HIAD 2.0). https://www.fch.europa.eu/sites/default/files/documents/Lessons%20learnt%20from%20HIAD%202.0-Final.pdf

Enagás et al. (2020). European Hydrogen Backbone: How a dedicated hydrogen infrastructure can be created https://gasforclimate2050.eu/wp-content/uploads/2020/07/2020_ European-Hydrogen-Backbone_Report.pdf

ERF. (2015) Better Framework for Innovation. http://www.riskforum.eu/uploads/2/5/7/1/25710097/businesseurope-erf-ert_innovation_principle_joint_statement.pdf

ERF. (2015). Monograph. https://www.eriforum.eu/uploads/2/5/7/1/25710097 /monograph innovation_principle.pdf

ERF. (2015). Highlights Note 02. https://www.eriforum.eu/uploads/2/5/7/1/25710097/erf_highlights_2_-_hazardbased_regulation_-_nov.15.pdf.

ERF. (2015). Highlights Note 03. https://www.eriforum.eu/uploads/2/5/7/1/25710097 /erf_highlights_3_-_precaution_- _dec.15.pdf

ERF. (2015). Innovation principle Q&A, 5 March 2015. http://www.risk forum.eu/uploads/2/5/7/1/25710097/innovation_principle_q&a_5_march_2015.pdf

ERF. (2015). Precaution And Risk Management – Modern Issues – Highlights Note 03 https://www.eriforum.eu/uploads/2/5/7/1/25710097/erf_highlights_3_-_precaution_-_dec.15.pdf

ERF. (2015). The Innovation Principle – Overview. http://www.riskforum.eu/uploads/2/5/7/1/25710097/innovation_principle_one_pag er_5_march_2015.pdf.

ERF. (2016). Highlights Note 08. https://www.eriforum.eu/uploads/2/5/7/1/25710097/erf_highlights_8_- _defensive_r_d_and_innovation_-_jul.16.pdf

ERIF. (2021). A short history of ERIF 1991-2021. https://www.eriforum.eu/uploads/2/5/7/1/25710097 /erif_short_history_-_www_jan.21.pdf

ERIF. (2021). Highlights Note 15. https://www.eriforum.eu/uploads/2/5/7/1/25710097/erif_highlights_15_-_time_to_market_final.pdf

ERIF. (2021). Highlights Note 16 https://www.eriforum.eu/uploads/2/5/7/1/25710097 /erif_highlights_16_-_essentiality.pdf.

ERIF. (2021). List of Members. Companies. https://www.eriforum.eu/uploads/2/5/7/1/ 25710097/erif_list_of_members_21.pdf

ERIF. (2022). Monograph Scientific Excellence In Consumer Safety Insights For The EU Better Regulation Agenda March https://www.eriforum.eu/uploads/2/5/7/1/25710097/erif_monograph_-_consumer_safety_workshop_final.pdf

ERIF. (n.d.) Innovation Principle Q&A. https://www.eriforum.eu/uploads/2/5/7/1/25710097/ innovation_principle_qa_-_jan.21.pdf

ERIF. (n.d.) Latest publications. https://www.eriforum.eu/latest-publications.html

EU Court of Justice Case C–180/96 UK v Commission [1998] ECR I–2265

EU Court of Justice Case T–13/99 Pfizer Animal Health SA v Council [2002] ECR II–3305.

EU Court of Justice Cases T–74, 76, 83–85, 132, 137, and 141/00, Artegodan GmbH v Commission [2002] ECR II–4945.

European Commission Directorate-General for Communication. (2021). *The role of hydrogen in meeting our 2030 climate and energy targets*. Publications Office. https://data.europa.eu/doi/10.2775/833

European Commission Directorate-General for Energy, Breitschopf, B., Zheng, L., Plaisir, M., et al. (2022). The role of renewable H_2 import & storage to scale up the EU deployment of renewable H_2 report https://data.europa.eu/doi/10.2833/727785

European Commission Directorate-General for Energy, Joint Research Centre, Bossmann, T., Cornaggia, L., Vautrin, A., et al. (2021). Assistance to assessing options improving market conditions for bio-methane and gas market rules: final report. Publications Office https://data.europa.eu/doi/10.2833/912333

European Commission Directorate-General for Research and Innovation (2016). Strategic Plan 2016-2020 https://ec.europa.eu/info/sites/info/files/strategic-plan-2016-2020-dg-rtd_ march2016_en.pdf

European Commission Directorate-General for Research and Innovation. (2019). Simonelli, F. & Renda, A., Study supporting the interim evaluation of the innovation principle: final report. Publications Office https://data.europa.eu/doi/10.2777/620609

European Commission Directorate-General for Research and Innovation. (2021). Horizon Europe, budget: Horizon Europe- the most ambitious EU research & innovation programme ever, Publications Office. https://data.europa.eu/doi/10.2777/202859

European Commission Joint Research Center. (2019). Final insights into hydrogen use. (Public version) https://ec.europa.eu/jrc/sites/default/files/final_insights_into_hydrogen_use_public_version.pdf

European Commission press release: Commission proposes new EU framework to decarbonise gas markets, promote hydrogen and reduce methane emissions https://ec.europa.eu/commission/presscorner/detail/en/ip_21_6682

European Commission. (2015). Staff Working Document Better regulations for innovation-driven investment at EU level 15.12.2015 SWD (2015) 298 final https://data.consilium. europa.eu/doc/document/ST-15392-2015-INIT/en/pdf

European Commission. (2015). Staff Working Document Better regulations for innovation-driven investment at EU level SWD (2015) 298 final. https://www.eumonitor.nl/9353000/1/j4nvgs5kjg27kof_j9vvik7m1c3gyxp/vjzx9axjibzm/f=/15392_15.pdf

European Commission. (n.d.). Better Regulation: why and how. https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en#:~:text=The%20Better%20Regulation%20 agenda%20ensures,where%20it%20matters%20the%20most

European Environment Agency. (2001). *Late lessons from early warnings: The precautionary principle 1896–2000*. Environmental issue report No. 22, Luxembourg: Office for Official Publications of the European Communities.

European Hydrogen Safety Panel. (n.d.). FCH JU. https://www.fch.europa.eu/page/european-hydrogen-safety-panel

European Parliament Committee on Industry, External Trade, Research and Energy. (2002). *Report on the Proposal for a Directive of the European Parliament and of the Council Amending Directives 96/92/EC and 98/30/EC Concerning Common Rules for the Internal Market in Electricity and Natural Gas*. Doc. A5-0077/2002, Amendments 110 and 118.

European Parliament Committee on Industry, Research and Energy (2021). *Report on a European Strategy for Hydrogen*. https://www.europarl.europa.eu/doceo/document/ A-9-2021-0116_EN.html

European Parliamentary Research Service. (2015). *The precautionary principle. Definitions, applications and governance*. https://doi.org/10.2861/821468

European Political Strategy Centre. (2016). Issue 14: Towards an Innovation Principle Endorsed by Better Regulation.

European Union Finnish Presidency. (2019, December 3). *Report on the High level Conference on Innovation Principle – Developing an innovation-friendly legislative culture*. https://tem.fi/documents/1410877/2132258/InnovationPrincipleConferenceReport.pdf/1e06570a-7969-60d1-0cce-aec51fc35d3a/InnovationPrincipleConference Report.pdf?t=1643103404994

European Clean Hydrogen Alliance. (2020). Declaration of the European Clean Hydrogen Alliance. https://ec.europa.eu/docsroom/documents/43526

Ewald et al. (2001). *Le Principe de Précaution*. Paris: Presses Universitaires de France.

FCH 2 JU. (2020). *Opportunities for Hydrogen Energy Technologies considering the National Energy & Climate Plans*. https://www.fch.europa.eu/sites/default/files/file_attach/Final%20Report%20Hydrogen%20in%20NECPs%20%28ID%209501746%29.pdf

Fernández, L. (2022). *Number of chemical industry employees in the EU-27 2007-2020*. https://www.statista.com/statistics/1307411/chemical-industry-number-employees-eu/

Figge, F. (2005). Capital Substitutability and Weak Sustainability Revisited: The Conditions for Capital Substitution in the Presence of Risk. *Environmental Values,* vol.14, no.2, 185-201.

Fisher, E. & Harding, R. (1999). *The Precautionary Principle: Towards a Deliberative, Transdisciplinary Problem-Solving Process*. In Perspectives on the Precautionary Principle, ed. Ronnie Harding and Elizabeth Fisher. Federation Press.

Fleming, R. (2020). Clean or renewable – hydrogen and power-to-gas in EU energy law. *Journal of Energy & Natural Resources Law*. https://doi.org/10.1080/02646811.2020.1795382

Florence School of Regulation. (2022). *The Commission's new Gas and Hydrogen Package.* https://www.youtube.com/watch?v=ZrBNmqKyKCU&t=19s&ab_channel=FlorenceSchoolofRegulation

Florence School of Regulation. (2022, March 21). *The EU Hydrogen and Decarbonised Gas Market Package: Revising the governance and creating a hydrogen framework.* https://fsr.eui.eu/the-eu-hydrogen-and-decarbonised-gas-package-revising-the-governance-and-creating-a-hydrogen-framework/

Garnett, K., Calster, G. V. & Reins, L. (2018). Towards an innovation principle: an industry trump or shortening the odds on environmental protection? Law, Innovation and Technology 10 (1) 1–14. https://doi.org/10.1080/17579961.2018.1455023.

GAZBİR. (2021). Sector Bulletin. https://www.gazbir.org.tr/uploads/page/Mart-Nisan-2021-Bulten.pdf.

