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Climate Risk Tools and Market Inertia in Dutch Real Estate

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LIST OF ABBREVIATIONS

CRA	Climate Risk Assessment
CREEM	Carbon Risk Real Estate Monitor
CSRD	Corporate Sustainability Reporting Directive
DCRP	Dutch Climate Risk Portal
DNB	De Nederlandsche Bank (The Dutch Central Bank)
DPSA	Delta Plan on Spatial Adaptation
DuPa	Duurzaamheidsparagraaf (Sustainability Section)
EAL	Expected Annual Loss
ECB	European Central Bank
ECB SREP	European Central Bank Supervisory Review and Evaluation Process
ESG	Environment, Social, and Governance Framework
EU	European Union
FCAB	Framework on Climate Adaptive Buildings
GDP	Gross Domestic Product
GHG	Green House Gases
GRESB	Global Real Estate Sustainability Benchmark
GREX	Grondexploitatie (Land development exploitation)
IPCC	Intergovernmental Panel on Climate Change
KNMI	Koninklijk Nederlands Meteorologisch Instituut (The Royal Netherlands Meteorological Institute)
LEED	Leadership in Energy and Environmental Design
PD	Probability of Default
RCP	Representative Concentration Pathway
SFDR	Sustainable Finance Disclosure Regulation
SME	Small and Medium Enterprises
TCFD	Taskforce on Climate-Related Financial Disclosure
UNEP FI	United Nations Environment Program Finance Initiative
VaR	Value at Risk

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Introduction

1.1 ABOUT THE RESEARCH

Physical climate risks pose material threats to the Dutch real estate sector and financial system. The 2021 Limburg floods generated €400 million–€500 million in insurable losses, yet only 40%–60% of Dutch property damage is privately insured, leaving households dependent on government compensation (Kok et al., 2023). One year later, drought reduced agricultural yields by 10%-30% for grass and drought-sensitive crops, directly impacting the €66 billion agricultural industry (6.9% of GDP) (De Molenaar, 2023). In 2024, climate hazards resulted in a total of €278 million in damages, with losses continuing to escalate annually (KNMI, 2025). Critically, one in three Dutch households cannot afford to cover flood damage costs, yet climate risk has only recently been added to mortgage underwriting and insurance pricing (NL Times, 2025). In the same year, a cluster of heavy rainfall events struck Enschede, forcing 80 residents to relocate to temporary accommodations and resulting in prolonged financial strain and uncertainty regarding insurance coverage (Louwes, 2024). These are not projections but recent events that have been reshaping investment decisions, insurance underwriting, and property valuations.

In response, physical climate risk assessment (CRA) tools have proliferated across the real estate sector, and Dutch real estate actors—investors, banks, insurers, developers, and municipalities—face a fragmented landscape. For example, many global tools classify the Netherlands as "high flood risk" without accounting for the flood protection measures that are in place while local/national tools use different methodologies, which prevents cross-city comparisons. This discrepancy in assessment methodologies is not limited to flooding but extends to other hazards that will be elaborated upon in this report.

This research addresses three core questions:

1. How do Dutch real estate actors currently select and use physical CRA tools across the different stages of the investment process?
2. What are the barriers to effective physical CRA tool adoption?
3. What improvements are needed for physical CRA tools to function as effective decision-making instruments?

1.2 RELEVANCE

Despite regulatory momentum, adoption remains uneven as only 36% of EU financial institutions have integrated climate risks into internal capital models (probability of default calculations) (UNEP, 2025). Although integration of physical climate risk in capital is increasing in reporting and supervisory frameworks, their influence on real estate capital allocation remains poorly understood in practice. At the same time, Dutch real estate actors report that using CRA tools selectively creates a fragmented landscape of physical climate risk assessment.

This research traces how regulatory expectations, tool design choices, and organizational workflows interact to shape when and how physical climate risk information enters real estate and financial decision-making. By documenting the market mechanisms through which physical climate risk is translated and the different stages of the investment process, this study clarifies where reforms are needed to align tool use with climate-resilient investment outcomes.

1.2.1 REPORTING FRAMEWORKS

Physical climate risk assessment has emerged as a critical operational requirement across European financial and real estate sectors, driven by converging regulatory mandates and methodological standardization. Some regulatory frameworks (e.g., CSRD, TCFD, or SFDR) increasingly demand that organizations not merely identify climate hazards but quantify their financial consequences. This shift from qualitative risk description to quantified financial impact represents a fundamental reorientation of how climate risks are priced into capital, valuation, and investment decisions. The frameworks mandate multi-scenario analysis across defined climate pathways (RCP 2.6, 4.5, and 8.5), with assessments spanning both medium-term (2030-2040) and long-term (2050+) horizons, creating a technical and methodological complexity that extends beyond traditional risk management.

Regulatory pressure to conduct these assessments conflicts with a structural data gap as standardized asset-level climate risk data remains scarce and fragmented across proprietary platforms, open-source tools, and consulting models. This mismatch between regulatory mandates and data availability has catalyzed the rapid adoption of CRA tools, not as optional analytical instruments, but as necessary compliance mechanisms. Moreover, the EU Taxonomy's explicit requirement to implement adaptation measures (rather than merely identify risks) repositions CRA from a defensive, backward-looking risk exercise into a strategic planning function that directly shapes investment criteria, asset valuation methodologies (as evidenced by DuPa 3.0 in Dutch real estate), and financial decision-making across the investment lifecycle (Arup, 2024; C40, 2018; Higuera Roa et al., 2025; Hubert et al., 2021, and Smithers & Dworak, 2023).

Data and compliance represent one challenge, but even when users utilize the same data and climate scenario, the variable CRA calculation methodologies yield varying results (Paisley & Nelson, 2025). This fragmentation of results and methodologies is one of the issues this research aims to address.

Understanding how Dutch real estate actors, financial institutions, and investors select, deploy, and integrate these tools into their workflows provides essential empirical grounding for assessing whether regulatory ambitions for climate-informed capital allocation can in fact be applied in practice, or if tool adoption will remain decoupled from substantive changes in underwriting, pricing, and investment discipline.

Table 1: *Different Sustainability Framework Reporting Obligations for Physical Climate Risk (National to Global Levels)*

Framework	CRA	Physical CRA Requirement
		Netherlands
DuPa 3.0 (Duurzaamheids-paragraaf). Dutch Real Estate Valuation Standard	Sustainability section	Property valuations must include an assessment of climate risks, including flooding, drought, and heat stress. Assessment is integrated into valuation methodology affecting asset values.
OER (Omgevings-effectrapportage - Dutch Environmental Risk Management). Dutch Environmental Planning Decree; Delta Programme on Spatial Adaptation	Municipal climate adaptation plans; spatial planning instruments	Municipalities assess physical climate risks (flooding, drought, heat, and waterlogging) in spatial planning and infrastructure planning in a multi-hazard risk assessment.
ERA (Environmental Risk Assessment). Dutch Environmental Impact Assessment Directive	Project/ plan-level assessments	Environmental risk assessment, including climate hazards and adaptive capacity of assets.
		EU Level obligations
CSRD (Corporate Sustainability Reporting Directive)	Article 8; ESRS E1 (Climate Change)	Double materiality assessment that addresses both financial materiality (risks affecting financial position, cash flows, and cost of capital) and impact materiality (environmental impacts on people/nature). Disclosure of physical climate risks and their financial impacts is mandatory.
EU Taxonomy (Regulation EU 2020/852)	Article 8; Annexes I & II	Robust climate risk and vulnerability assessment required for activities claiming adaptation contribution. Screening step to identify material physical risks; assessment step to evaluate magnitude; adaptation solutions required. Hazards include flooding, droughts, heat stress, wildfires, sea-level rise, and storms.

