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CLIMATE CHANGE ADAPTATION IN EX-ANTE ASSESSMENT OF LEGAL ACTS – A PROPOSAL OF INDICATORS FOR POLAND

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ABSTRACT: This article is aimed at developing a proposal of indicators to integrate climate change adaptation into the process of designing legislation and assessing the effectiveness of this legislation in adapting the society, the economy and the environment to climate change. Based on a review of climate change adaptation monitoring indicators used in selected European countries, an assessment of potential indicators according to the proposed criteria was carried out and a proposed list of indicators for monitoring climate change adaptation in selected economic sectors was developed for use in the ex-ante assessment of legislation.

The proposed set of indicators can be used for ex-ante assessment of legal acts in terms of implementation of climate change adaptation requirements – both to determine the values of indicators selected for a given sector that are relevant to climate change adaptation, and then to monitor changes in these indicators to assess the effects of implementing legal regulations in terms of supporting the state's climate change adaptation policy.

KEYWORDS: monitoring indicators of adaptation to climate change, ex-ante assessment, legislative process, regulatory impact assessment

Introduction

The European Climate Law (Regulation, 2021) introduces in its Article 5 the obligation to integrate adaptation to climate change into relevant policies, and also stipulates that the implementation of these policies shall take into account the evaluation of progress and indicators, based on the best available and most up-to-date scientific evidence.

The issue of incorporating the adaptation indicators into the development of climate change adaptation strategies and plans is highlighted in the new European adaptation strategy. In this document, the European Commission emphasises the need to improve strategies and plans, of which the monitoring, reporting and evaluation are to be an important elements, against which progress on adaptation to climate change will be measured. Among the actions planned are:

- upgrading monitoring, reporting and evaluation for climate change adaptation by using a harmonised framework for standards and indicators,
- providing ex-ante evaluation tools for projects to better identify co-benefits and positive economic impacts of climate change adaptation and prevention projects,
- updating the better regulation guidance and toolkit to better address the principles of policy coherence for climate risk management (Communication, 2021a).

As both of these documents indicate, climate change adaptation indicators will be used not only at the stage of developing adaptation strategies, but also at the stage of their implementation, which in turn demonstrates the necessity of using indicators in the process of creating regulatory arrangements, drafting legal acts that will implement the above mentioned adaptation strategies.

The process of evaluating regulatory solutions is part of the regulatory impact assessment procedure and is carried out at multiple levels, under which the relevant sets of indicators should be used.

As mentioned, indicators are essential both at the stage of formulating adaptation policy (as risk and impact indicators are useful for identifying the most serious problems and setting priority areas for action), and at the stage of implementing, evaluating and improving adaptation policy. Response indicators measure the scale, and progress in implementing adaptation actions, while exposure and impact indicators reflect the effects of these actions in terms of reducing the impact of climate change on the ecological-socio-economic system, as well as reducing exposure to climate change (risks).

In the law-making process, indicators can be used, inter alia, to assess the adequacy of proposed solutions in terms of achieving the identified regula-

tory objectives, the selection of legal alternatives (based on a comparison of ex-ante indicators), and the final assessment of their impact (ex-post analysis).

The mainstreaming of climate change adaptation in law-making is part of a broader process of integrating public policies as a tool for sustainable development. The mainstreaming and integration of adaptation to climate change into routine procedures is done through the use of the Strategic Environmental Assessment (SEA) of regional policies, plans and programmes. Consequently, the policy implementation stage, i.e. the introduction of specific legislation, should also be subject to appropriate evaluation. At European Union level, this is addressed by the Interinstitutional Agreement on Better Law-Making (Agreement, 2016), which provides for systemic solutions concerning the monitoring and evaluation of the impact of legislation. As a result of the provisions of this agreement, a Better Law-Making programme has been developed, which also formulates guidelines for regulatory impact assessments (Better Regulation Guidelines, 2017; Communication, 2021b). These documents underline that establishing the monitoring and evaluation framework (including a set of indicators) for the implemented policy measure is a necessary element of effective policy- and law-making. All these considerations confirm that integrating climate change adaptation into the law-making process, including in the form of indicators, is an urgent need in member states.

In justifying the undertaking of the topic in relation to Poland, the following rationales can be identified: (1) the existing legislation mandating the development of indicators and guidelines for monitoring the implementation of climate change adaptation strategies, (2) the lack of developed indicators for Poland that could be used in the process of assessing the effects of legal acts affecting the achievement of climate change adaptation strategy objectives. This practical gap is also accompanied by a research gap – there are no scientific works on indicators for the assessment of legal acts for Poland.