Gökalp, İ. (2019). A Holistic Approach to Promote the Safe Development of Hydrogen as an Energy Vector. Proceedings of the Ninth International Seminar on Fire and Explosion Hazards. Vol. 2: 21-26 April 2019, Saint Petersburg, Russia. https://doi.org/10.18720/SPBPU/2/k19-127

GRTgaz et al. (2019). *Technical and economic conditions for injecting hydrogen into natural gas networks.* https://www.elengy.com/images/Technical-economic-conditions-for-injecting-hydrogen-into-natural-gas-networks-report2019.pdf

Hansson, S.O. (2020). How Extreme Is the Precautionary Principle? Nanoethics 14, 245–257. https://doi.org/10.1007/s11569-020-00373-5

Hartzell-Nichols, L. (2013). From 'the' precautionary principle to precautionary principles. Ethics, Policy and Environment, 16, 308–320. https://doi.org/10.1080/21550085.2013.844569

Hoecke, M. H. (2011). Methodologies of Legal Research – Which Kind of Method for What Kind of Discipline? Oxford and Portland, OR: Hart Publishing

Hydrogen Council. (2021). Hydrogen Insights 2021 Report: A perspective on hydrogen investment, market development and cost competitiveness. https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021 .pdf

IISD. (2020). Earth negotiations bulletin BRIEF #4 The Precautionary Principle October 2020 https://www.iisd.org/system/files/2020-10/still-one-earth-precautionary-principle. pdf p.3

International Court of Justice. (1974). Nuclear Tests Case (Australia v. France). December 20th,1974, ICJ Reports

International Court of Justice. (1974). Nuclear Tests case (New Zealand v. France). December 20th, 1974, ICJ Reports

International Energy Agency. (2020). IEA World Energy Statistics and Balances (database), www.iea.org/statistics.

International Energy Agency. (2021). *Global Hydrogen Review*. https://www.iea.org/reports/global-hydrogen-review-2021

International Law Association. (2014). Washington Conference, *The Legal Principles Relating to Climate Change.* http://www.ila-hq.org/download.cfm/docid/2FE72F08-8E2B-4D98-9259BF3060AC0B3B, page 16.

Johannesburg Declaration on Sustainable Development. (2002). U.N. Doc. A/CONF.199/20. 23.

Joint NGO letter. (2021). *The hydrogen and gas decarbonisation package under publication needs to improve*. https://ecostandard.org/wp-content/uploads/2021/12/COM-Letter_improving-gas-package-1.pdf

Kart, A.Ş. & Gökalp, İ. (2021). *Decarbonizing with hydrogen and precautionary regulating: what energy sciences and policy & law studies have to say in common.* 10th European Combustion Meeting, Apr 2021, Naples (Virtual), Italy.

Kurmayer, N.J. (2021). The lesser-known hydrogen roadblock: safety concerns. *EURACTIV*. https://www.euractiv.com/section/energy/news/the-lesser-known-hydrogen-roadblock-safety-concerns/

Kysar, D. A. & Salzman; J. (2008). Making Sense of Information for Environmental Protection, *Texas Law Review*, Vol. 86, No 7.

Kyoto Protocol. (2005). https://unfccc.int/resource/docs/convkp/kpeng.pdf

Lascoumes, P. (1997). La précaution: Un nouveau standard de jugement. *Esprit* (November): 129–140.

Law, J., Martin, E. A. (2009). *A Dictionary of Law* 7th ed. Oxford University Press. https://doi.org//10.1093/acref/9780199551248.001.0001.

Löfstedt, R. E. (2004). The Swing of the Regulatory Pendulum in Europe: From Precautionary Principle to (Regulatory) Impact Analysis. *The Journal of Risk and Uncertainty* 28(3): 237–60. https://doi.org/10.1023/B:RISK.0000026097.72268.8d

Marong, A.B.M. (2003). From Rio to Johannesburg: Reflections on the Role of International Legal Norms in Sustainable Development", *Georgetown International Environmental Law Review*, vol. 16: 21-31.

Montreal Protocol on Substances that Deplete the Ozone, Final Act. (1987, September 16). *International Legal Materials*, vol. 26, p. 1541.

Neuymayer, E. (1999). *Weak versus Strong Sustainability – Exploring the Limits of Two Opposing Paradigms*. Edward Elgar, Cheltenham, UK/Northampton, MA, USA.

Official Gazette. (2006). 9th Development Plan. https://www.sbb.gov.tr/wp-content/uploads/2021/12/Dokuzuncu_Kalkinma_Plani-2007-2013.pdf.

Parke, E. C., & Bedau, M. A. (2009). The precautionary principle and its critics. Cambridge, MA: MIT Press.

Pascal, B. (1910). *Pensées (Thoughts).* In: Charles W.E. (Ed.). The Harvard Classics, vol. 48 (1st Edition - 1660). P. F. Collier & Son, New York, (Translation: W. F. Trotter).

Pelkmans, J. & Renda, A. (2014, July). *How Can EU Legislation Enable and/or Disable Innovation?* Report by European Commission. https://ec.europa.eu/futurium/en/system/files/ged/39-how_can_eu_legislation_enable_and-or_disable_innovation.pdf

Pesendorfer, D. (2014). *Converging ideas about risk regulation? The precautionary principle in national legal systems*. In H. Jörgens, A. Lenschow, & D. Liefferink (Eds.), Understanding Environmental Policy Convergence: The Power of Words, Rules and Money (pp. 209-236). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139795357.008

Peterson, M. (2017). The ethics of technology: A geometric analysis of five moral principles. New York, NY: Oxford University Press.

Porter, M. and Kramer, M. (2006). *Strategy and society: the link between competitive advantage and corporate social responsibility*. Harvard Business Review, December Issue.

Presidency of the Republic of Turkey Presidency of Strategy and Budget. (2019). *11th Development Plan.* https://www.sbb.gov.tr/wp-content/uploads/2021/12/Eleventh_Development_Plan_2019-2023.pdf

Protocol To The 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions 14 June 1994. https://treaties.un.org/doc/Treaties/1994/06/19940614%2004-27%20PM/Ch_XXVII_01_ep.pdf

Read, R. & O'Riordan, T. (2017). The Precautionary Principle Under Fire. *Environment: Science and Policy for Sustainable Development*, 59(5), 4-15. https://doi.org/10.1080/00139157.2017.1350005

Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean 2018 https://repositorio.cepal.org/bitstream/handle/11362/43583/1/S1800428_en.pdf

Regulation (EU) 2021/695 of the European Parliament and of the Council of 28 April 2021 establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, and repealing Regulations (EU) No 1290/2013 and (EU) No 1291/2013 http://data.europa.eu/eli/ reg/2021/695/oj

Rehn, O. (2008). *A stronger Europe through deepening and widening*. European Commission, 8(184), 1-5. https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_08_184

Renda, A. (2017). *How can Sustainable Development Goals be 'mainstreamed' in the EU's Better Regulation Agenda?,* CEPS Policy Insights, 2017/12. http://aei.pitt.edu/85601/1/Better_regulation_and_sustainable_development_CEPS_Policy_Insights__A_Renda.pdf

Republic of Turkey Ministry of Development. (2015). *10th Development Plan Mining Policies Specialization Commission Report*. https://www.sbb.gov.tr/wp-content/uploads/ 2018/10/10_MadencilikPolitikalari.pdf.

Republic of Turkey Ministry of Energy and Natural Resources. (2021, September 16). *Energy Exploration Activities and Documentation*. https://enerji.gov.tr/bilgi-merkezi-enerjide-arama-etkinlikleri-ve-belgeler

Republic of Turkey Ministry of Energy and Natural Resources. (n.d.). *2019-2023 Strategic Plan*. https://sp.enerji.gov.tr/dergi/index.html

Republic of Turkey Ministry of Environment and Forestry. (2007). *First National Communication on Climate Change under the UN Framework Convention on Climate Change*. http://www.surdurulebilirkalkinma.gov.tr/wp-content/uploads/2016/07/turnc1.pdf

Republic of Turkey Presidency Strategy and Budget Department. (2021). *On Birinci Kalkınma Planı*. https://www.sbb.gov.tr/wp-content/uploads/2019/07/OnbirinciKalkinmaPla- ni.pdf.

Republic of Turkey Presidency Strategy and Budget Department. (n.d.). *Annual Programs*. https://www.sbb.gov.tr/yillik-programlar/

Republic of Turkey State Planning Organization. (2018). *11th Development Plan, Mining Specialization Commission*. https://www.sbb.gov.tr/wpcontent/uploads/2018/11/09MadencilikMadenci-lik.pdf.

Republic of Turkey State Planning Organization. (2009). *9th Development Plan Mining Specialization Commission.* https://www.sbb.gov.tr/wp-content/uploads/2018/11/09 Madencilik_Enerji-HammaddeleriLinyit-Ta%C5%9Fk%C3%B6m%C3%BCr%C3 %BC-Jeotermal.pdf.

Rio Declaration on Environment and Development. (1992). Rio de Janeiro, 3-14 June 1992. U.N.Doc.A/CONF.151/26.https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf

Rockwood, L. L, Stewart, R. E. & Dietz, T. (2008). *Foundations of environmental sustainability: the coevolution of science and policy.* Oxford University Press, Inc.

Sachs, N. M. (2011). Rescuing the Strong Precautionary Principle from its Critics. *University of Illinois Law Review* 2011: 1285–1338.

Saltelli, A. Dankel, D. J., Fiore, M.D., Holland, N. & Pigeon, M. (2022). Science, the endless frontier of regulatory capture, *Futures*, Volume 135. https://doi.org/10.1016/j.futures.2021.102860.

Salter, M and Mason, J. (2007). *Writing Law Dissertations: An Introduction and Guide to the Conduct of Legal Research*. Pearson

Sandin, P. & Peterson, M. (2019). Is the Precautionary Principle a Midlevel Principle? *Ethics, Policy & Environment*, 22:1, 34-48. https://doi.org/10.1080/21550085.2019.1581417

Sandin, P., Peterson, M., Hansson, S. O., Rudén, C., & Juthe, A. (2002). Five charges against the precautionary principle. *Journal of Risk Research,* 5, 287–299.

Sands, P. & Peel, J. (Eds). (2012). *Principles of international environmental law, third edition*. Cambridge University Press.