Table 1: *Different Sustainability Framework Reporting Obligations for Physical Climate Risk (National to Global Levels)*

Framework	CRA	Physical CRA Requirement
		EU Level obligations
ECB SREP (Single Supervisory Mechanism Review & Evaluation)	Expectation 11 (Scenario Analysis & Stress Testing); ICAAP integration	Banks must incorporate physical and transition climate risks into capital planning and stress testing. Scenario analysis must cover physical hazards (floods, droughts, and heat stress) over medium and long-term horizons. Materiality assessment is required.
SFDR (Sustainable Finance Disclosure Regulation)	Articles 7-9; Annex I (PAI indicators)	Financial market participants must disclose principal adverse impacts (PAIs) on climate, including physical climate hazards. Reporting on climate-related risks and opportunities affecting investment portfolios is also required.
		Global
Global Real Estate Sustainability Benchmark (GRESB) Real Estate Assessment	RM6.3 (Physical Risk Identification); RM6.4 (Physical Risk Impact Assessment)	Asset-level physical climate risk identification and impact quantification. Hazard screening (floods, droughts, heat, storms, and sea-level rise); vulnerability assessment; financial impact estimation. Climate resilience indicators were added in the 2025 update.
TCFD (Task Force on Climate-Related Financial Disclosures)	Strategy pillar; Risk Management pillar; Metrics & Targets pillar	Organizations must disclose actual and potential impacts of physical climate risks on business, strategy, and financial planning. Scenario analysis required inclusion of 2°C or lower pathways. Resilience assessment is mandatory and currently integrated into IFRS S2.
IFRS S2 (Climate-Related Disclosures) as part of ISSB Standard 2023 (replacing TCFD)	Risk Management core content; Metrics core content	IFRS S2 identifies, assesses, and discloses climate-related risks (physical and transition). The Risk Management section requires disclosure of processes to identify and assess material climate risks.

1.2.2 UNDERSTANDING CLIMATE ADAPTATIONS AND ACTIONS

This research endeavors to explain why climate risk assessment tools fail to translate identified risks into effective adaptation measures. While national and European frameworks increasingly quantify physical hazards, they primarily serve as risk documentation mechanisms rather than driving adaptation action. This highlights structural misalignment between assessment cycles, project timelines, and the financial needs of actors (Hubert et al., 2021; UKGBC, 2022). Therefore, it is essential to examine this science-policy gap by revealing the Dutch real estate market dynamics and clarifying how practitioners navigate between standardized CRA tools and local decision-making requirements.

The core contribution of this research lies in explaining why recognition of climate risk has not resulted in proportional action. It operates at the analytical junction of regulatory mandates for risk disclosure and persistent inaction. By documenting how transparent risk assessment is obscured by reductive methodologies and temporal mismatches, this research illustrates the mechanisms sustaining the recognition-without-action pattern observed across the Dutch real estate and finance sectors. This understanding is essential for developing adaptation policies that bridge the critical gap between risk identification and effective implementation (Hubert et al., 2021; Kuzma et al., 2023).

1.3 METHODOLOGY

This research employs a mixed-methods qualitative design conducted in two stages by combining systematic desk research with semi-structured interviews with Dutch real estate stakeholders. An analytical approach is used to establish what CRA tools are (Chapter 2) and then to examine both how practitioners use them and the barriers that constrain their effectiveness (Chapters 3-5). This progression from theory to evidence reflects the recognition that understanding tool ecosystems requires both conceptual rigor and practical grounding. The study then follows the pragmatic realism approach commonly used in policy research, which treats tools as embedded in institutional workflows, regulatory pressures, and financial incentives that shape their use patterns (Heeks et al., 2025; Imran, 2024).

The research conducted 26 semi-structured interviews with representatives from nine stakeholder groups in Dutch real estate: institutional investors (n=3), commercial banks (n=1), insurers (n=3), large developers and SME (n=5), real estate consultants (n=3), a municipal representative (n=1), a national government representative (n=1), tool providers (n=2), real estate investment managers (n=3), and homeowners (n=3). This stakeholder mapping approach prioritizes actors with direct decision-making authority over CRA tool selection and use. Interview subjects were identified through existing research partnerships or referrals from initial contacts and outreach. Interviews lasted 60 minutes and were structured around five thematic blocks: (1) organizational CRA workflows; (2) tool selection criteria; (3) integration into investment/underwriting/development decisions; (4) data gaps and limitations, and (5) perceptions of tool reliability and trust. The interviews were not recorded but written notes were taken and analyzed using qualitative coding software (Atlas.ti). The parallel desk research systematically reviewed four dimensions: regulatory frameworks, CRA tools and methodologies, sector context, and the specific context in the Netherlands, using academic literature, gray literature, and tools literature.

Data was analyzed using hybrid coding that combined deductive codes (i.e., standardization, transparency, and black box) with inductive codes emerging from data. All coded interviews were systematically analyzed to identify concordance across stakeholders, divergence between actor types, and the mechanisms by which tools influence decisions. Representative quotes as well as specific CRA tools features that reveal tool names were anonymized to ensure the confidentiality and neutrality of this report.

Interview findings were triangulated against desk research where interviews reported tool characteristics, desk research verified accuracy, and while desk research identified regulatory mandates, interviews clarified implementation barriers. This integration revealed critical gaps between regulatory assumptions (tool outputs are credible inputs for financial decisions) and practitioner experience (tools are approximate indicators).

Limitations of this research

This research has several limitations that constrain the extent to which its findings can be generalized beyond the studied cases and context.

First, it covers a limited subset of CRA tools mentioned by interviewees and found in documents, instead of a comprehensive sample of the market. Therefore, the analysis reflects a particular cluster of widely used policy-relevant tools but not all available CRA solutions in the market.

Second, the design is qualitative and interpretive; it relies on interviews and document analysis rather than systematic quantitative comparison of tool outputs. This foregrounds practitioner experience but limits statistical generalization and does not provide benchmark tests across tools on identical assets or scenarios.

Third, the stakeholder sample overrepresents large, climate-mature institutions and underrepresents SMEs and homeowners, meaning that less resourced actors' constraints and practices are only partially captured. Finally, the research is country- and time-bound to the Netherlands between 2025 and early 2026, during early CSRD and evolving ECB expectations, so it provides a situated snapshot and can in no way purport to be a timeless account in a rapidly changing field.

2

What are CRA Tools?

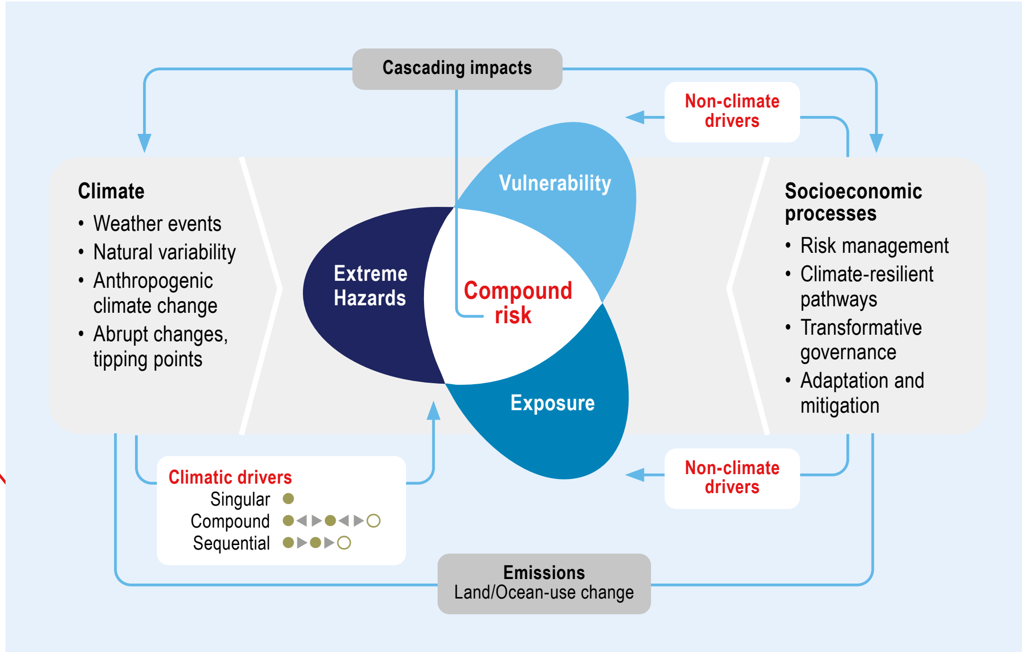
2.1 DEFINITION OF CLIMATE RISK ASSESSMENTS TOOLS

Climate risk assessment tools operationalize the conceptual framework established by the Intergovernmental Panel on Climate Change (IPCC), which defines climate risk as physical climate hazards combined with the exposure and vulnerability of assets, systems, and populations. In the context of real estate, CRA tools quantify or qualify the potential adverse impacts of climate hazards—such as flooding, precipitation extremes, heat stress, drought, and soil subsidence—on property values, financial returns, and operational viability (Arup, 2024; Palermo et al., 2025).