The aim of this paper is to develop a proposal for indicators to address climate change adaptation in the process of designing legislation and assessing the effectiveness of that legislation in adapting the society, the economy and the environment to climate change. The realisation of the stated objective required a review of indicators for monitoring the effects of climate change adaptation and mitigation in selected European countries, an assessment of the relevance of the indicators to Polish conditions and to the assessment of legal acts, and the development of a list of indicators for monitoring adaptation to climate change in Polish conditions. The results of the study, including the proposed indicators, will allow the adaptation to climate change to be taken into account in the process of designing legislation in Poland and assessing its effectiveness.

The research results presented in this article are the outcomes of a research project entitled *Development of indicators and guidelines for their monitoring aimed at including the issue of adaptation to climate change in the process of designing legal regulations and assessing the effectiveness of these regulations in terms of adapting society, the economy and the natural environment to climate change* (Broniewicz et al., 2021), carried out by the authors of this article under the project entitled “Knowledge base on climate change and adaptation to its effects and its dissemination channels in the context of increasing the resilience of the economy, the environment and society to climate change and counteracting and minimising the effects of extraordinary threats”. “Knowledge Base on Climate Change and Adaptation to its Impacts and its Dissemination Channels in the Context of Increasing the Resilience of the Economy, Environment and Society to Climate Change and Counteracting and Minimising the Effects of Extraordinary Hazards” commissioned by the Institute of Environmental Protection – National Research Institute in the period August – December 2021.

Literature review on monitoring and evaluation of climate change adaptation policies

At all stages of any public policy, including climate change adaptation policy, indicators are an essential tool in the monitoring and evaluation process (Figure 1). Indicators are useful throughout the public policy cycle, from the identification of problematic phenomena based on indicators, to the assessment of alternative options, to the evaluation of the impact of policy implementation. They are a necessary link in the policy feedback loop. This statement can also be applied to the very process, design and implementation of the legislation through which the policy is implemented. The purpose of monitoring and evaluation is primarily to improve the quality of the policy itself – to improve its design and implementation, and to assess its effectiveness, efficiency and impact.

Indicators are an indispensable tool both in the policy formulation stage (risk and impact indicators are useful for identifying the most serious problems and prioritising areas for action), and in the implementation and evaluation of adaptation policy (Guidelines, 2013). This is because adaptation action indicators (implementation of measures) allow for measuring the scale, progress of implementation of actions, while exposure and climate change impact indicators reflect the effects of these actions in terms of reducing the impact of climate change on the ecological-socio-economic system, as well as reducing exposure especially used for the evaluation and selection of

regulatory alternatives (based on the comparison of ex-ante indicators) and the final evaluation of their impact (ex-post analysis).

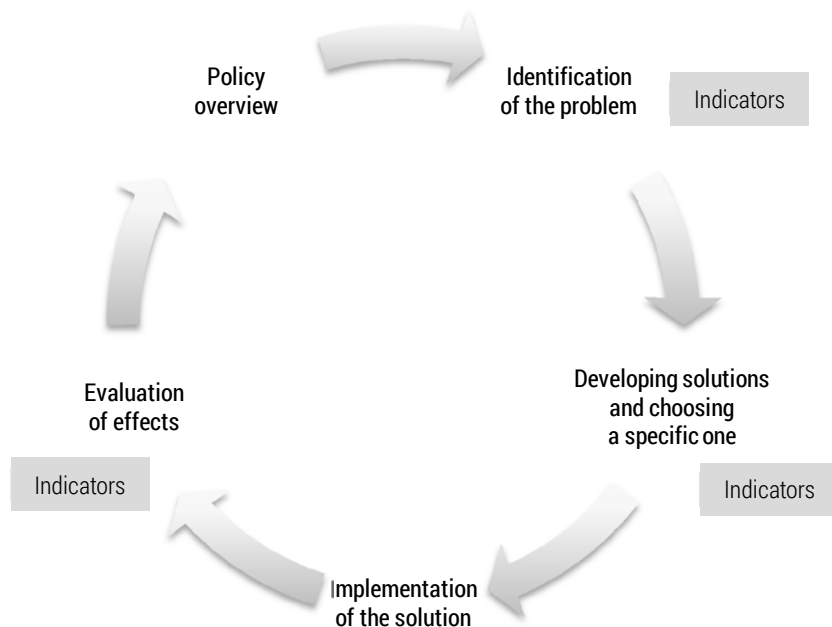


Figure 1. Stages of public policy implementation and the use of indicators

Source: authors' work based on Dziemianowicz et al. 2012, p. 10.

Monitoring and evaluation of climate change adaptation is not a simple issue. It poses many challenges, including the following:

- 1) There is a need to define what adaptation looks like in practice if we are to develop indicators and identify appropriate data sources for monitoring and evaluation. Adaptations can take many forms, reflecting divergent conceptualizations of vulnerability driving action, the goals and functions of adaptation in different contexts, and a myriad of sectors and scales at which adaptation takes place.
- 2) Characteristics of success need to be identified to capture the effectiveness of adaptation in reducing vulnerability. While some actions may have direct and measurable outcomes, in many instances impacts on vulnerability are not directly visible and/or will be evident only over many decades, with different interpretations on what characterizes "success".
- 3) Appropriate data sources need to be identified to facilitate the development and tracking of indicators (Ford et al., 2013).