SHURA. (2021). *Türkiye'nin Ulusal Hidrojen Stratejisi için Öncelik Alanları*.. https://www.shura.org.tr/wp-content/uploads/2021/03/Turkiyenin_ulusal_hidrojen_ stratejisi_icin_oncelik_alanlari.pdf

SHURA. (2022). *Türkiye'nin yeşil hidrojen üretim ve ihracat potansiyelinin teknik ve ekonomik açıdan değerlendirilmesi*. https://shura.org.tr/wp-content/uploads/2022/ 01/rapor_TR-.pdf

Smith, K. E., Fooks, G., Gilmore, A. B., Collin, J., & Weishaar, H. (2015). Corporate coalitions and policy making in the European Union: how and why British American Tobacco promoted "Better Regulation". *Journal of health politics, policy and law*, 40(2), 325–372. https://doi.org/10.1215/03616878-2882231

Smith, K. E., Fooks, G., Collin, J., Weishaar, H., Mandal, S. & Gilmore, A. B. (2010). "Working the System"- British American Tobacco's Influence on the European Union Treaty and Its Implications for Policy: An Analysis of Internal Tobacco Industry Documents. *PLoS medicine*, 7(1). ISSN 1549-1277. https://doi.org/10.1371/journal.pmed.1000202

Söğüt, İ. S. (2014). *Roma Hukukunda Çevrenin Korunmasına İlişkin Hukuki Vasıtalar*. On İki Levha Yayıncılık.

Som, C., Hilty, L.M., Kohler, A.R. (2009). The precautionary principle as a framework for a sustainable information society. *Journal of Business Ethics*, 85, p.493-505. https://doi.org/10.1007/s10551-009-0214-x

Steel, D. (2015). *Philosophy of the Precautionary Principle*. Cambridge University Press.

Stirling A. (2007). Risk, precaution and science: towards a more constructive policy debate. Talking point on the precautionary principle. *EMBO reports*, III 8(4), 309–315. https://doi.org/10.1038/sj.embor.7400953

Taffoni, G. (2020). Regulating for Innovation? Insights from the Finnish Presidency of the Council of the European Union. *European Journal of Risk Regulation*, 11(1), p.141-147. https://doi.org/10.1017/err.2020.7

Thireau, J-L. (1993). La doctrine civiliste avant le Code civil in Y Poirmeur et al, La doctrine juridique (Paris, Presses Universitaires de France) 13–51.

Thomas, S. (1994). Artifactual study in the analysis of culture: A defense of content analysis in a postmodern age. *Communication Research,* 21(6), 683-697.

Tickner et al. (1999). *The Precautionary Principle in Action: A Handbook*. Windsor, ND: Science and Environmental Health Network.

Trouwborst, A. (2006). Precautionary Rights and Duties of States. *Nova et Vetera Iuris Gentium*, 25. Martinus Nijhoff Publishers. ISBN: 978-90-04-15212-0

U.S. Department of Energy. (2020, December). *Energy Storage Grand Challenge: Energy Storage Market Report.* https://www.energy.gov/sites/default/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf

U.S. Environmental Protection Agency. (2015). *Updating ozone calculations and emissions profiles for use in the atmospheric and health effects framework model.* www.epa.gov/sites/production/files/2015-07/documents/_ozone_calculations_and_ emissions_profiles_for_use_in_the_atmospheric_and_health_effects_framework_model.pdf

UN Environment Program. (n.d.). *About Montreal Protocol*. https://www.unep.org/ozonaction/who-we are/about-montreal-protocol

Underwood, A. J., (1997). Environmental decision-making and the precautionary principle: what does this principle mean in environmental sampling practice? *Landscape and Urban Planning*, 37 (3–4), p.137-146. https://doi.org/10.1016/S0169-2046(97)80000-X.

UNDP Montreal Protocol/Chemicals Unit. (2017). *Past successes and future opportunities* case studies from the UNDP portfolio and innovative approaches to cooling without warming. https://www.agora-parl.org/sites/default/files/agora-documents/Past%20Successes%20and%20Future%20Opportunities%20-%20Case%20Studies%20From%20the%20UNDP%20Portfolio%20and%20Innovative%20Approaches%20to%20Cooling%20Without%20Warming.pdf

UNEP. (n.d.). *The Montreal Protocol*. https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

UNIDO. (n.d.). *The Montreal Protocol Evolves to Fight Climate Change*. https://www.unido.org/sites/default/files/2017-07/UNIDOleaflet07MontrealProtocol Evolves170126_0.pdf

United Nations Framework Convention on Climate Change 1992 https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

United Nations General Assembly. (1982). World Charter for Nature. A/RES/37/7, 48th plenary meeting, 28.10.1982. https://www.un.org/documents/ga/res/37/a37r007.htm

United Nations General Assembly. (n.d.) Rio Declaration on Environment and Development. Annex I of the Report of The United Nations Conference on Environment and Development. A/CONF.151/26 (Vol. I), 12.08.1992. https://www.un.org/ documents/ ga/conf151/aconf15126-1annex1.htm

United Nations Industrial Development Organization. (2011, October 7). *First hydrogen energy production on a Turkish Island has started on Bozcaada*. https://www.unido.org/news/first-hydrogen-energy-production-turkish-island-has-started-bozcaada

Vick, D. W. (2004). Interdisciplinarity and the Discipline of Law. *Journal of Law and Society*, June 2004, Vol. 31, No. 2, pp. 163-193.Wiley on behalf of Cardiff University https://www.jstor.org/stable/1410523

Vogel, D. (2012). *The Politics of Precaution: Regulating Health, Safety, and Environmental Risks in Europe and the United States*. Princeton; Oxford: Princeton University Press.

Weber, R. P. (1990). *Basic content analysis*, second edition. Newbury Park, CA: Sage Publications.

Whiteside, K. (2016). *Precautionary Politics: Principle and Practice in Confronting Environmental Risk*. Cambridge, Ma: MIT Press

White & Case. (2022, April). *Global Hydrogen Guide: Emerging Policy & Regulatory Initiatives.* https://www.whitecase.com/sites/default/files/2022-04/global-hydrogen-guide-2nd-edition.pdf

Wiener, J. B. (2007). Precaution, in Bodansky, D., Brunnée, J., & Hey, E. (Eds.). *The Oxford Handbook of International Environmental Law*. Oxford University Press.

Yale University. (2015). *Oslo Principles on Global Climate Change Obligations*. ed. Pogge, T., Spier, J. http://global justice.macmillan.yale.edu/sites/default/files/files/Oslo Principles.pdf.

Zoroddu, M. A., Aashet, J., Crisponi, G., Medici, S., Peana, M. & Nurchi, V. M. (2019). The essential metals for humans: a brief overview. *Journal of Inorganic Biochemistry*, 195, 120-129. doi:10.1016/j.jinorgbio.2019.03.013.

APPENDICES

A. CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Kart, Ayşe Şehnaz
Nationality: Turkish (TC)
Date and Place of Birth: January 23rd, 1988 , Konya
Marital Status: Single
Phone: +90 505 683 34 34
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EDUCATION

Degree	Institution	Year of Graduation
M.Sc.	METU Science and Technology Policy Studies	2022
LLM.	Galatasaray University Law Faculty	2015
High School	Istanbul American Robert College	2006

WORK EXPERIENCE

May 2020 – May 2022	The Scientific and Technological Research Council of Turkey (TÜBİTAK) Project Researcher at the International Fellowship for Outstanding Researchers Program.

Apr 2021 – Present	İYEV (Foundation for the Second Centennial Institute) President of the Supervisory Board and Founding Member of the Board of Trustees. Ankara, Turkey.
Jan 17 – Present	Lawyer registered to Istanbul Bar Association. Partner at Kart Law Offices. Ankara, Turkey.
Apr 16 – Present	Certified Translator, Sworn at Istanbul Beyoğlu 17th Notary from/to Turkish, English and French.
Oct 11 – Oct 13	Research assistant to the former Member of Parliament, Atilla Kart (CHP Konya), for the Turkish Grand National Assembly, Conciliatory Commission for Turkish Constitution.

FOREIGN LANGUAGES

Advanced English, Fluent French, Elementary Latin

SCIENTIFIC PUBLICATIONS

Online Publications

1. Kart, A.Ş. & Gökalp, İ. (2022). *Hidrojenle Karbonsuzlaştırma: Teknik, Ekonomik ve Hukuksal Boyutların Çatışması*, STS Turkey Book, Ankara. (*in final review process*).

2. TTGV & METU TEKPOL (2021). *Research and Innovation Outlook of Turkey RIOT 2020.* (TTGV Policy Level Publication. RIOT aims to shed light on all aspects of science, technology and innovation (STI) policies in Turkey between 2015-2020. Regulatory and legal part of the report undertaken as well as a subchapter on talent drain. https://www.ttgv.org.tr/tur/images/publications/616d3c9738fea.pdf

3. Kart, A.Ş. & Gökalp, İ. (2021). *Decarbonizing with hydrogen and precautionary regulating: What energy sciences, policy and legal studies have to say in common.* 10th European Combustion Meeting Conference Booklet https://hal.archives-ouvertes.fr/hal-03192621

Conference Booklets and Presentations

1. Kart, A. Ş. (2021). STS TURKEY 2021 Conference, Ankara. Nov. 22-24th, 2021, Online. *COVID-19 Aşıları Özelinde Bilim Hakkı ve Fikri Mülkiyet Rejimi Çatışmasının Güncelliği Üzerine* p. 17-18. (*A Reflection on the Conflict of the Right to Science and Culture with the Current Intellectual Property Regime: COVID-19 Vaccines as Case Study*).

http://ststurkey.net/wp-content/uploads/2021/11/STSTURKEY21-bildiri-kitapc%CC%A7%C4%B1k.pdf

2. Kart, A.Ş. & Gökalp, İ. (2021). *Hidrojenle Karbonsuzlaştırma: Teknik, Ekonomik ve Hukuksal Boyutların Çatışması.* STS TURKEY 2021 Conference, Ankara. Nov. 22-24th, 2021, Online. p. 27-30. (*Decarbonization by Hydrogen: Intersections of Technical, Economic and Legal Aspects*).
http://ststurkey.net/wp-content/uploads/2021/11/STSTURKEY21-bildiri-kitapc%CC%A7%C4%B1k.pdf

3. Kart, A.Ş. (2021). *Just And Safe Energy Relations: Unfolding the Precautionary Principle with the Advent of Hydrogen Technologies.* Society for Social Studies of Science (4S) Conference, Toronto. Oct. 6th, 2021, Online.