The IPCC framework distinguishes three interconnected dimensions. Hazard refers to the probability and magnitude of physical climate events (river floods with specific return periods, heat waves exceeding temperature thresholds, etc.) (Figure 1). Exposure applies to which assets, people, or systems are located in areas where hazards occur. Vulnerability encompasses the sensitivity of assets to hazard impacts and the adaptive capacity of actors to reduce or mitigate those impacts. For example, a building located in a flood-prone area has high exposure. If that building lacks either flood-resistant design or elevation above the expected flood levels, it is highly vulnerable. The combination of hazard probability, exposure, and vulnerability determines the overall climate risk (Kythreotis et al., 2024; Palermo et al., 2025).

CRA tools translate this abstract framework into operational instruments by combining spatial climate data (hazard maps), property-level information (exposure), and measures of structural resilience or adaptive capacity (vulnerability) to produce risk assessments that inform financial, insurance, and development decisions. However, the practical findings in the following chapters demonstrate that tool designers and practitioners interpret each framework component differently, creating divergence in how tools define, measure, and communicate risk.

Figure 1: *IPCC Framework for Climate Risk. One or several climate drivers can generate extreme hazards and cascading impacts, which, combined with non-climatic drivers that shape exposure and vulnerability, result in compound risks (IPCC, 2022).*



2.2 TYPOLOGY

Rather than a single standardized tool, Dutch real estate actors navigate a fragmented ecosystem of CRA instruments, distinguished across four key dimensions: access model, scale of coverage, hazard scope, and assessment output format. This typological diversity reflects both the technical constraints of and strategic choices by tool providers and users (see Table 2: Classification of Climate Risk Assessment Platforms for an overview and examples).

2.2.1 ACCESS AND GOVERNANCE MODELS

Open-source and public tools are mostly government-mandated or freely available platforms and guidelines developed by national or municipal authorities. These tools are valuable because of their methodological transparency, their alignment with official Dutch climate scenarios (KNMI23), and because local flood defenses (e.g., dikes and dunes) are explicitly embedded in their models. Open-source tools enable cross-city comparability within the Netherlands and are perceived as credible by local stakeholders and regulators. However, they face persistent data currency challenges as they require costly updates, which limits their forward-looking utility.

Global commercial platforms operate on subscription or licensing models and are typically developed by private firms that often have insurance or financial-service backgrounds. These platforms claim global coverage, incorporate multiple climate scenarios, and offer API integration into investor systems. However, they frequently operate as opaque systems where methodological details remain proprietary, and users may not fully scrutinize the data sources or computational logic underlying these platforms' risk assessments. For example, global commercial platforms often do not adequately incorporate local flood defenses or adaptation measures.

Hybrid or purpose-driven local platforms combine proprietary data with local and global public data and frameworks. While global platforms operate on licensing, these platforms adopt the "consultant" model as the users outsource the analysis to the platform creator. Therefore, the CRA is mostly done on a project-basis, a portfolio scan, a neighborhood level, or at the job-specific level. These platforms usually offer API integration and have their own methodologies and indicators (KPIs), which are typically accessible to clients for scrutiny when necessary. Although these tools appear transparent, the methodologies they employ are subject to debate among clients and experts.

Framework-based tools provide standardized methodologies that practitioners can apply using available public or private data sources. These frameworks, which are mostly open-source and developed by independent agencies, guide users through structured assessment processes but do not generate data. Instead, they specify how to combine hazard maps with building characteristics to produce comparable and transparent risk scores. The overall effectiveness of these tools depends on the quality and quantity of data as well as user interpretation.

In-house or customized models are developed by financial institutions or developers to align CRA with their specific decision needs, risk tolerance, and portfolio characteristics. Some of these tools construct quantitative expected annual loss models calibrated against historical insurance claims and data specific to building types (hotels, residential, commercial, and sports facilities). Others create simple qualitative scoring frameworks—sometimes as Excel tools—to assess climate adaptation, circularity, and nature on a project-by-project basis. In-house models offer flexibility and proprietary advantage but require substantial technical capacity and raise concerns about methodological rigor and comparability across organizations.

2.2.2 CRA TOOLS COVERAGE

CRA tools operate across multiple spatial scales as well, creating systematic misalignment between what is needed for initial screening and what is required for project-level decision-making:

Geographic Scale:

Area-level or location-based assessment delivers risk at the municipal, neighborhood, or postal code scale. These assessments identify regional climate exposure and are efficient for initial screening and portfolio-level risk profiling. Area-level tools typically use coarser spatial resolution (e.g., 90 m/grid cell for global platforms, 10 m-25 m for Dutch municipal tools, or 1 m-1 m for specific hazards) and provide categorical risk labels (e.g., very low to very high) rather than building-specific estimates. Investors and developers use area-level assessments as the first filtering step, often extracting risk information directly from municipal zoning plans, open-source public tools, or water plans that incorporate municipal climate stress tests.

Portfolio-level aggregation compresses asset-specific or area-level results into summary metrics (e.g., percentage of portfolio in high-risk areas and aggregate expected annual loss) suitable for regulatory reporting and investment committee communication. However, aggregation obscures which individual assets drive portfolio risk and can mask concentration in particularly vulnerable sub-portfolios.

Building-level or asset-specific assessment incorporates property characteristics (e.g., construction year, building height, and proximity to water) to refine risk estimates for individual structures. This scale is necessary for insurance underwriting, collateral valuation, and detailed adaptation planning, yet it introduces significant data collection burdens and requires specialized technical expertise. Global commercial platforms often do not provide building-level outputs, instead aggregating to portfolio risk profiles. However, the interviews reveal that even building-level assessments frequently ignore specific adaptation measures already implemented on properties (e.g., elevation, dry-proofing materials, and green roofs), resulting in risk estimates that do not reflect actual property resilience.

Hazard Scope:

The extent of methodological depth and rigor of CRA tools varies substantially, as do the climate hazards they assess:

Water-focused tools prioritize flooding in all its multiple forms: river (fluvial), rainwater (pluvial), coastal/sea-level rise, and groundwater hazards. This emphasis reflects both the unique hydrology of the Netherlands and the maturity of flood modeling relative to other hazards. Reinsurance market models have advanced flood differentiation in recent years, now distinguishing between rainfall-driven, river, and sea-level components rather than treating flooding as a single category. However, certain water hazards remain difficult to model or insure, for example, primary dike failure (impact too severe for insurance), or groundwater and foundation risk (location uncertainty violates insurance principles).

Multi-hazard tools assess four or more climate hazards alongside flooding: heat stress, drought, wildfires, earthquakes, hail, soil subsidence, biodiversity, and other hazards. The scope reflects regulatory requirements (the EU Taxonomy lists multiple hazards as material) and global applicability demands. Nevertheless, multi-hazard coverage frequently entails a trade-off in terms of depth. Drought assessment remains limited, and heat assessment in some tools relies on crude proxies (number of tropical nights) that do not translate well to commercial buildings with air conditioning, for example. Wildfires, earthquakes, and hail remain poorly modeled or absent in Dutch-focused tools, requiring users to supplement with separate assessments or to accept data gaps.