In the practice of developing a system of climate change adaptation indicators, a scheme is used that distinguishes three groups of indicators that form a logical sequence:

- 1) Exposure (risk) indicators, which reflect exposure or vulnerability to the effects of climate change, e.g. flood risk maps, thermal island maps.
- 2) Climate change impact indicators, which measure the actual effects of climate change. Monitoring indicators of this group allows to assess to some extent the effects of adaptation measures (if they are effective, the impact of climate change should be less, e.g. the number of deaths due to heat waves).
- 3) Adaptation action indicators – implementation of measures and decision-making, to measure to what extent adaptation actions have been implemented. Indicators in this group provide a quantitative snapshot of what is being done in the realm of adaptation and what the direct ‘products’ of these actions are, regardless of the extent to which they will actually contribute to mitigating the problem (e.g. the percentage of municipalities with an up-to-date adaptation plan).

This approach is represented in climate change adaptation policies in countries such as Finland (Lilja-Rothsten, 2016) and Scotland (ClimateX-Change, 2021). It is in line with the pressure-state-response (P-S-R) or driving forces-pressure-state-response (D-P-S-R) frameworks commonly used by international organisations: UNEP (2019), OECD (2003), World Bank (El-Habil, 2012), and UN (2013) in analysing environmental issues (Segnestam, 1999).

The essence of the P-S-R indicator framework is a sequence of questions:

- 1) pressure/cause indicators: why does the problem exist? what are the causes of the problem?
- 2) state/effect indicators: does the problem exist? how significant is the problem?
- 3) response indicators: how to solve the problem?

The obligation to integrate climate change adaptation issues into relevant policies, is formulated in the European Climate Law (Regulation, 2021) (hereafter: ECL Regulation). This act imposes on the member states the obligation to make continuous progress in enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change. The EPC Regulation attributes a key role in achieving climate resilience to strategic planning. The largest responsibility in this area falls to the member states, which are required to adopt and implement national adaptation strategies and plans. The ECL Regulation, in Article 5, stipulates that the implementation of these strategies shall take into account the assessment of progress and indicators, based on the best available and most recent scientific evidence. It is worth noting that the strategies and plans created in Poland at various levels,

which are supposed to form the basis of climate change adaptation policies, do not fully meet the contemporary challenges generated by the increasing effects of climate change and the rapidly changing legal environment. The shortcomings of strategic documents sometimes relate to the lack of adequate evaluation tools, including a set of appropriate indicators. With this in mind, it should be concluded that the process of planning and implementing climate change adaptation policies in Poland requires some adjustments (Bukowska & Wróblewski, 2022). The essence of the obligation introduced by the ECL Regulation is the programming of a cyclical mechanism for planning, implementation, monitoring and evaluation of adaptation policies, strategies and action plans rather than the development of the document itself (national adaptation strategies).

An important role in the process of design, implementation, but also in the subsequent evaluation of the effectiveness of adaptation measures is played by regulatory impact assessment, which has a dual role: as an analytical method supporting decision-makers in the law-making process, but also as an auxiliary (evaluation) method in the design, implementation and monitoring of the expected effects of the regulatory system (Śliwa & Żaba-Nieroda, 2017).

The European Commission has developed general impact assessment guidelines that apply to its legislative proposals. In the *Better regulation guidelines* document, in the classification of significant impacts that should be taken into account, the action against climate change is mentioned (European Commission, 2021). In contrast, the Better Regulation Toolkit contains question whether the proposed option affects adaptability to climate change.

In the practice of regulatory impact assessments, climate change adaptation is rather addressed in those legislative proposals where climate change adaptation is key, such as in the field of water management (European Commission, 2018), or energy infrastructure. In contrast, climate change adaptation issues are not systematically addressed in all impact assessments, even those on climate policy, such as the use of alternative fuels or energy efficiency (European Commission, 2021b).

The issue of adaptation to climate change and the use of relevant indicators are taken into account in line with to the issues of regulation: in the case of climate and adaptation issues, indicators are used in particular at the stages of problem presentation, analysis and selection of possible solutions (for each of the options considered within the framework of the regulation, indicators demonstrate the level of achievement of the objectives) and monitoring the effectiveness of the regulation introduced. In contrast, in the case of legislative proposals on issues indirectly linked to climate and adaptation, such references are rather absent (European Commission, 2021a).