4. Kart, A.Ş. & Gökalp, İ. (2021). *Decarbonizing with hydrogen and precautionary regulating: What energy sciences, policy and legal studies have to say in common.* European Combustion Meeting, Novel concepts, technologies and systems #1, Poster session #10. Naples. April 14th, 2021, Online.

5. Kart, A. Ş. (2020). *A Preliminary Analysis of the Turkish Hydrogen Legal Landscape* Kadir Has University Center for Energy and Sustainable Development 3rd Graduate Student Conference on Energy and Sustainable Development, İstanbul. Nov 17th, 2020, Online. min: 1:02:30- 1:33:00

https://www.youtube.com/watch?v=5E5h6Xc6zJM&ab_channel=KHASCESDEnerjiveS%C3%BCrd%C3%BCr%C3%BClebilirKalk%C4%B1nmaMerkezi

6. Kart, A.Ş. & Gökalp, İ. (2020). *A Preliminary Analysis of the Turkish Hydrogen Legal Landscape*. GSCESD-2020 Conference Booklet, p.10-11. https://cesd.khas.edu.tr/tr/gscesd

7. Kart, A.Ş. (2020). *The Absence of a Justice Matrix in Japan's STI for SDGs Policy: Society 5.0*. Society for Social Studies of Science (4S) EASST 2020 Conference. August 21st, 2020, Online.

HOBBIES

Travelling, swimming, activities in nature, enjoying music, dancing

B. TURKISH SUMMARY / TÜRKÇE ÖZET

Geniş ölçekli enerji sistemlerinin sosyo-teknik değişim süreçleri, iklim krizinin de etkisiyle bugün her zamankinden daha güncel ve acil hale gelmiştir. Fosil yakıt sonrası dünya, karbonsuz enerji sistemlerini hedeflediği için, günümüzde hidrojen benzeri olmayan bir ilgi görmektedir. Evrenin kadim ve ilk sakinlerinden olan hidrojen, enerji dönüşümü, yeşil enerji, sürdürülebilirlik gibi tartışmalar söz konusu olduğunda, iddialı bir oyuncu olarak sahnede yerini almaktadır.

Hidrojenin bu denli gündemde olmasının sebeplerinden biri olarak, Paris İklim Anlaşması ve net sıfır karbon hedeflerine hidrojen sisteme dahil olmadan, mevcut yenilenebilir enerji kaynaklarıyla ulaşılamaması gösterilebilir. Yenilenebilir enerji kaynaklarında fosil yakıtlardaki gibi 'base load' yani sürekli enerji emre amadeliği kavramı geçerli değildir. Bu enerji kaynaklarının küresel dağılımı fosil kaynaklara göre daha dengeli olmasına karşın, aralıklı-kesintili olmaları bir dezavantaj teşkil etmektedir. Emre amadelik ve kapasite faktörü sorunları mevcuttur. Dolayısıyla yenilenebilir enerjilerden üretilen elektrik ve ısı için depolama sorunu söz konusudur. "Bir enerji taşıyıcısı olarak hidrojen mevzuu" tam olarak burada devreye girmektedir. Pek çok ülke ve yatırımcı, hidrojenin potansiyelini yenilenebilir enerjilerin sürekliliğini sağlamaya ciddi katkılar sunabilecek nitelikte görmekte ve bu yönde somut adımlar atmaktadır.

Evrende en yaygın bulunan kimyasal madde olan hidrojen, helyum ve lityum gazlarıyla beraber evrenin ilk bileşenlerinden olup, yaklaşık olarak 13,8 milyar yaşındadır. İnsan vücudunun yüzde 9'u da hidrojenden oluşmaktadır. Ancak evrenin oluşumundan beri moleküler yapısını koruyan hidrojen molekülüne büyük yeni görevler yüklenmektedir. Bu yeniliğin çok çeşitli sebepleri vardır.

Ana sebep, nasıl ürettiğimize bağlı olmak kaydıyla, hidrojenin temiz bir yakıt/enerji taşıyıcısı olmasıdır. Hidrojenin termokimyasal süreçlerle ısıya dönüştürülmesinin (yanma) yan ürünü yalnızca su buharıdır. Hidrojenin elektrokimyasal süreçlerle elektriğe ve ısıya dönüştürülmesinin (yakıt pilleri) yan ürünü de yine yalnızca sudur. Yani yeşil hidrojen faydalı enerjiye dönüştürülürken sıfır zararlı kirletici üretmektedir. Sıfır karbon monoksit, sıfır azot oksitler, sıfır kükürt dioksit, sıfır partikül madde söz konusudur.[7]

İkincil olarak, hidrojene yüklenen yeni görevler onun döngüsel ekonomi için mükemmel bir örnek teşkil etmesiyle açıklanabilir. 1 metreküp su 1000 kilogramdır ve bunun 111 kilogramı hidrojen, gerisi oksijendir. Hidrojenin elektroliz yöntemiyle sudan temiz bir şekilde üretildiği senaryoda, hidrojen faydalı enerjiye dönüştürüldüğünde, yakılarak veya yakıt pillerinde, kendi kaynağını, yani su üretmektedir. Ayrıca hidrojen çeşitli teknolojilerle organik atıklardan da üretilebilmektedir. Böylece temiz hidrojen, çevresel sorunları atıkları bertaraf ederek çözdüğü gibi, enerji sorununun çözümüne da katkı vermektedir.

Üçüncül olarak, "elektriğin gaz hali" olan düşünülebilecek hidrojen, sektörel entegrasyonu da mümkün kılmaktadır. Hidrojenin enerji sisteminin her sektörüne erişme ve entegre olma yeteneği, yenilenebilir enerjileri çok daha büyük ölçekte dağıtma ve kullanma fırsatları sunar. Yenilenebilir enerjilerden elde edilen elektrik, enerji sektörüne ciddi bir karbonsuzlaştırma imkânı sağlarken; endüstri, ısı ve ulaştırma sektörlerinin henüz benzer karbonsuzlaştırma imkanları yoktur. Hidrojenin çok yönlülüğü, bu sektörlerin ileri derecede karbonsuzlaştırlmasını ve enerji dönüşümüne katkıda bulunmalarını sağlar.

Özetle, hidrojen geniş ölçekli enerji sosyo-teknik sistemine eklemlenirken pek çok açıdan muhtemel katkıları ve avantajları söz konusudur. Öncelikle hidrojeni üretme kaynakları çeşitlidir (su, organik atıklar, kömür/linyit, doğalgaz) ve bu kaynaklara ulaşılabilirlik yüksektir. Yine üretim yöntemleri (elektroliz, katı yakıt gazlaştırması, biyokütle fermantasyonu, piroliz, hidrotermal süreçler vb.) çeşitlidir. Kullanılabilir enerjiye dönüştürülmesi temizdir ve daha da ötesi hidrojen kendi kaynağını ürettiğinden döngüsel ekonomi için iyi bir örnek teşkil etmektedir. Kilogram başına enerji yoğunluğu yüksektir. Bölgesel/yerel, dağıtık/çok merkezli enerji sistemleri için uygundur.

[7] Bu ve takip eden iki paragraf ODTÜ Bilim ve Teknoloji Politikaları Anabilim Dalı'nda Bahar 2020-2021 Döneminde verilen STPS 545 kodlu ders kapsamında Prof. Dr. İskender Gökalp tarafından verilen seminerlerin notlarından derlenmiştir.

1. Hidrojenle Karbonsuzlaştırmanın Ekonomisine ve Politikalarına Genel Bakış

Enerji sistemlerinin karmaşık toplumsal-teknik sistemler olduğunun, enerji bilim ve teknolojilerinin savunma, havacılık ve uzay teknolojileri ile büyük ölçüde örtüştüğünün farkında olan, döngüsel sürdürülebilir enerji ve ekonomi sistemini hedefleyen ülke ve yatırımcılar; kaynak ve teknoloji bağımsızlığı sorununa çözüm içeren, çevre ve atık sorununa çözümler üreten, yenilikçi enerji ve çevre teknolojilerine kapı açan, yenilenebilir enerji teknolojilerine geçişi hızlandıran hidrojen teknolojilerini son yıllarda iyiden iyiye artan bir hızla gündemlerine almışlardır.

Büyük çokuluslu şirketler, yenilikçi KOBİ'ler ve yatırımcılar dahil olmak üzere 20'den fazla ülkede ve tüm hidrojen değer zincirinde bulunan 123 şirketten oluşan bir grubu bir araya getiren Hydrogen Council’in Hydrogen Insights 2021 Raporu’nda (bundan böyle “rapor” olarak anılacaktır), hidrojen değer zincirinin mevcut ekonomik ve hukuki durumuna dair birtakım önemli bulgular yer almaktadır (Hydrogen Council, 2021). Bu bulgulardan bir kısmı, hidrojen değer zincirinin mevcut durumu ile ilgili detaylı bilgiler vermektedir.