Biodiversity and compound risk extensions are emerging in newer tools, reflecting consultants' and municipal demands to assess climate risk alongside ecosystem services and other environmental factors. Although they aim to provide a holistic view of climate risks, these expansions can introduce methodological inconsistencies across domains as they do not allow for comparability, and their adaptation measures are still under scrutiny.

2.2.3 ASSESSMENT OUTPUT FORMAT

Tool outputs vary along a spectrum from purely qualitative risk labels to detailed quantitative financial loss estimates. This variation reflects different end-user requirements:

Qualitative risk scales present assessment results as categorical labels (very low, low, moderate, high, and very high) or stoplight color-coded visualizations (i.e., light green up to dark red). These outputs enable rapid categorization across large portfolios and are intuitive for non-technical audiences. However, qualitative scales obscure underlying assumptions and create ambiguity about what "high risk" means in financial or operational terms, although many actors do not ask detailed questions about scale definitions, accepting categorical labels as sufficient for portfolio-level decisions or home purchases.

Quantitative risk scores assign numerical ratings (i.e., very low-risk A up to very high-risk *F* or very-low risk 1 up to very-high risk 10) that combine probability and severity into comparable metrics. These scores facilitate benchmarking across assets and enable systematic decision rules (e.g., choosing to reject projects scoring F). Score-based systems can create a false sense of certainty by discarding the inherent uncertainties and vulnerabilities in climate predictions. Some tools aggravate this problem by failing to clearly differentiate between the likelihood of an event and the physical vulnerability of the assets. This ambiguity hinders stakeholder ability to distinguish between what they can mitigate and what they cannot control.

Financial loss estimates, including expected annual loss (EAL) calculations and market value impacts, quantify climate risk in monetary terms aligned with investor decision-making. EAL estimates integrate hazard probability, asset exposure, and

vulnerability into a single figure that represents the average annual damage cost. Market impact estimates capture potential losses in property value, business income, or insurance premiums due to climate risk. However, loss estimates introduce substantial methodological complexity and uncertainty; translating physical climate impacts into financial consequences requires assumptions about repair costs, market dynamics, and adaptive behavior that vary across regions and asset types. Several actors noted that EAL figures are useful but approximate, and they continue to rely heavily on professional judgment and qualitative assessment alongside quantitative outputs.

Adaptation cost and benefit analyses estimate the financial cost and risk-reduction effectiveness of climate adaptation measures (e.g., floodproofing and green infrastructure). Some frameworks require users to specify adaptation scenarios and model their risk reduction impact based on it. However, few available tools systematically quantify the change in risk after adaptation, leaving practitioners unable to build robust business cases for climate-resilient investments.

Table 2: *Classification of Climate Risk Assessment Platforms*

Access Model	Scale of Coverage	Hazard Scope	Output Format	Key Characteristics	Limitations	Typical Users	Examples
Open-Source / Public	Area-level (neighborhood, municipal, national).	Multi-hazard (i.e., flood, heat, drought, soil subsidence, windstorms, etc.).	Color-coded risk or hazard scale (very low to very high) represented in qualitative or quantitative spatial maps and dashboards.	Government-mandated, transparent methodology, locally calibrated (KNMI scenarios), incorporates flood defenses.	Outdated hazard maps and lack of building-specific adaptation measures.	Investors, consultants, municipalities, and developers (initial screening).	*Klimaateffect-atlas,* municipal dashboards and maps, and LIWO maps.
Commercial / Proprietary	Portfolio-level aggregation, optional building-level modules.	Multi-hazard (Global list of hazards, subset for EU).	Quantitative risk scores (A–F or 1–10 ratings); financial loss estimates (EAL); probability–severity matrixes.	Global coverage, multi-scenario analysis (RCP 2.6, 4.5, 8.5), API integration, and methodological documentation available.	Black box calculations, may not incorporate local flood defenses and difficulty translating to building-specific adaptation.	Global asset managers, large institutional investors, international real estate funds.	Climate X, Munich RE platform, Jupiter Intelligence, Moody's climate analytics, BlueLabel, and NL Green Label.
Hybrid / Purpose-driven	Project-based, neighborhood, and portfolio-scan level (job-specific assessments).	Multi-hazard tailored to local context (e.g., flood, heat, drought, soil subsidence, biodiversity).	Quantitative risk scores (A–F or 1–10 ratings); combination of spatial maps and dashboards with custom KPIs, scores, and narrative reports.	Mix of proprietary datasets with local, global, and public data and policy frameworks; analyses outsourced to the platform; API integration; methodologies and indicators accessible for client scrutiny.	Methodologies remain heterogeneous and subject to debate; limited standardization and cross-portfolio comparability; scalability depends on consultancy capacity and may be cost- and time-intensive for repeated use.	Municipalities, developers, institutional investors, and sustainability consultants.	BlueLabel, NL Green Label, Register *Duurzame Leefomgeving,* and NL Greenlabel.
Framework-Based / Methodology	Dual scale: area-level + building-level assessment.	Multi-hazard (flood, heat, drought, flooding, and rainwater).	Qualitative risk scales (very low to very high, color-coded), structured assessment protocols, adaptation recommen-dations.	Standardized assessment process, uses open-source or available data, guides users through vulnerability assessment, and integrates adaptation measure identification.	Effectiveness depends on input data quality; assessment proxies may misalign with different building types and user interpretation variability.	Sustainability consultants, asset managers, developers, and Dutch institutional investors.	FCAB (Framework for Climate Adaptive Buildings).
In-House / Customized	Building-level and/or portfolio-level (user-defined).	Variable (often water-focused initially, expanding to multi-hazard).	Quantitative loss models (EAL by building type; calibrated to insurance claims). Qualitative rankings; custom scoring systems.	Calibrated to organization-specific risk tolerance and portfolio composition, proprietary advantage, and aligned with internal decision processes.	Methodological rigor varies, limited cross-organizational comparability, requires substantial technical investment, and strong internal capacity required.	Large institutional investors, global asset management companies, and large-scale developers.	Investor/ insurer/ developer models calibrated to building type; Developer Excel-based scorers.

3

The Real Estate Investment Process

3.1 WHEN DO REAL ESTATE ACTORS USE THE CRA TOOLS?

Climate risk assessment tools do not function uniformly across the real estate investment cycle. Rather, they are deployed selectively at specific decision gates, with deployment patterns varying significantly by actor profile and portfolio scope. Understanding where and why CRA tools are used requires mapping the investment workflows that real estate actors follow. These workflows vary significantly by actor type and organizational structure. Investors more often conduct assessment primarily during screening and origination, relying on developer input and municipal compliance for ongoing management. Insurers may rely on their own claims data to provide insurance products and during contract renewals. Different tools and outputs are matched to different stages of acquisition, asset management, and disposition.

This chapter presents schematic diagram derived from interviews with institutional investors, banks, insurers, developers, and asset managers. As the investment process can vary per building type and location, this research focuses only on processes related to brownfields[1] within the city boundaries, while a greenfield[2] or other type of development may involve different processes and stages. These diagrams reveal that CRA tools operate at distinct points in the investment cycle: area-level screening during origination; building-level assessment during transaction due diligence; portfolio-level monitoring during asset holding, and standardized reporting during disclosure phases. After mapping these processes in sequence, the following chapters clarify how CRA tools are operationalized across the investment lifecycle, where their influence is most concentrated, and where the disparity between the capabilities of tools and the requirements of decision-makers is most pronounced.