A review of the impact assessment procedures used in selected European countries showed that:

- in Germany, one indicator of climate change adaptation is included within the sustainability impact assessment procedures (Bundestag, 2021),
- in Finland, the regulatory impact assessment form (Ministry of Justice, 2021) includes a section on environmental impacts, where climate change issues, including adaptation, are to be addressed,
- in Lithuania, in the methodology for assessing the expected impact of regulations (the Government of the Republic of Lithuania, 2003), an assessment of the impact on climate change, including adaptation, is provided for under environmental impact.

In the impact assessment form (Chancellery, 2022), used for the purposes of assessing draft of legal acts in Poland, the natural environment is included as a part of broad range of issues concerning the impact on other areas. This reflects very general approach to the issue of the impact of the proposed regulation, which not only fails to analyse the impact of the act from the perspective of the various components of the environment (i.e. water, air, fauna and flora), but also completely ignores the issue of its impact on adaptation to climate change and improved resilience to climate change.

There is no one-size-fits-all method for selecting indicators on resilience and adaptation to climate change. Many different approaches can be found in the literature, but each is characterised by collecting the widest possible range of indicators in a first step. Engle et al. (2014) propose the following approach to indicator selection. The entire pool of indicators should be divided into five categories: 1) Governance and security, 2) Natural resource systems, 3) Social systems, 4) Economic systems, 5) Built environment/infrastructure). Then, within each category, short and long term indicators should be sought and at different spatial scales. The selection of indicators should be made using an expert method, applying the criteria of feasibility, recognisability and relevance. It is necessary to define the desired outcome/trend for each indicator. The set of indicators chosen should be flexible – indicators can be replaced if they fail to fulfil their informative role or if new, more relevant sources of information emerge.

Bours et al. (2014) also advocate the collection of a wide pool of qualitative and quantitative indicators, both already present in other documents and new ones that reflect the thrust of climate change adaptation. In selecting appropriate indicators, attention should be paid to the fact that complex socio-economic dynamics underlie adaptation effectiveness and are often either hard to quantify or the data is not available. Simplifications and aggregation of indicators that are easy to report but may falsify results should be avoided. They emphasise that climate change adaptation is a local issue and universal indicators for international comparisons should not be sought.

Research methodology

In this study, the starting point was an analysis of documents on climate change adaptation indicators in seven selected countries, namely: Austria, Finland, France, Germany, Lithuania, Spain and the United Kingdom. When selecting countries for analysis, the country's level of progress in implementing adaptation strategies were taken into account, as well as the similarity of geographical and economic circumstances. Pragmatic criteria – the availability of relevant documents – were also taken into account.

Information sources used were:

- European Environment Agency Climate-ADAPT database on climate change adaptation: <https://climate-adapt.eea.europa.eu/>,
- national adaptation strategies and national adaptation plans, as well as monitoring reports on their implementation,
- national guidelines for integrating adaptation into regulatory impact assessment,
- European Environment Agency database: Indicators – European Environment Agency https://www.eea.europa.eu/data-and-maps/indicators/#c0=30&c12-operator=or&b_start=0,
- EUROSTAT database: Climate Change – Impacts and Adaptation <https://ec.europa.eu/eurostat/web/climate-change/data/database>,
- online resources of national institutions responsible for strategic climate change adaptation planning and adaptation monitoring.

The review of source materials first addressed national strategic documents on climate change, including the national adaptation strategy (NAS) and the national action plan (NAP). In these documents, in line with the strategic planning methodology, a monitoring approach, including relevant indicators, was usually defined.

Another important source of information were the reports of individual countries on monitoring the progress in the implementation of climate change adaptation goals and targets, as well as reports and studies of Polish and European institutions, which include indicators of climate change and adaptation to it. The Polish Strategic Adaptation Plan for Sectors and Areas Vulnerable to Climate Change to 2020 identifies indicators for the implementation of individual climate change adaptation goals (Ministry of Environment, 2013). The National Fund for Environmental Protection and Water Management within the Infrastructure and Environment 2014-2020 programme for Measure 2.1 Adaptation to climate change with protection and increased resilience to natural disasters, in particular natural catastrophes,

and environmental monitoring has identified several dozen project indicators (NFOŚiGW, 2021).

Among the institutions responsible for strategic climate change adaptation planning, the European Environment Agency (EEA) and the European Union's statistical office EUROSTAT have the greatest achievements in this area. The EEA has developed 24 climate change adaptation indicators (EEA, 2021). Also EUROSTAT presents data on 16 impact and adaptation to climate change indicators on an ongoing basis (Eurostat, 2021).

According to the criterion indicator function, following types of indicators were highlighted: input indicator, process indicator, output indicator, outcome indicator. However, according to the criterion indicator content can be listed: exposure indicator, adaptive capacity indicator, sensitivity indicator, composite vulnerability indicator, hazard indicator (Mäkinen et al., 2018).