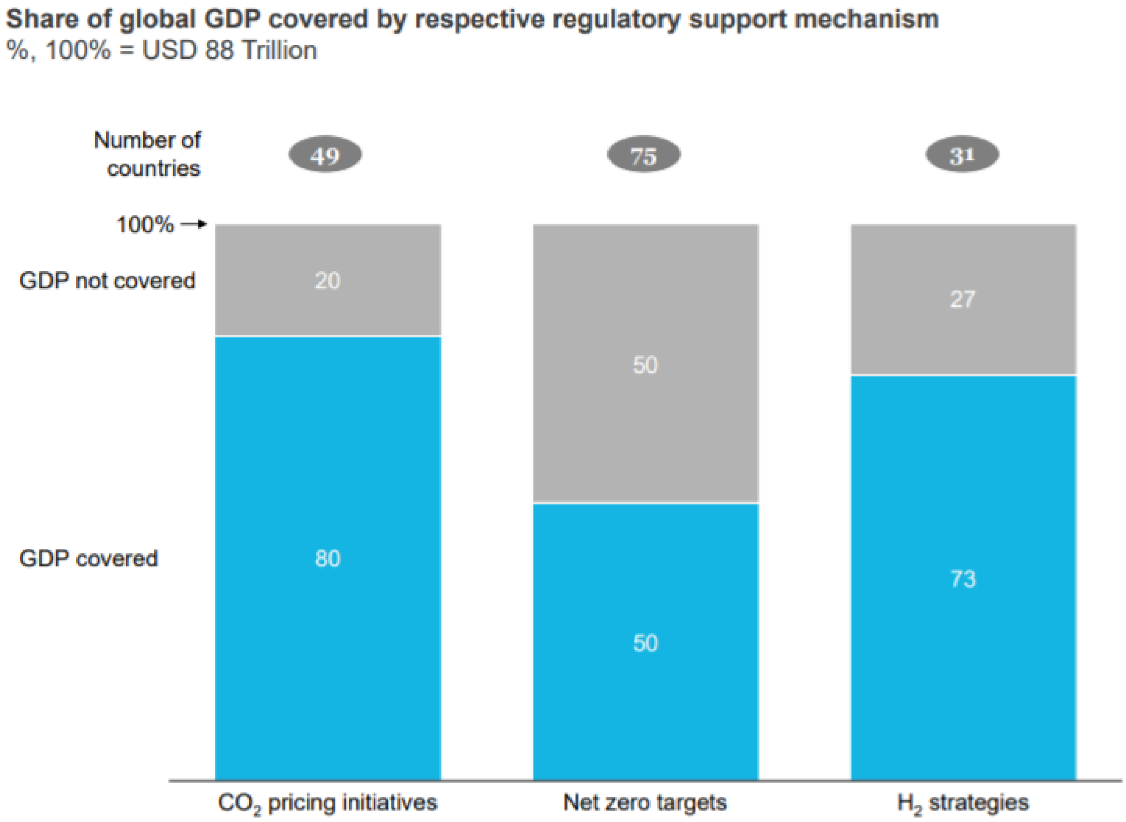
Rapor, değer zincirinde 2021 itibariyle 228 ilan edilmiş proje tespit etmiştir. Projelerden 17’si giga düzeydedir (giga düzey: yenilenebilir hidrojen için 1 GW elektrik ve fazlası güç ve düşük karbonlu hidrojen için yılda 200.000 tonun üzerinde). Bu projeler 6 kıtaya yayılmakla birlikte, yüzde 55 gibi baskın bir oranla başı Avrupa kıtası çekmektedir[8]. Raporda, 2030 yılına kadar hidrojen projelerine yapılacak yaklaşık 80 milyar ABD doları kesin yatırım, ayrıca 262 milyar ABD doları ise ilan edilmiş yatırım tespit edilmiştir. Ayrıca, ilan edilmiş temiz hidrojen üretim kapasitelerine dair 2019 ve 2020 yılları arasında bir karşılaştırma da mevcuttur. 2019 projeksiyonlarına göre, 2,3 milyon ton olan bu kapasite, 2020 projeksiyonlarına göre 6.7 milyon ton olarak tespit edilmiştir. Bir yıl süresinde gerçekleşen bu yüzde 300’e yakın sıçrama, hidrojen ekonomisinin büyük bir hızla ivmelendiğine işaret etmektedir. Çarpıcı bir bulgu olarak, hidrojen üretim maliyetlerinin 2020’ye kıyasla 2030’da

[8] Bu makalenin ileri bölümlerindeki değerlendirmeler hem bu sebeple hem de ihtiyat ilkesinin Avrupa menşei sebebiyle, Avrupa Birliği kapsamıyla sınırlı tutulmuştur.

yüzde 62 daha düşük olacağı öngörülmektedir (H.C., 2021, sf. 6-9). Maliyetler düştükçe üretim kapasitesinin artması kaçınılmazdır.

Yeşil dönüşüm ve karbonsuzlaştırmaya yönelik çalışmalar ve bu çalışmalar içinde hidrojenin yeri her geçen gün önem kazanmaktadır. Dünya gayri safi hasılasının (GSH) önemli bir bölümünü temsil eden onlarca ülke hem karbon fiyatları, hem net sıfır karbon hedefleri, hem de hidrojen stratejileri belirlemekte ve uygulamaktadırlar. Rapordan alınan Şekil 1'den de görüleceği üzere, dünya GSH'sının yüzde 73'ünü temsil eden 31 ülke, ulusal hidrojen stratejileri oluşturmuş vaziyettedir.

Şekil 1: Hidrojen ve yeşil regülasyon



10'a yakın ülkede de bu yönde çalışmalar devam etmektedir. Ulusal hidrojen stratejisi geliştiren ülkelerin sayısı görece az olsa dahi, bu ülkelerin ekonomik gücü, hidrojenin önümüzdeki dönemdeki özgül ağırlığını artırmaktadır. Ayrıca raporda, 75 ülkenin net sıfır karbon hedefi koyduğu gözlemlenmektedir. Bu ülkelerden, ulusal hidrojen stratejisi olmayanların net sıfır karbon hedeflerinde de hidrojen önemli bir unsur olarak yer almaktadır.

Bir diğer kaynak olan, Avrupa Komisyonu Ortak Araştırma Merkezi Hidrojen Çalışması'nda (kamuya açık sürüm) çeşitli kurum ve kuruluşların AB (Avrupa Birliği) karbonsuzlaştırma senaryoları bir arada değerlendirilmiştir (Avrupa Komisyonu Ortak Araştırma Merkezi, 2019). Bulgulara göre, çoğu senaryoda, hidrojen ve türevi yakıtlar 2050 AB nihai enerji tüketiminin yüzde 10 ila yüzde 23'ünü oluşturmaktadır. Hidrojenle ilgili bir diğer önemli kaynak olan Avrupa Hidrojen Yol Haritası ise, 2050 yılına kadar hidrojenle ilişkili 5,4 milyon iş yaratılabileceğini öngörmektedir (Avrupa Komisyonu, 2019). Bu sayı, bugün AB kimya endüstrisindeki istihdamın 3 katına eşdeğerdir.

Uluslararası Enerji Ajansı'nın Küresel Hidrojen İncelemesi isimli çalışmasına göre, ulusal hidrojen stratejilerinde 2030'a kadar Fransa 7,2 milyar €, Almanya 9 milyar €, İspanya 1,6 milyar € ve Portekiz 900 milyon € kamu yatırımı taahhüt etmişlerdir. Ulusal taahhütlerin yanı sıra, AB Hidrojen Stratejisi 2030'a kadar Birlik çapında 3,77 milyar € kamu yatırımı taahhüdünde bulunmuştur. Bu yatırımın 1 milyar €'su Ar-Ge çalışmalarına tahsis edilmiştir (Uluslararası Enerji Ajansı, 2021, sf. 27-29).

Hidrojen Risk Zinciri

Hidrojen değer zinciri günümüzde, şimdiye kadar hiç olmadığı kadar hareketlidir ve çeşitli verilere dayanarak bu hareketliliğin artarak süreklilik arz edeceği rahatlıkla söylenebilir. Hidrojenin, küresel ve ülkeler arası enerji kaynaklı çekişmeleri azaltma, çevresel kirlilik ve sağlık sorunlarına çözüm olma, devasa altyapı gereksinimlerini en aza indirme potansiyeli mevcuttur. Ancak hukukta olduğu gibi burada da bir nimet-külfet dengesi söz konusudur. Hidrojen tatsız, kokusuz, renksiz ve çok kolay tutuşabilir bir madde olduğundan çok tehlikeli bir gazdır. Pozitif bilimcilerin tabiriyle, bu "yaramaz gaz"ı fiziksel ve kimyasal özelliklerinden kaynaklanan risk potansiyelini en aza indirerek kullanmak mecburiyeti vardır.

Bir STS (Science, Technology and Society- Bilim, Teknoloji ve Toplum) yaklaşımı olan bu çalışma özelinde, bu risklerin teknik detaylarına inmeden, doğalgazda en yoğun bileşen olarak (%85-98) bulunan gaz olan metan gazıyla basit bir karşılaştırma yapmak suretiyle, hidrojenin olası riskleri değerlendirilmiştir. Minimum parlama enerjisi hidrojen için metana göre son derece düşüktür ve bu özellik gazın en ufak bir tetiklenmede alev alabileceğini gösterir. Hava içinde tutuşma-yanma sınırları ise hidrojen için son derece geniştir. Alev yanma hızı metana göre neredeyse on kat daha fazladır, yani bir kere tutuştuğu takdirde alev son derece hızla ilerleyebilmektedir. Alevin geri tepme riski oldukça yüksek olup bu durum yangın riskini önemli ölçüde artırmaktadır. Ayrıca metaller dahil tüm malzemelere nüfuz etme-gevrekleştirme potansiyeli de oldukça yüksektir, dolayısıyla hidrojenin taşınmasında güçlükler doğmaktadır.

Avrupa Komisyonu, çelik, çimento gibi ağır sanayileri karbondan arındırmak ve AB'nin 2050 iklim tarafsızlığı hedefine ulaşmasına yardımcı olmak için temiz hidrojeni "bulmacanın hayati bir eksik parçası" olarak görmektedir. Fakat emniyet açısından hidrojenin taşıma ve kullanımının sıkı protokollere tabi olması gerekmektedir. Hidrojenin yüksek yanıcılığı, AB yasa yapıcılarını, bu gazın potansiyel güvenlik sorunlarının hidrojenin pazarda tutunmasını engellememesini temin etmeye teşvik etmiştir. Yine de yasa yapıcılar arasında önemli fikir ayrılıkları bulunmaktadır.