[1] *Brownfields can be generally defined as previously developed land, either industrial or commercial, that is abandoned, underused, or derelict. It might also be contaminated and requires redevelopment for sustainable urban growth.*

[2] *Greenfields refer to undeveloped land, often in rural areas or on the edge of urban areas, that has never been built on before.*

3.2 CRA TOOLS THROUGH REAL ESTATE INVESTMENT PROCESS DECISIONS

3.2.1 INITIAL SCREENING (MACRO-LEVEL FILTERING)

CRA role: *Early risk flagging, location triage, and area-level risk categorization*
At the earliest stage, investors use CRA tools to identify high-risk geographies or sectors before detailed due diligence is carried out. This typically involves area-level assessments using publicly available tools, municipal stress test maps, or a proprietary tool. Investors assign risk scores to locations (for example, on a scale of 1 to 10) before progressing to quantitative analysis. This stage rarely results in outright rejection, but triggers negotiations and establishes a risk hierarchy that influences the subsequent depth of investigation and pricing expectations.

3.2.2 TRANSACTION DUE DILIGENCE (ASSET-SPECIFIC ASSESSMENT)

CRA role: *Building-level risk quantification, adaptation cost estimation, and contract term negotiation*
When acquiring or disposing of individual assets, investors conduct building-specific assessments to inform valuation adjustments, adaptation requirements, and contractual terms. The specific location hazards are then combined with the building-level attributes, which are usually compiled by property managers. In some cases, large-scale developers provide the building characteristics data after onsite investigation or after direct acquisition of data from a third party. Buildings are then classified according to their estimated risk profiles, which influence investment committee decisions.

3.2.3 PORTFOLIO MONITORING (RISK SURVEILLANCE AND COMPLIANCE)

CRA role: *Tracking risk evolution, identifying assets for upgrade or divestment, and informing strategic hedging and scenario planning*
Once assets are in portfolios, institutional investors conduct periodic portfolio scans ranging from quarterly property checks to annual comprehensive assessments. These serve both operational monitoring (identifying deteriorating risk profiles) and regulatory compliance purposes (feeding into TCFD and ESG reports). In maintenance terms, the costs of climate-adaptation interventions are combined with maintenance costs and are not explicitly stated as climate adaptation measures.

3.2.4 REGULATORY REPORTING (DISCLOSURE CYCLES)

CRA role: *Quantifying climate risk exposure, demonstrating alignment with TCFD/CSRD/EU Taxonomy frameworks, and justifying risk management practices*
CRA tool outputs are heavily utilized during mandatory reporting windows. GRESB portal openings, CSRD first reporting deadlines, or UK SDR entity-level filing deadlines create concentrated periods of tool usage. Asset managers incorporate climate risk results into annual investment proposals and investor communications.

3.3 THE REAL ESTATE INVESTMENT PROCESS IN MOTION

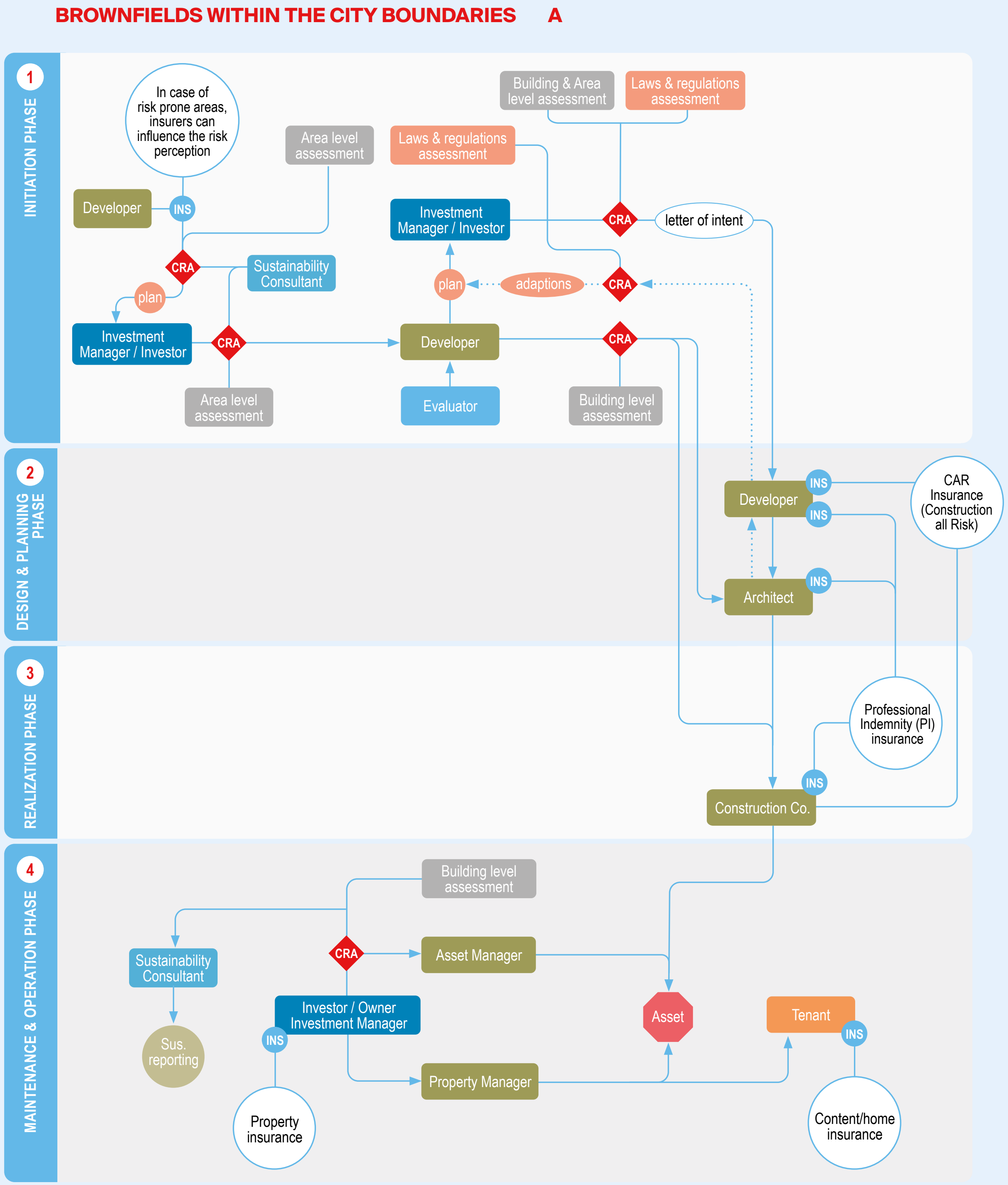
To simplify this complex and intertwined process, the real estate investment can be divided into four stages:

1. Initiation phase,
2. Design and Planning phase,
3. Realization (construction) phase, and
4. Maintenance and operation phase.

The duration of each phase is highly dependent on the scale of the project, the number of parties involved, and location negotiations. Most interviewees estimated that the first two phases could take between 3 to 5 years, while the duration of the following two phases was difficult to estimate due to the high degree of variation.