An algorithm for selecting climate change adaptation indicators is presented in Figure 2.

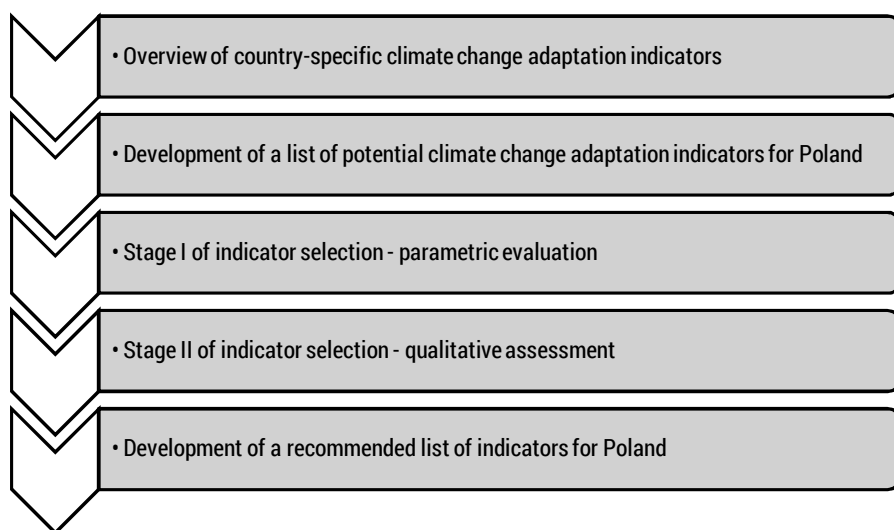


Figure 2: Algorithm for selecting climate change adaptation indicators

Source: authors' work based on Broniewicz et al. (2021).

In the first stage of the work, we made an overview of country-specific climate change adaptation indicators. Then we grouped them into 14 sectors, which were most common in the strategic documents of the analyzed countries (Table 1).

Table 1. Number of climate change adaptation indicators used in the analysed countries

Sector	Number of indicators in countries							Total
	Austria	Finland	France	Spain	Lithuania	Germany	United Kingdom	
Agriculture	6	12	7	1	17	11	20	74
Forestry	3	1				13		17
Water management	5	10	3	7	10	13	15	63
Tourism	4			1		7	1	13
Energy	4	2		3	1	8	7	25
Construction, spatial planning, and housing	9	2		9	5	5	12	42
Protection against natural hazards	10							10
Health	3	8	16	23	28	9	8	95
Environment	7	4	17	15	15	5	33	96
Transport	3	2			4	2	9	20
Industry	3	1			1	7	9	21
Communication networks		1						1
Civil society		2				5		7
Cross-cutting indicators				5		5		10
Total	57	45	43	64	81	90	114	494

Source: authors' work based on Broniewicz et al. (2021).

In total, almost 500 climate change adaptation indicators were identified. The total number and the distribution between sectors varied greatly across the countries analysed. A detailed list of indicators identified in each country is included in Annex 1 (available online).

The indicators identified fell into one of three categories:

- 1) pressure indicators (P), understood as indicators of climate change,
- 2) state indicators (S), understood as:
 - indicators of exposure or vulnerability to the effects of climate change,
 - indicators of climate change impacts, which measure the actual effects of climate change;
- 3) response indicators (R), i.e. adaptation actions taken.

In the next stage of work, all country-specific climate change adaptation indicators were assigned to one of eleven sectors/areas: (1) agriculture; (2) energy efficiency; (3) energy infrastructure; (4) construction, spatial planning, and housing; (5) transport; (6) nature protection and biodiversity conservation; (7) water management; (8) industry; (9) health; (10) tourism; (11) governance – all indicators that are applicable to several of the sectors analysed have been placed in this sector.

The next stage of the proposed procedure was a two-stage selection of a set of indicators. The first stage involved parametric analysis, and the second stage involved qualitative analysis.

For the parametric analysis, all the indicators identified at earlier stages of the work were included, with only the climate change indicators omitted. The following criteria were used to assess the relevance of the selected indicators to Polish conditions:

- 1) prevalence – the occurrence of the indicator in the analysed countries,
- 2) relevance and adequacy – the indicator should be applicable to the Polish conditions,
- 3) suitability – the indicator should be meaningfully linked to adaptation activities,
- 4) recognizability (communicability) – the indicator should be easy to understand for its users,
- 5) measurability – the identified indicator should be easy to measure in the most objective manner,
- 6) reliability – the results described by the indicator should be characterised by a limited degree of uncertainty and the smallest possible margin of error.

The evaluation of individual indicators was carried out using the expert method. The results of the assessment carried out by the authors were reviewed by a wide range of experts and practitioners (representatives of government and local government institutions, academics and NGOs) during three rounds of workshops. The workshops were held in November 2021.