Avrupa Parlamentosu'ndaki merkez sağ grup olan Avrupa Halk Partisi'ne mensup (European Public Party-EPP) Alman Milletvekili Angelika Niebler, AB hidrojen ekonomisinin başarılı bir şekilde gelişmesi için yüksek güvenlik standartlarının oluşturulması gereğini vurgularken; EURACTIV'e verdiği demeçte, "Şayet onlara güveneceksek, teknolojilerin önce güvenli olması gerektiğini" söylemiştir (Kurmayer, 2021). Niebler, Avrupa Komisyonu'nun 2020 Temmuz ayında sunduğu taslak hidrojen stratejisine ilişkin AB parlamentosu raporunu hazırlayan milletvekillerinden biridir. AB'ye, hidrojen değer zincirinde güçlü bir güvenlik kültürünü teşvik etmek için önlemler alınması çağrısında bulunan raporda, "Halkın kabulünün hidrojen ekonomisinin başarılı bir şekilde yaratılmasının anahtarı olduğuna" Avrupa Parlamentosu'nun kuvvetle inandığı ifade edilmektedir (Avrupa Parlamentosu, 2021). Öte yandan, bazı diğer AB milletvekilleri daha az endişeli görünmektedir. Parlamento raporunun baş yazarı olan Sosyalistler ve Demokratlar'dan (S&D) bir Alman Milletvekili Jens Geier, EURACTIV'e verdiği demeçte, "Endüstri on yıllardır hidrojen üretiyor ve işliyor. Bu nedenle, hidrojen kullanımıyla ilgili güvenlik ve güvenlik standartları uzmanlığı zaten var" diyerek, yeni ve farklı tedbirlerin değerlendirilmesine gerek olmadığını belirtmiştir (Kurmayer, 2021).

Hidrojenin üretimi ve kullanımı yeni bir teknoloji değildir ve riskleri de bilinmektedir. Yüksek yanıcılığı, hidrojen bombası ve 1937 yılında Almanya'daki bir hava gösterisi sırasında alevler içinde patlayışı kameralara yakalanan ünlü zeplin Hindenburg felaketi ile olan ilişkisi nedeniyle imaj sorunlarından muzdariptir. Ayrıca, 2011'de Japonya Fukuşima'da gerçekleşen felaketteki patlama, hidrojen oluşmasından kaynaklıdır. Patlamada 3 nükleer reaktör binası zarar görmüştür. Ancak hidrojenin yeni fonksiyonu enerji taşıyıcılığının öne çıktığı günümüzde, güvenlik 'kamuoyu kabulü"nden öteye giderek, daha bütüncül ele alınması gereken bir sorundur. Zira hidrojen değer zincirinin aşağıda belirtilen tüm halkalarında (üretim, iletim/dağıtım, depolama, enerji dönüşüm) sızıntı, yangın ve patlama riskleri mevcuttur (Gökalp, 2021).

Bu riskler soyut riskler değildir. Her ne kadar Avrupa Parlamentosu'nda ortak bir hidrojen güvenliği anlayışı halen tartışılmakta olsa da; sanayinin karbondan arındırılmasında hidrojenin önemini de göz önüne alarak, AB politika yapıcıları hidrojen üretimi, taşınması ve kullanımının mümkün olduğunca güvenli tutulmasını sağlamak için çeşitli girişimler başlatmışlardır. Avrupa Komisyonu, hidrojen güvenliğine yönelik kamu-özel ortaklığı olan Yakıt Hücreleri ve Hidrojen Ortak Girişimi'ni (Fuel Cell and Hydrogen Joint Undertaking-FCH JU), "hidrojen güvenliğinin yeterince ele alındığından ve yönetildiğinden emin olmak" için 2017 yılında bir uzman paneli kurmakla görevlendirmiştir: Avrupa Hidrojen Güvenliği Paneli (European Hydrogen Security Panel- EHSP).

EHSP, hidrojen güvenliğini daha iyi anlamak için, Komisyonun Ortak Araştırma Merkezi (Joint Research Center-JRC) ile yaptığı iş birliği sonucunda çok detaylı bir veri tabanı oluşturmuşlardır. Avrupa Hidrojen Olayları ve Kazaları Veri Tabanı'nında (HIAD 2.0), 21 Eylül 2021'deki son raporuna göre yaklaşık 600 vaka kaydedilmiştir. Bu kazaların sebepleri ve bağlamları başka bir kapsamlı analizi gerekli kılmaktadır.

EHSP Task Force TF3, Temmuz 2020'de veri tabanında yer almakta olan 485 vukuatı incelemiştir (EHSP Task Force TF3, 2021). Çalışma, istatistikleri, öğrenilen dersleri ve önerileri kapsamaktadır. İstatistikler, kaza ıle ilgili endüstriyel sektörler ve sistemler kaza nedeni, kazaya neden olan hidrojen miktarı ve maddi ve kişilere verdiği hasarın ciddiyet seviyeleri açılarından toplanmıştır. Raporun önemli çıkarımlardan bir tanesi, daha iyi eğitim ve öğretimin hidrojenle ilgili kazaların dörtte birinden fazlasını önleyebileceğidir. Tablo 1’de görülen vaka çeşitlerine göre yapılan sınıflandırma, bu çalışma konusu açısından önem arz etmektedir.

Tablo 1: Sebeplerine göre sınıflandırılmış HIAD vakaları

Sebep	Sebep kaynaklı vaka sayısı
Sistem tasarımı hataları	126
Malzeme/üretim hataları	127
Kurulum hataları	38
Yapılan iş ile ilgili sebepler	98
Bireysel hatalar	94
Organizasyon ve yönetim hataları	158

Operatör hatalarıyla ilgili geçmiş vakalardan alınan derslere yönelik incelemelerde, vakanın ola geldiği kurumun Sağlık ve Güvenlik Yöneticisi (SGY) tarafından önerilen sınıflandırma uyarlanmıştır. Operatör hatalarıyla ilgili kategori, daha sonra “iş faktörleri, bireysel/insan faktörleri ve organizasyon ve yönetim faktörleri” olmak üzere üç alt kategoriye ayrılmıştır.

HIAD 2.0'dan toplanan istatistikler, her türlü insan kaynaklı hatanın oluşumunu ve etkisini azaltmak amacıyla bu üç kategoride alınacak dersler hakkında ciddi olarak düşünmenin önemini açıkça göstermektedir. Operatör hatalarına dair bu derslerin pek çoğu, bu çalışmanın aşağıdaki kısımlarında değinilecek ihtiyat ilkesinin önleme ilkesi[9] kanadının somut uygulamalarıyla doğrudan ilişkilidir.

Maliyet Sorunu

Hidrojen değer zincirinin oluşmasının artan bir hızla ivmelendiği bu dönemde, hidrojen risk zincirinin de hızla hareket kazanacağını öngörmek makuldür. Etkisi

[9] Önleme ilkesi kısaca “çevre üzerinde olumsuz etkiler yapabilecek faaliyetleri gerçekleştirmeden önce, bunların olumsuz sonuçlarını öngörerek gerekli önlemleri” almaktır. Hukukta, büyük çoğunlukla önleme ilkesi ve ihtiyat ilkesi birbirinin devamı ve bütünleyicisi olarak kabul edilmektedir; bu makalede bu ayrıma değinilmeyecektir. İhtiyat ilkesi kavramı ilke olarak önleme ve ihtiyat ilkelerini birlikte kapsamaktadır.

yüksek dışsallıklarla beslenen hidrojen ekonomisinde hayata geçen projeler arttıkça, hidrojen kazalarının artması da beklenebilir. Mümkün olan en katı güvenlik kurallarını önerenlerin hidrojenin ticarileştirilmesini çok pahalı hale getireceğini belirten FCH JU Proje Yetkilisi Garcia Hombrados, "Güvenlik ve maliyet arasında her zaman bir ödünleşim" olduğunu belirtmektedir. EHSP üyesi Georg Mair ise, bunun "Optimizasyon için klasik bir çatışma" olduğunu ifade etmektedir. Kazaları her ne pahasına olursa olsun önlemenin ekonomik açıdan uygulanabilir bir çözüm olmadığını belirten üye, daha etkili bir "güvenlik önce gelir" yaklaşımı çağrısında bulunmaktadır. Görüldüğü üzere, uzmanlar arasında hidrojen güvenliğine dair fikir ayrışmaları mevcuttur. Maliyet hesaplarına, maliyetin sosyal, çevresel ve nesiller arası boyutları da dahil edilmelidir. Bu sorunsal, Mair'in de işaret ettiği üzere, ihtiyat prensibinin uygulandığı mekanizmaların hayata geçirilmesiyle iyileştirilebilir.

Hidrojenin mevcut sorunlara yenilerini eklememesi için dikkat edilmesi gereken önemli noktalar vardır. Bu noktaları makro ve mikro yaklaşımlar olarak ikiye ayırmak mümkündür. Makro yaklaşımlar olarak, evrende bildiğimiz en basit atomik yapıya sahip olan hidrojenin var olan karmaşık enerji sistemini ve enerji/çevre etkileşimini sadeleştirmesi beklenmektedir. Ayrıca hidrojenin enerji sektöründeki belirsizlik ve istikrarsızlıkları mümkün olduğunca azaltması arzulanmaktadır. Hidrojen teknolojileri güvenliğine dair bütüncül bir yaklaşım ancak bu makro yaklaşımlarla mikro yaklaşımların, yani ihtiyat ilkesinin somut uygulamaları birlikte işletildiğinde ortaya konabilecektir.