> *DISCLAIMER: These diagrams were based on interviews and, in some instances, are ideal and generic, and therefore may not accurately capture the intricacies of processes. Process steps can be executed in different ways, and the investment processes usually involves a greater number of actors.*

Figure 2: *Investor's Perspective of the Most Common RE Investment Process*



CRA = Climate Risk Assessment **INS** = Insurance Product **Req** = Investment Requirements
Inv. Plan = Investment Plan **Sus. Reporting** = Sustainability Reporting

Process A: The Investor Perspective

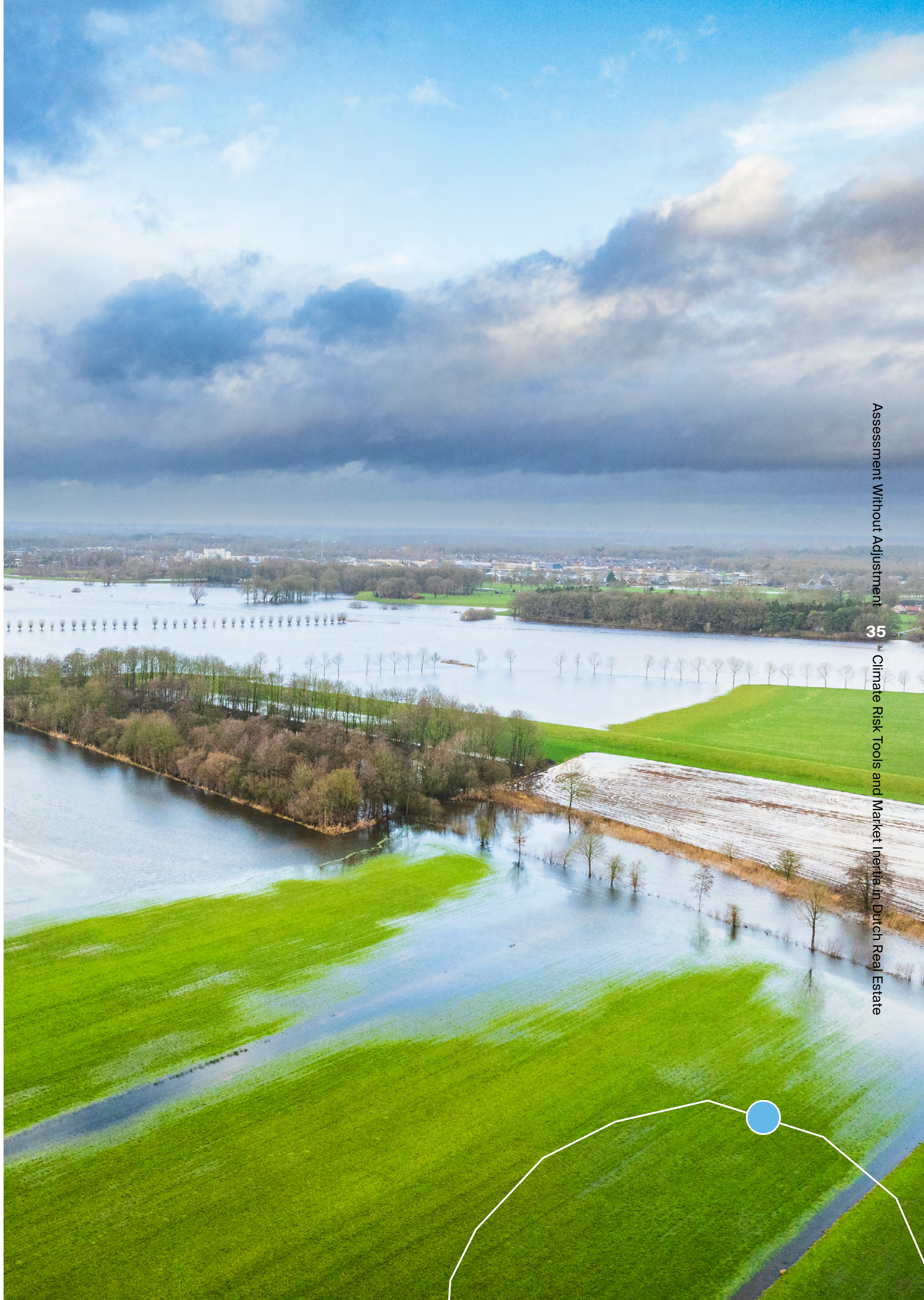
This diagram represents the most generic real estate investment process:

1. A developer with a development plan initiates the process. This plan has already undergone an initial climate risk assessment at the area level, contingent upon the developer's firm size.
2. The developer approaches an investor (or investment manager) with a real estate investment plan.
3. The investor (or investment manager) revises the plan and utilizes their Climate Risk Assessment (CRA) tool to conduct an initial assessment of climate hazards at the location level. This assessment identifies potential red flags and estimates the necessity of major climate adaptation measures on-site. In some cases, a real estate investment manager or a sustainability consultant performs this work on behalf of the investor.
4. Based on the initial CRA, the investor may request revisions to the original plan. In such instances, developers collaborate closely with their architects and relevant experts to implement "climate adaptations" if required. The new design is based on the applicable climate regulations.
5. The investor revises the plan using their CRA tool, incorporating a more thorough combination of location hazards with building-level assessments and necessary regulations, such as the municipal water plan *(waterparagraaf)*. This stage concludes with the issuance of a letter of intent to commence the development plan.
6. During the design phase, developers work with the design and development team to create all essential design elements of the project. This phase typically concludes with the acquisition of the necessary permits. For many developers, this marks the end of their involvement in the process, as a construction partner then assumes responsibility. In some cases, another department within the same real estate development firm or a sister company may take over, depending on the size of the firm.
7. The construction partner executes the designs, and the realization phase concludes with the transfer of a physical asset to the owner or the asset manager. The latter operates on behalf of the investor, owner, or real estate investment manager.

8. While the property manager manages the day-to-day operations of the asset, the asset manager is responsible for its “financial” performance. At this stage, the CRA is utilized to determine the maintenance costs.

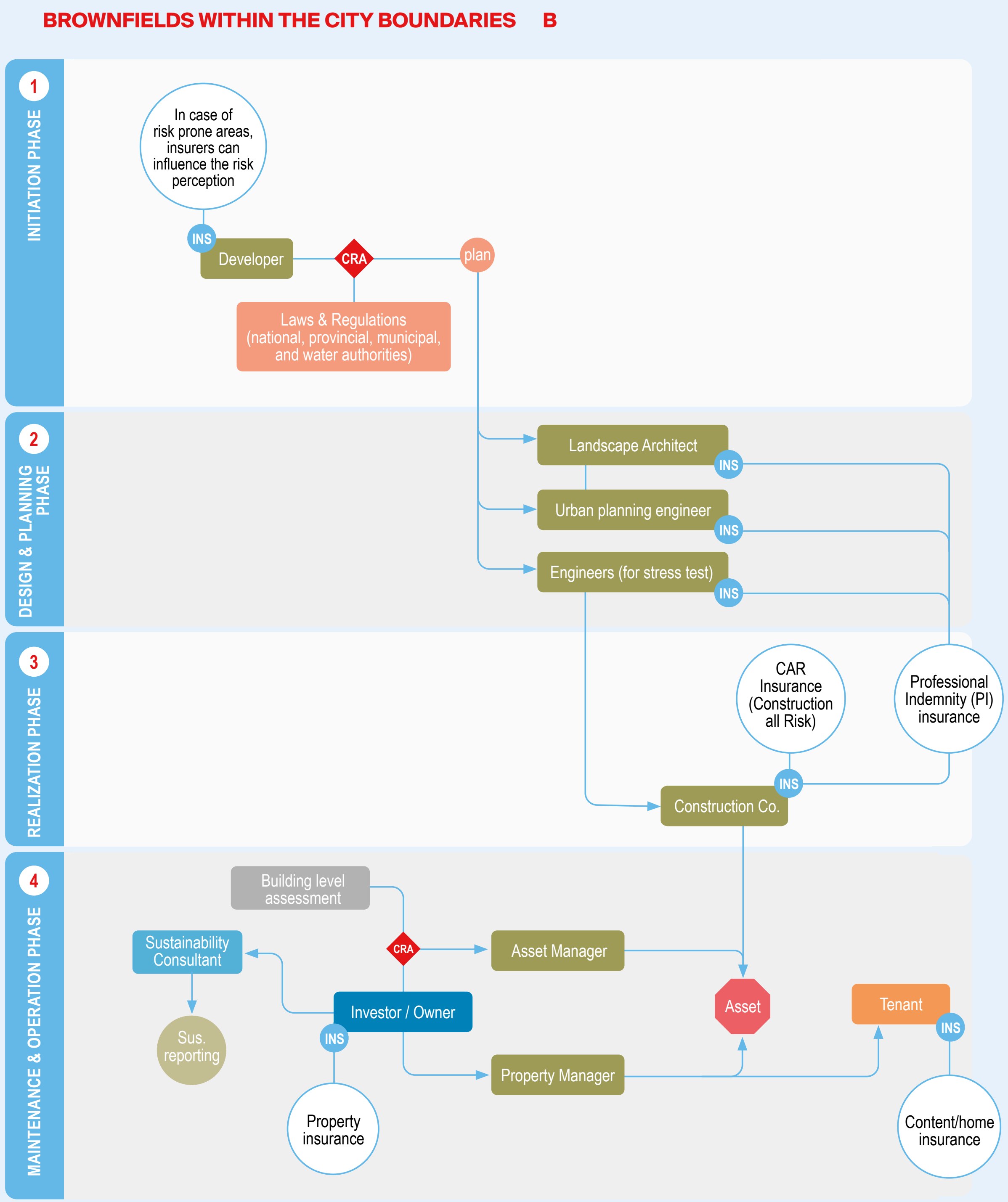
NOTES:

A. The sustainability consultant can be involved in the early stage and/or final stage to perform the CRA on behalf of the asset owner and include it in the asset owner's portfolio ESG reporting as well.
B. Insurers express their interest in participating at the earliest stages of plan development to indicate potential conflicts with climate hazards.
C. Appraisers *(taxateurs)* might be involved to suggest improvements to the asset points[3] to raise its value (het *WoningWaarderingsStelsel,* WWS).



[3] *The Housing Valuation System or Woning Waarderings Stelsel WWS is a Dutch points-based system used to determine the maximum (permitted) rent for a property. Higher points mean higher rent.*

Figure 3: *Developer's Perspective of the RE Investment Process*



CRA = Climate Risk Assessment **INS** = Insurance Product **Req** = Investment Requirements
Inv. Plan = Investment Plan **Sus. Reporting** = Sustainability Reporting

Process B: The Developer-initiated Process

This diagram represents a (large) developer's journey in the real estate investment process:

1. A developer acquires a potential brownfield that can be "upgraded."
2. The developer creates an investment plan while considering environmental requirements and climate hazards at the location. This involves aligning with regulations from municipal, provincial, and national frameworks.
3. In collaboration with an urban planner (advice on the GREX),[4] a landscape architect (advice on green and blue interventions), and engineers (for stress testing), the developer creates an investment plan and acquires the necessary permits.
4. The construction arm (or another company) takes over the realization phase and transfers the physical asset to the new owner of the asset or an asset manager. The latter works on behalf of the investor, owner, or real estate investment manager.
5. The realization phase ends with the hand-over of the asset to its new owner. While the property manager manages the daily operations of the asset, the asset manager is responsible for its financial performance. At this stage, the CRA is utilized to determine the maintenance costs.

NOTES:

A. The sustainability consultant can be involved in the early stage and/or final stage to perform the CRA on behalf of the asset owner and include it in the asset owner's portfolio ESG reporting.

B. Insurers express their interest in participating at the earliest stages of plan development to indicate potential conflicts with climate hazards.

C. Appraisers (taxateurs) might be involved to suggest improvements to the assets points to raise its value (het WoningWaarderings-Stelsel, WWS).

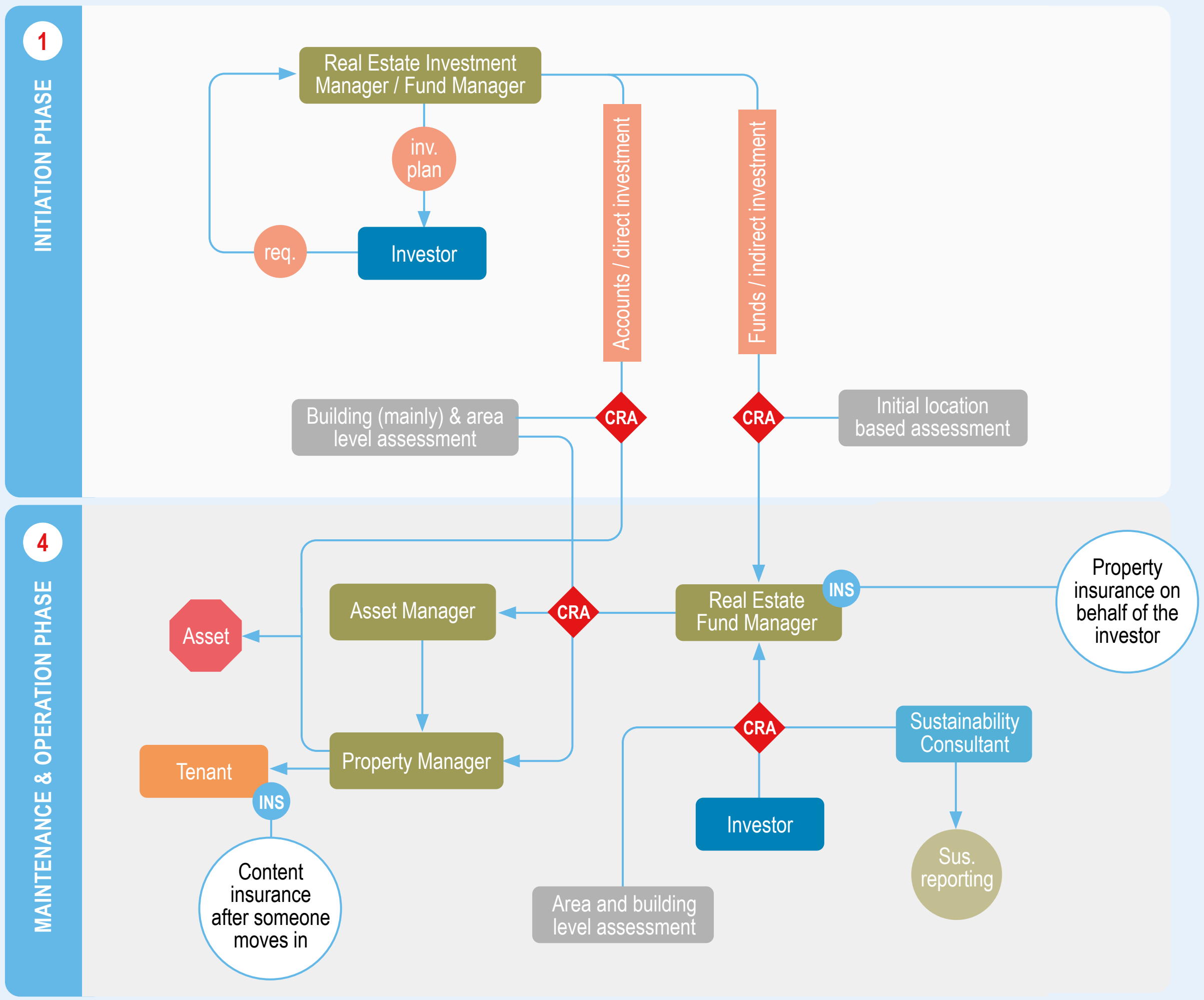
D. Climate adaptation (and mitigation) measures are sometimes called Value Addition but are not solely and explicitly treated as (part of) a risk aversion plan.

E. In some cases, developers and investors may establish a joint venture instead of a hierarchal relationship.

[4] *GREX is short for* Grondexploitatie, *(Land Development/Exploitation). It is a financial tool and budget used by municipalities and developers to map out all costs and revenues associated with spatial development projects, such as housing construction, infrastructure projects, or changes to zoning plans.*

Figure 4: *The RE Investment Process from an Investment Management Perspective*

BROWNFIELDS WITHIN THE CITY BOUNDARIES C



CRA = Climate Risk Assessment **INS** = Insurance Product **Req** = Investment Requirements
Inv. Plan = Investment Plan **Sus. Reporting** = Sustainability Reporting

Process C: The Investment Manager

This diagram represents a real estate investment manager/fund. It deviates from the previous cases mainly because phases 2 and 3 are skipped in this case, and instead it revolves around two possible routes of investments or a combination of the two:

A. Direct Investment/Accounts

1. An investment manager (IM) or fund manager proposes an investment plan to an investor. This plan encompasses existing assets within the manager's portfolio which have previously been assessed for climate risk. Alternatively, the manager may acquire potential assets on behalf of the investor. In less common instances, the investor directly requests a plan from the fund manager or investment manager.
2. Upon reaching an agreement between both parties, the IM conducts a (new) climate risk assessment of the asset and initiates the asset transfer process.