The 'prevalence' indicator was measured by the number of countries in which the indicator was present. A three-point indicator rating scale was adopted for the other criteria, where:

- value 1 – criterion not met or met to a low degree,
- value 2 – criterion fulfilled to a moderate degree,
- value 3 – criterion fulfilled to a high degree.

In the second stage of indicator selection, the indicators were analysed in qualitative terms:

- 1) the usefulness of the indicator in the legislative process,

- 2) the existence of the indicator in Eurostat, the EEA or in the Strategic Adaptation Plan 2020, or as targets of the European Adaptation Strategy 2021 (Communication, 2021a),
- 3) the source and characteristics of the data, including their availability,
- 4) uniqueness – within the identified group, indicators should not share the same characteristics.

The usefulness of an indicator in the legislative process was assessed as the ability to quantify the relationship between the regulation and the phenomenon in question, in other words, the reality of the actual impact of the regulation on the phenomenon in question (controllability of the phenomenon).

All recommended indicators should be subject to ex-ante and ex-post evaluation. Regulatory impact assessment exists as an ex-ante evaluation, which is carried out at the stage of draft legislation, and as an ex-post evaluation, which is carried out after the regulation has been implemented. The purpose of ex-post evaluation is to answer the question of whether the stated objectives of the regulation are actually achieved (effectiveness of the regulation). The conclusions of the ex-post evaluation constitute a recommendation to amend the regulation.

At this stage, a criterion of uniqueness was applied – if there were indicators addressing a similar issues within a sector among the previously qualified indicators, one indicator was selected.

For the qualitative analysis, we selected indicators that met the following criteria:

- which were scored the maximum number of points (3 points) in five criteria (excluding the criterion of frequency of occurrence),
- which received a lower number of points but were considered relevant to the sector. This occurred: (1) in the energy efficiency and transport sectors, where none of the indicators received the maximum score, (2) in the industry sector, where no indicators with possible broad applicability were obtained (the selected relevant indicators were only relevant for water supply and wastewater companies).

The result of the second stage of the analysis was the final selection of a set of indicators that could be used in the process of designing legislation and assessing the effectiveness of that legislation in adapting society, the economy and the environment to climate change. We decided to limit the number of indicators to 2-3 in each area for the sake of applicability.

The results of the individual stages of the analysis of climate change adaptation indicators are presented in Table 2. A sheet with the results of the parametric assessment is included in Annex 1 (available online).

Table 2. Results of the assessment of climate change adaptation indicators

Sector	Number of indicators		
	identified total	subjected to parametric evaluation	subjected to qualitative assessment
Agriculture	61	49	6
Energy efficiency	3	3	3
Energy infrastructure	16	16	7
Construction, spatial planning and housing	38	37	9
Transport	18	18	6
Nature protection and biodiversity conservation	77	74	15
Water management	50	39	17
Industry	17	17	5
Health	69	67	17
Tourism	14	11	4
Risk management and protection against risks	9	9	1
Total	372	340	90

Source: authors' work based on Broniewicz et al. (2021).

Based on the parametric and qualitative analysis, a set of indicators in each area/sector recommended for use in the process of designing legislation and assessing the effectiveness of this legislation in adapting society, the economy and the environment to climate change was developed (Table 3).

Table 3. Recommended indicators in the different areas covered by the analysis

Area	Indicator, unit	Methodology for determining the indicator
Agriculture	Yields of selected crops [decitons per hectare]	The yield of any crop is calculated as the ratio of the production volume in a given year and the area of the crop: $\text{Yield per hectare} = \frac{(\text{Production volume in decitons})}{(\text{Area cultivated in hectares})}$
	Area (percentage) of insured agricultural land [percentage, hectare]	Proposed crops: potato, spring wheat, spring and winter barley. The indicator is calculated as a percentage of the insured crop area in relation to the total crop area. It can also be used in absolute form (area of insured crops) if spatial comparisons are not needed. Proposed crops: total crops