2. Hidrojenle Karbonsızlaştırmanın Hukuki Boyutu: AB Resmî Belgelerinin Metin Analizi

Çalışmamız kapsamında, söz konusu risk zincirinin hukuki alandaki yansımasını değerlendirmek için, hidrojenle karbonsuzlaştırma konusunda önemli adımlar atmış ve birçok bilgi ve belge üretmiş olan Avrupa Birliği'nin hidrojene değinen tüm resmî belgelerini metin analizine tabi tuttuk. Araştırmamızda, metinler içinde "güvenli", "güvenlik", "ihtiyat" ve "önleme" kelimelerini taradık. Çok çarpıcı biçimde, hidrojen güvenliğine ilişkin neredeyse hiçbir önlemin öngörülmediğini;

güvenlik kavramının yer aldığı çok nadir birkaç noktada da konunu çok dar bir kapsamda ele alındığını tespit ettik.

FCH 2 JU'nun 31/08/2020 tarihli "Hidrojenin Ulusal Enerji ve İklim Planlarındaki Rolü" çalışması (FCH 2 JU, 2020) hidrojen teknolojilerinin AB ve Üye Ülkelerinin (Birleşik Krallık dahil) 2030 iklim ve enerji hedeflerine etkin ve verimli bir şekilde ulaşılmasına katkıda bulunma olanaklarını belirlemekte ve vurgulamaktadır. Çok kapsamlı olan 144 sayfalık bu çalışmada, hidrojen güvenliğine yalnız bir kere değinilmiştir. Macaristan'ın ulusal planında "...uygun koşullar (güvenlik dahil) ve teşvikler oluşturmayı" planladığı ifade edilen cümle haricinde, ele alınan hiçbir Üye ülkenin planında güvenlik meselesinin etraflıca değerlendirilmediği görülmektedir.

8 Temmuz 2020 tarihli, COM/2020/301 sayılı 24 sayfadan oluşan "AB Hidrojen Stratejisi'nde (Avrupa Komisyonu, 2020) güvenlik meselesine, birer cümle ile üç kere değinilmiştir. İlk tespit edilen cümlede açık ve rekabetçi piyasaların temiz ve güvenli hidrojen üretimine katkısından söz edilmektedir. İkinci tespit edilen cümlede standartların oluşturulması öncesi araştırma faaliyetlerine güvenlik boyutunun da eklenmesi gerektiğine değinilmiştir. Son olarak yine araştırma faaliyeti olarak iyileştirilmiş ve uyumlaştırılmış standartların oluşturulması gereğinden bahsedilmiştir. Bu bağlamda, AB'nin temel hidrojen stratejisi belgesinde, hidrojen güvenliğinin sadece bir araştırma konusu olarak yer aldığı gözlemlenmektedir.

"İklim Açısından Tarafsız bir Ekonomiye Güç Verilmesi: Enerji Sistemi Entegrasyonu için bir AB Stratejisi" adlı COM/2020/299 sayılı Avrupa Komisyonu Tebliği'nde de (Avrupa Komisyonu, 2020) hidrojen güvenliği konusu hiç yer almamaktadır.

Bir diğer resmî belge olan Avrupa Komisyonu'nun Temmuz 2020 tarihli "Avrupa'da Hidrojen Üretimi- Maliyetlere ve Temel Faydalara Genel Bakış" adlı 45 sayfalık çalışmasında da (Avrupa Komisyonu, 2020) hidrojen güvenliği konusu tamamen göz ardı edilmiştir. Metinde güvenlik kavramı bir kere bile yer almamaktadır. Oysa yukarıda değindiğimiz üzere, güvenlik ve maliyet birbirileriyle doğrudan ilişkili konulardır.

14 Temmuz 2021 tarihli "Hidrojenin 2030 İklim ve Enerji Hedeflerimize Ulaşmadaki Rolü" isimli belgede de (Avrupa Komisyonu, 2021) güvenli hidrojene hiç değinilmemiştir.

AB’nin resmi bir girişimi olan, sanayi, kamu otoriteleri, sivil toplum ve diğer paydaşları bir araya getiren Avrupa Temiz Hidrojen İttifakı Deklarasyonu’nda da hidrojen güvenliğinden hiç söz edilmemiştir (Avrupa Temiz Hidrojen İttifakı, 2020). İttifakın diğer çalışmaları da rekabet, endüstriyel stratejiler gibi konularda olup, güvenlik konusunda herhangi bir çalışması bulunmamaktadır.

Her ne kadar bir stratejik belge niteliğinde olmasa da, AB’nin konuya yaklaşımını daha iyi anlamak için 2017-2018 yıllarında 23 üye ülke ile gerçekleştirilen HyLaw Projesi’ne de değinmekte fayda vardır. Proje, hukuka bir “engel” olarak yaklaşmakta, “yakıt hücrelerinin ve hidrojen uygulamalarının konuşlandırılmasına yönelik yasal engellerin kaldırılması”nı amaçlamaktadır. Oysaki, Avrupa Komisyonu'nun yeni girişimler ve öneriler hazırlarken ve mevcut mevzuatı yönetirken ve değerlendirirken izlediği ilkeleri belirleyen “Better Regulation” Ajandası’nda da (Avrupa Komisyonu, t.y.) isabetle değinildiği üzere, yenilikçilik ilkesi ve ihtiyat ilkesi birbiriyle yarışan değil birbirini tamamlayan, destekleyen, güçlendiren ilkelerdir. Ancak AB’nin ‘Better Regulation’ yaklaşımının hidrojen ekonomisi bağlamında uygulanmadığı, hatta aksi yönde bir yaklaşım gözlemlenmektedir.

Yukardaki özetlemiş olduğumuz detaylı metin analizi, hidrojen risk zinciri ile değer zincirinin arasında bir tutarsızlık olduğunu göstermektedir. Bu tutarsızlığın, uluslararası çevre hukukunun temel ilkelerinden biri olan ihtiyat ve önleme ilkesinin bihakkın işletilmesiyle ortadan kaldırılabileceği ve bu iki zincirin ancak bu şekilde uyumlu hale getirilebileceği düşünülebilir. Bu nedenle ihtiyat ilkesinin bir çözüm önerisi olarak ele alınması ve bu ilkeye dayalı olarak politika önerileri geliştirilmesi ihtiyacı çalışmamızın ana mesajını oluşturmaktadır.

3. Çözüme Katkı Olarak İhtiyat İlkesi

1960’lı yılların sonunda önceleri politik bir yaklaşım olarak ortaya çıkan ancak zamanla hukuki bir ilkeye dönüşen ihtiyat ilkesi, sanayi toplumlarının ortaya çıkardığı acil çevre sorunlarına, politik ve hukuki bir yanıt niteliğindedir.

İhtiyat ilkesi, bir madde veya faaliyetin çevre açısından olumsuz neticeler doğuracağı hususunda ciddi bir şüphenin varlığı halinde, *bilimsel bir kanıtın ortaya* *çıkışı beklenmeden* önleyici tedbirlerin alınmasını emreder (Avrupa Parlamentosu, 2015). Almanya'da doğduğu genel kabul gören ihtiyat ilkesi, Birleşmiş Milletler'in (BM) ve 1992 yılında AB'nin kurucu antlaşmalarına eklendikten sonra birçok üye devletin hukukuna girmiştir (Trouwborst, 2006, sf. 151–2). Tanımı ve içeriği konusunda bir görüş birliği olmasa da; gerek ulusal, gerek bölgesel ve gerekse uluslararası birçok hukuk metninde yer almaktadır. Bundan dolayı da evrensel bir ilke haline geldiği kabul edilmektedir. Çevrenin korunmasının yanı sıra deniz kirliliği, iklim değişikliği, gıda güvenliği, kamu sağlığı ve biyo-çeşitlilik gibi birçok alanda uluslararası bağlayıcı sözleşmelerde yer edinmiştir.

İlke şu fikir etrafında şekillenmektedir: Bir faaliyetin veya maddenin zararlı/riskli olduğunun ispatlanmasından sonra alınacak tedbirler, çoğunlukla geç kalınmış olma sonucunu doğuracaktır. Bundan dolayı yeterince etkili olamayacak, hatta geri dönüşü olmayan zararlar doğabilecektir.

Bir Başarı Örneği Olarak Montreal Protokolü

Somutlaştırıcı bir örnek olarak, çevre konusunda oluşturulmuş en başarılı çok taraflı anlaşma olarak görülen; tüm BM üye ülkelerinin taraf olduğu tek anlaşma olan Montreal Protokolü gösterilebilir. Montreal Protokolü, tarihte ilk defa, o dönem zararı henüz bilimsel kesinlik kazanmamış olmasına rağmen; ozon tabakasını incelten 100'e yakın ozon tabakasını delici maddenin (ozone depleting substances, "ODS") üretiminin, satışının ve kullanımının kısıtlanmasını ve kiminin yasaklanmasını öngörmüştür.

Protokolün Tarafları, 1990lardaki seviyelerine kıyasla dünya genelinde ODS'lerin %98'inin kullanımını aşamalı halde bitirmiştir. Şayet bu Protokol imzalanmamış olsaydı, ozon tabakasının tükenmesi 2050 yılına kadar on kat artmış olacaktı (UNEP, t.y.). Öte yandan sağlık alanında da Protokolün önemli katkıları olmuştur ve ABD'de 2015 yılına kadar 8,3 milyonu melanom olmak üzere 283 milyon cilt kanserinin ve 46 milyon katarakt vakasının meydana gelmesini engellemiştir (EPA, 2015). İhtiyat ilkesini temel alan bir hukuk metni böylesine önemli bir etki yaratabilmektedir. Jacques Van Engel'in BM Kalkınma Programı için 2017'de hazırladığı analize göre, 1987 tarihli bu Protokol, 2015'te hayata geçirilen 17 Sürdürülebilir Kalkınma Hedefinin 15'ini ve 169 alt hedefin 39'unu karşılamaktadır (UNDP MPU, 2017).