Area	Indicator, unit	Methodology for determining the indicator
Energy efficiency	Energy consumption of the economy [kgoe / euro 2010 (constant prices)]	<p>The energy intensity indicator is calculated in general terms as the ratio of the amount of energy consumption to the amount of output, whereby the measure of output can vary depending on the level of measurement.</p> <p>For national and regional levels and economic sectors, the energy consumption of gross domestic product is an adequate indicator:</p> $\frac{\text{Primary energy consumption}}{\text{Gross domestic product}} \left[\frac{\text{kgoe}}{\text{euro 2010}} \right]$
	Household energy consumption per 1 inhabitant [GJ/person/year] [MWh/person/year]	<p>This is the broadest indicator that takes into account all energy consumption and all energy uses, i.e. the total new value generated in the economy.</p> <p>The indicator covers the total consumption of individual energy carriers in households, related to the number of inhabitants</p> <p>Household energy consumption per capita</p> $\frac{\sum E_i}{P}$ <p>where: E_i – energy consumption of the ith carrier in the area concerned, P – the population of the area concerned</p> <p>Electricity consumption per capita in households</p> $\frac{\text{Amount of electricity supplied to households}}{\text{number of inhabitants}}$
Energy infrastructure	System Average Interruption Duration Index SAIDI (for catastrophic interruption) [minutes / customer / year]	<p>The indicator is the sum of the products of the duration of blackouts (unplanned and catastrophic) and the number of customers affected by the blackout during the year divided by the total number of grid-connected customers:</p> $SAIDI = \frac{\sum_{i=1}^n U_i N_i}{\sum N_i}$ <p>where: U_i – annual length of catastrophic interruptions at group i customers (in hours) N_i – number of recipients in group i</p> <p>The length of the interruptions includes catastrophic breaks, i.e. longer than 24 hours.</p>
	Share of primary energy from renewable sources [percentage]	<p>The indicator includes energy: hydro, wind, solar photovoltaic, geothermal, biofuels (solid, gas, bioliquids, biodegradable municipal waste incinerated with energy recovery).</p> <p>Share of renewable energy in total primary energy production</p> $\frac{\text{Primary energy generated from renewable sources}}{\text{Total primary energy generation}}$ <p>Share of renewable energy in total electricity generation</p> $\frac{\text{Electricity production from renewable sources}}{\text{Total electricity production}}$

Area	Indicator, unit	Methodology for determining the indicator
Construction, spatial planning, and housing	Proportion of buildings and population in areas at risk of flooding [percentage]	1) Proportion of buildings in flood risk areas: $\frac{\text{Number of buildings in flood risk areas}}{\text{Number of buildings in total}} \times 100\%$ 2) Proportion of population in areas at risk of flooding: $\frac{\text{Number of residents in flood risk areas}}{\text{Total number of residents}} \times 100\%$
	Proportion of green areas in the urban environment [percentage].	Existing indicator – share of parks, greens and estate green spaces in total area. Proposed indicator – share of all urban green space (including lawns, wasteland, private gardens and unpaved properties).
Transport	Transport infrastructure at risk of flooding [percentage]	The indicator covers: road network at risk of flooding and rail network at risk of flooding, including road and rail bridges. $\frac{\text{Number of kilometres of roads and railways running through flood risk areas}}{\text{Total number of kilometres of roads and railways}} \times 100\%$
	Sections of national roads and railways closed due to extreme events [percentage]	The indicator is expressed as the percentage of sections of the road and rail network that are out of service as a proportion of the total length of the network. Optimally, it would be desirable to give an indicator taking into account the time when a section is taken out of service by road or rail, according to a formula: $\frac{\sum O_i t_i}{\sum O t} \times 100\%$ where: O _i – the length of the section where the traffic interruption occurred t _i – duration of traffic interruption in hours O – total length of roads/railways T – number of hours in the period under assessment.
Nature conservation and preservation of biodiversity	Fire hazard of forest areas [percentage]	The fire danger index is expressed on a 4-grade scale: grade 0 – no danger, grade 1 – low danger, grade 2 – medium danger, grade 3 – high danger (in accordance with the Regulation, 2006) $ZPL = \frac{\sum_{i=1}^n P_i D_i}{P \times 183} \times 100\%$ where: ZPL – forest fire risk i – prognostic zone number, P _i – area of the i-th forecasting zone D _i – number of days with high fire danger in the i-th forecasting zone during the monitoring period P – total area of the forecasting zones 183 – number of days in the monitoring period (1 IV to 30 IX)
	Number of alien species [Number of species]	The indicator is expressed as the number of alien species in a given year.
	Raised bogs degraded but capable of natural and stimulated regeneration [percentage]	The indicator is expressed as a percentage of the number of monitored raised bogs where there has been a change in: a) improvement, b) deterioration in terms of specific structure and function compared to the previous monitoring period.

Area	Indicator, unit	Methodology for determining the indicator
Water management	Water consumption per capita in households	Water consumption rate per capita.
	Surface area of retention areas [number of facilities] [dam ³]	Small water retention facilities: (1) number of facilities, (2) capacity It would be desirable to include areas of natural and small-scale retention (for example, channel retention, wetlands, flood valleys) and landscape retention (for example, maintenance of meadows and pastures in river valleys).
	Population in drought-risk areas [percentage]	The indicator expressed as a percentage of population in drought-risk areas requires a combination of spatial information on drought-risk areas and information on the number of people living in the area.
Industry	Industrial water consumption [hm ³ /year]	Production water consumption rate per year.
	Business support programmes for adaptation to climate change [thousands PLN (current prices); needs to be adjusted for inflation for comparisons over time] [number of projects]	An indicator captured in two dimensions: <ul style="list-style-type: none"> • the value of the resources allocated to support businesses in adapting to climate change, • number of enterprises that have received support in the area of climate change adaptation.
Health		The indicator monitors: (1) incidence, (2) number of hospitalisations, (3) percentage of hospitalisations. Incidence rate – number of new cases registered per year per 100,000 (or 10,000) inhabitants
	Incidence and hospitalisations due to vector-borne diseases resulting from climate change [number of people] [percentage]	$\text{incidence rate of disease } A = \frac{\text{Number of new cases of a disease } A \text{ in period } n}{\text{Population in the period } n} \times k$ where: k – a conversion factor to express the incidence rate in terms of the number of new cases per standardised number of persons in the exposed population, e.g. 10 000 persons, 100 000 persons (k=100 000 or 10 000) A – a disease for which the incidence rate is calculated n – a period of time (e.g. a year) Number of hospitalisations – number of people requiring hospitalisation Proportion of hospitalisations $\text{Proportion of hospitalisations} = \frac{\text{number of hospitalisations due to disease } A}{\text{total number of cases of disease } A} \times 100$
	Hospital admissions due to effects of hot weather [number of people]	Indicator expressed as number of hospital admissions due to effects of hot weather
Tourism	Accommodation in winter sports centres [percentage]	The indicator expresses the occupancy rate of total accommodation by county
	Percentage of funds under tourism support programmes that address adaptation issues [percentage]	Indicator – the percentage of funds under tourism support programmes that address adaptation issues is calculated based on the equation: $\text{indicator} = \frac{FA}{FC} \times 100\%$ where: FA – the amount of funding under tourism support programmes that address adaptation issues FC – total volume of funding under tourism support programmes

Area	Indicator, unit	Methodology for determining the indicator
Risk management and protection against risks	Losses avoided due to climate change adaptation measures [PLN (current prices)]	<p>The indicator represents the total value of the economic effects that will arise as a result of a given action. These effects are understood as the reduction or avoidance of losses that would have occurred if the action had not been taken, as well as the additional economic benefits that will arise as a result of the action. Where the design of an action would contribute to an increase in climate change losses, the indicator has a negative value.</p> <p>It is not possible to establish a common method for determining the indicator, for each specific type of project/project it will be necessary to establish an individual methodology for calculating this figure.</p>

Source: authors' work based on Broniewicz et al. (2021).

The recommended set of indicators is the author's proposal and results mainly from the selection criteria used. Two or three indicators were selected for each of the areas analysed. In most cases, one indicator related to climate change impacts or vulnerability, and one indicator related to adaptation in a given sector. In this way, it will be possible to capture in the ex-ante assessment of a legal proposal whether the regulation will have an impact on reducing the impacts of climate change and to what extent it will translate into adaptation measures and improved resilience to climate change.

Summary and recommendations

A review of adaptation indicators in the countries analysed showed varying progress in this area. Relatively the most advanced work appeared to be in the UK (Scotland), Germany and Spain. In none of the countries analysed is the issue of adaptation addressed in the RIA at the indicator level. Only in Germany, Finland and Lithuania is the impact on adaptation mentioned as a possible impact of the project.

The consideration of adaptation indicators in the development and implementation of climate change adaptation strategies and plans is reflected in the EAP regulation and in the new European Adaptation Strategy. Among other things, it calls for the provision of ex-ante assessment tools for projects to better identify the co-benefits and positive economic impacts of climate change adaptation and prevention projects (Communication, 2021a).

This study proposes a set of indicators to be used in the process of designing legislation and assessing the effectiveness of that legislation in adapting society, the economy and the environment to climate change. These indicators can be used for ex-ante assessment of the solutions proposed in the draft legislation in terms of the implementation of climate change adaptation requirements – both to determine the values of the indicators selected for a

given sector that are relevant to climate change adaptation and to monitor changes in these indicators to assess the effects of the implementation of the legislation in terms of the state's support for climate change adaptation.

The proposed indicators could be used in guidelines for the preparation of regulatory impact assessments, as part of the assessment of the impact of a given regulation. They should be treated as key indicators in each sector and should be accompanied by specific indicators, selected on a case-by-case basis according to the specific matter of the regulation. A further step should be the development of separate "Guidelines for the integration of climate change and adaptation issues in the regulatory impact assessment process". The guidelines would indicate the most common impacts that are likely to occur in a given sector. They would be particularly helpful for those sectors where climate change adaptation is not yet an obvious issue in Poland, such as health care or tourism.

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The contribution of the authors

The article is a collaboration between all authors without specifying the detailed contribution of each.

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