İhtiyat İlkesi Önlemlerinden Bir Seçki

İlkenin somut uygulaması olarak çok çeşitli politika araçları mevcuttur. Yasaklama, izne bağlama, planlama, çevresel etki değerlendirmesi, bildirim yükümlülükleri ve mevcut en iyi teknolojinin kullanılması gibi yöntem ve araçlar önleme ilkesi ve ihtiyat ilkesinin ortak araçları olarak kabul görmektedir. Daha büyük güvenlik sınırları oluşturmak, yedek güvenlik sistemleri geliştirmek, acil durum planlarını hayata geçirmek ve eğitim öğretim faaliyetleri bu politikalar arasında sayılabilir. Buraya kadar sıralanan politikaların, yukarıda "Hidrojen Risk Zinciri" bölümünde ele alınan EHSP Task Force TF3'ün tespit ettiği operatör/kullanıcı kaynaklı kazaları en aza indirmede ciddi katkılar sunma potansiyeli vardır.

İhtiyat ilkesi ayrıca ispat yükünün tersine çevrilmesi, izin sistemlerinde değişiklik, karar alma usullerinde değişiklik ve çevresel standartların sıkılaştırılması gibi araç ve yöntemleri de kapsamaktadır. Bir diğer yöntem olan alternatiflerin değerlendirmesi, "aksiyon almama" alternatifini de içerdiği için, bütüncül bir bakış açısı sunar. Amacı risk hakkında daha fazla bilgi toplamak ve bu konuda birbirini izleyen varsayımları test etmek olan araştırma programlarının oluşturulması bu ilkenin bir uygulamasıdır (Ewald et al., 2001). İhtiyat ilkesi, sistematik olarak çevresel anlamda "temiz" teknolojileri tercih etmeyi gerektirir. Böyle bir yaklaşıma alternatiflerin değerlendirmesi denir. Değerlendirme süreci, bir faaliyetin çok tehlikeli mi veya gereksiz mi olduğunu sorarak "faaliyete geçmeme" alternatifini de ciddiye alır (Tickner et al., 1999).

Kamu hukuku bağlamında ihtiyat ilkesi, uzun vadeli çevre ve sağlık izleme sistemlerininin oluşturulması (Avrupa Çevre Ajansı, 2001, 170–173), düzenleyici kurumların bağımsızlığının güçlendirilmesi ve devlet kurumları, üreticiler ve kullanıcıların faaliyetleri, devam eden deneyler, güvenlik protokolleri, gözlenen anormallikler, kazalar ve güvenlik ihlalleri hakkında kamuoyuna düzenli bilgi vermeleri ödevi anlamına de gelmektedir (Lascoumes 1997).

4. İhtiyat İlkesi – STS İlişkisi

Görüldüğü üzere, ihtiyat ilkesi tam da STS çalışmalarının gerektirdiği gibi; parçalı, eksik, dağınık bilgi ve eleştirel bakış açılarını yeni yollarla bir araya getirir. Farklı metodoloji ve varsayımlara sahip farklı bilimlerin sistematik olarak birbirleriyle temas etmesini sağlar. Transdisipliner uzmanlığın bilinçli şekilde düzenlenmesini de içerir (Harding & Fisher, 1999).

İhtiyat ilkesi ekolojik karmaşıklığı gözetir; şeffaflık, katılımcılık ve kapsayıcılık imkanları sunar. Risk değerlendirme sürecinin niteliksel meselelere açılması taleplerine karşılık verir. Bilimsel belirsizlikleri kabul eder, tartışmalarda ek şeffaflık sağlar. İhtiyat ilkesi bilgiyi sürekli yenilemeye açık tutar; sürekli tetikte olmayı gerektirir. Denetlemenin "bütüncül" olmasını önerir (Deville & Harding, 1997). Ayrıca ihtiyat ilkesi bireylere, karar süreçlerine dinamik demokratik katılım, mülahaza ve müzakere imkânı tanır.

Hidrojene Dair Türkiye'deki Yasal ve Politik Çerveçe

4646 sayılı Kanun'un kapsamında yer almayan hidrojen, bir yasal düzenleme ile bu kapsama eklenmelidir. Ayrıca henüz hidrojen için açık olarak yetkilendirilmemiş EPDK'nın mutlaka yasa koyucu tarafından bu yönde yetkilendirilmesi gerekmektedir. Tükiye'deki hidrojen regülasyonları temel olarak ulaşım, güvenlik ve enerji kategorilerine ayrılabilir. Bu kategorilerden ilk ikisi görece daha olgun olup, AB mevzuatıyla uyumlu bir görünüm sergilemektedirler. Enerji kategorisi ise henüz başlangıç aşamasında olup, EPDK'nın birtakım muğlak düzenlemeleriyle dikkat çekmektedir.

Hidrojen ile Karbonsuzlaştırmaya Yönelik İhtiyat İlkesi Çerçevesinde Yaklaşım Önerileri

Hidrojenle karbonsuzlaştırma alanındaki düzenleme girişimlerinin genellikle maliyet-fayda analizinin tam olarak yakalayamadığı, dağılımsal ve etik etkileri vardır. Bu bağlamda ihtiyat ilkesinin somut uygulamaları, bu soruna etkili çözümler getirebilecektir. Çalışmamız kapsamında yaptığımız değerlendirme sonucunda, ihtiyat ilkesi hidrojenle karbonsuzlaştırma alanına uygulandığında, aşağıdaki düzenleme önerilerinin geliştirilebileceği düşünülmüştür:

- Doğalgaza hidrojen karışımı oranlarında standardizasyon sağlanması; farklı kullanımlar, kullanıcılar, ülkeler ve bölgeler için farklı uygulamalar geliştirilmesi,
- Önleyici tedbirler geliştirmek için halihazırda mevcut teknik uzmanlığa sahip kullanımların ve kullanıcıların öncelikle teşvik edilmesi,
- AB düzeyinde 'yamalı (patchwork)' mevzuattan kaçınılması,
- Devam eden hidrojen güvenliği değerlendirme süreçlerinin hızlandırılması,
- Farklı ihtiyat düzeylerine sahip "düzenleyici deneme tahtaları (regulatory sandbox)" uygulamaları geliştirilmesi ve uygulanması,
- Endüstriyel kullanımlar ve hidrojene özgü boru hatları için daha düşük ihtiyat seviyeleri belirlenmesi,
- Genel kitle son kullanıcılar için daha yüksek ihtiyat düzeylerinin belirlenmesi,
- Hidrojen taşıma, iletim ve depolama risklerinin en aza indirilmesi amacıyla, mümkün olan uygulamalarda, kullanım yerinde, istenildiği zaman ve istenildiği kadar hidrojen üretimi teknolojileri için teşvikler tasarlanması ve uygulanması.

5. Sonuç

Hidrojen ile karbonsuzlaştırma tartışma ve uygulamalarının çevresel kaygılarla özellikle günümüzde böylesine önem kazandığını tekrar vurgulamakta fayda vardır.

Bu gelişmeler, Montreal Protokolüyle benzer kaygılardan kaynaklanmaktadır. Şekil 2'de Montreal Protokolü'ne Yönelik Değişiklik olarak imzalanan Kigali Değişikliği'nin anahatları görülmektedir (UNEP).

Kigali Değişikliği, Montreal Protokolü'nde yasaklanan CFC (kloroflorokarbonlar) gazını ikame eden HFC (hidroflorokarbon) gazından çıkış planıdır. 2019 yılında yürürlüğe girmiştir, uygulama süresi 2047'ye kadar sürmektedir. Değişikliğin HFC'lerin kullanımını aşamalı olarak azaltarak, yüzyılın sonuna kadar atmosferik sıcaklıkta 0,5°C bir artıştan kaçınmayı sağlaması beklenmektedir (UNIDO, t.y.).

Montreal Protokolüyle geçmişte CFC'ler ve HCFC'lerin (Hidrokloroflorokarbonlar) kullanımı durduruldu. Bu durum, özellikle soğutma sektöründe HFC'lerin kullanımını büyük ölçüde artırdı. HFC'ler ozon tabakasını etkilemez, ancak yüksek küresel ısınma potansiyeline sahiptir. Değişikliğe kadar, Montreal Protokolü sadece ozon tabakasına zarar veren maddelerin kontrolünü sağlıyordu. Kigali Değişikliği, bu sektöre daha fazla müdahale anlamına gelmektedir. Bu müdahaleye doğan ihtiyaç, Montreal Protokolünün tedbirlerinin uygulanması sonucunda gelişen yeni durumlarla doğmuştur. Montreal Protokolü'nün kazanımlarının vazgeçilmez önemde olduğu yukarıda açıkça tespit edilmiştir. Ancak Kigali Değişikliği'nden de anlaşılacağı üzere birinci nesil çözümler yeni sorunlar yaratabilmektedir. Bu sebeple, sürekli teyakkuz halinde olmak gerekmektedir. İhtiyat ilkesinin, bilginin sürekli yenilenmesini gerektirmesi bu bakımdan kritiktir.

Montreal Protokolü'nde halen örneği görülmemiş eşsiz bir başarı elde edilmiştir. Ancak bu anlaşma ile yasaklanan gazların ekonomik etkilerinin belirli üreticilerle sınırlı olduğu unutulmamalıdır. Kısa sürede sonuca gidilmiştir. Ancak bugünkü durum çok farklıdır, sorun fazlasıyla karmaşıktır. Bu sebeple de küresel merciler ancak 2050 ila 2060 yıllarında konulan iklim hedeflerine ulaşmayı öngörmektedir. Yanı sıra, iklim krizine çözüm olarak önerilen hidrojen, kendi sorunlarını da beraberinde getirebilecektir. Bu sorunlar Montreal Protokolü'ndeki kadar doğrusal ve basit çözümlere sahip değildir. Yine de bu sorunların en azından bir kısmını ihtiyat ilkesi bağlamında çözmek mümkün görünmektedir. Bu noktada bilim, teknoloji ve toplum etkileşimi çalışmalarına ve bunların hukuk ve politika bilimleriyle kesişimlerine ciddi çalışma alanları açılmaktadır.

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