B. Indirect Investment/Funds

1. A real estate IM proposes an investment plan in which the investor acquires a share in a pool of assets known as Funds.
2. Upon reaching an agreement, the investor becomes a shareholder in a pool of assets, and the climate risk assessment is conducted on a portfolio level.
3. Simultaneously, the process involves both a property manager and an asset manager.

NOTES:

A. The sustainability consultant can be involved in any of the above stages and/or the final stage to perform the CRA and include it in ESG reporting associated with their client's portfolio.
B. Real estate IMs do not use insurance products, but Fund Managers do (on behalf of the investors).

4

How Stakeholders use CRA Tools

4.1 REAL ESTATE INVESTORS AND BANKS

Dutch investors and banks use CRA tools selectively across the screening, due diligence, and portfolio-monitoring stages. Climate risk informs pricing negotiations, adaptation requirements, and regulatory disclosures, yet remains bundled within broader financial risk frameworks. This selective use reflects a practical constraint: address-level climate data remains scarce for initial screening, forcing reliance on area-level assessments combined with qualitative developer input. As regulatory disclosures tighten, tool adoption will accelerate, but climate risk's influence on capital allocation decisions will depend on whether tools can quantify financial impacts and enable systematic credit term modifications that current platforms do not yet deliver.

4.1.1 HOW DO INVESTORS USE THE CRA TOOLS?

Investors and banks in the Netherlands integrate CRA tools across multiple stages of the real estate investment process. Interviews with institutional investors, pension funds, and banking representatives reveal a two-tier assessment pattern in which CRA tools serve primarily as screening and due diligence instruments within broader financial risk frameworks.

These financial actors use CRA in this order: area screening and origination, transactions due diligence, portfolio monitoring and stress testing, and regulatory disclosure and ESG reporting.

4.1.2 WHICH OUTPUTS DO REAL ESTATE INVESTORS AND BANKS PRIORITIZE?

These financial actors demonstrate clear preferences for outputs that integrate into existing valuation and reporting frameworks, though requirements vary by use case.

Risk Rating Scales and Loss Estimates

Expected annual loss estimates are valued by investors who integrate climate risk into financial models, but they enter investment practice through two distinct channels. One institutional investor with substantial internal modeling capacity uses in-house quantitative models to calculate EAL differentiated by building type (e.g., hotels, housing, sports facilities, and commercial buildings) and calibrated against insurance claims data. By contrast, a global real estate investment manager relies on a commercial platform that embeds EAL within an A-F rating for each hazard and for the overall building score, thus using this platform output rather than developing a separate EAL model in-house. While the United Nations Environment Programme Financial Initiative has highlighted difficulties in converting sustainability factors into conventional financial metrics as a persistent barrier to accurate financial risk estimates and has identified the translation of physical hazards into financial metrics as a primary challenge (UNEP, 2025), most investors in this study fall into the second category; they obtain EAL estimates from proprietary platforms and rating scores rather than constructing their own quantitative loss models.

Scenario Outputs

Regulatory frameworks increasingly mandate multi-scenario climate risk disclosure, with TCFD requiring 2°C-scenario analysis and ECB SREP expecting stress testing across 1.5°C-, 2°C-, and 3°C-pathways (Carney, 2017; ECB, 2022b). However, investor demand for scenario diversity varies. One Dutch-focused institutional investor expressed dissatisfaction with single-scenario outputs from open-source tools, requesting more pessimistic scenarios and forward projections under RCP 2.6, 4.5, and 8.5 trajectories to better model downside risk for a concentrated Dutch portfolio. By contrast, a global real estate investment manager accepted salinification with the multiple scenarios provided by their purchased CRA platform as sufficient for their 20- to 30-year investment horizon, prioritizing global coverage over scenario granularity. Many open-source tools still provide only single-scenario outputs, requiring manual user adjustments when investors seek additional perspectives.

4.1.3 WHAT DECISIONS ARE BASED ON CRA OUTPUTS?

Pricing and Negotiation

When tools flag high climate risk, investors typically initiate negotiations with their developers about adaptation measures rather than withdrawing from opportunities. One global real estate investment manager reported that high-risk assessments influence price negotiations, holding period assumptions (accepting longer payback periods for riskier assets), and contractual terms (demanding floodproofing or elevation requirements in coastal projects). However, not all climate hazards are equally negotiable. The same investor accepted heat risk as widely shared across the market, but another one drew a hard line on fluvial flood risk, stating that it is impermissible because it is beyond their control. Across investor types, high-risk flags rarely determine transaction approval outright. Instead, climate risk is weighed against expected returns, market conditions, and developer commitment to risk mitigation.

Portfolio Strategy and Asset Selection

Some institutional investors use CRA tools for strategic portfolio rebalancing, though this varies by portfolio scope. Real estate investment managers and direct investors often conduct climate risk assessments at asset sale to guide disposition decisions, along with initial screening and annual monitoring. This proactive strategy is limited to a minority of investors with geographically diversified portfolios and long-term horizons. More commonly, climate risk affects asset selection and regional concentration limits rather than causing forced divestment. Disposition decisions are usually based on multiple factors like market conditions and capital needs, with physical climate risk factors acting as modifying variables rather than primary drivers.

Regulatory Compliance and ESG Reporting

CRA outputs directly feed into IFRS S2, CSRD, GRESB, and EU Taxonomy disclosures, creating institutional pressure to adopt and operationalize CRA tools regardless of their direct influence on transaction-level investment decisions (UNEP, 2025). Several interviewees noted that CRA tools they purchased do not directly generate the required exposure metric for sustainability reporting, forcing reliance on internally developed models to aggregate asset-level results. This mismatch between tool design (portfolio-level risk assessment) and regulatory requirements (asset-level risk reporting) illustrates how, for many institutional investors, asset-level data needs currently drive (new) tool adoption rather than regulatory compliance.

Credit Terms and Collateral Valuation

Banks use CRA outputs to adjust loan-to-value (LTV) ratios, interest margins, and collateral valuations for climate-exposed properties. However, Dutch bank representatives acknowledged that these adjustments remain *ad hoc* rather than systematic, with physical climate risk often being conflated with energy efficiency metrics. According to the ECB, approximately 60% of banks in the European Union lack a well-integrated climate risk framework (ECB, 2022a).

4.2 REAL ESTATE INSURERS

4.2.1 HOW DO INSURERS USE CRA TOOLS?

Dutch insurers deploy climate risk assessment tools across three distinct functions: underwriting and premium calculation, portfolio risk management, and ESG/regulatory reporting. Unlike investors who conduct assessments periodically during transactions, large insurers perform climate risk assessments at contract initiation and then validate their portfolios every year. Some others add an extra layer of validation every three years by comparing results across different tools. This assessment frequency is influenced by regulatory constraints, as insurance supervisory regulations restrict contracts to one-year terms. However, insurers are increasingly seeking longer term risk visibility for strategic planning purposes.

Insurers distinguish between two modeling approaches: historical trend-based (probabilistic) models and impact-based models built on actual damage claims. Notably, no available tools combine both approaches. Large reinsurance companies can process historical claims data to quantify wind and flood risks for example, but smaller insurers struggle to model hazards beyond these categories using claims alone.

4.2.2 WHICH OUTPUTS DO INSURERS PRIORITIZE?

Risk Labels and Sectoral Classification

Insurers value qualitative risk scales (very low to very high, color-coded green to red) because they enable rapid triage across thousands of policies, with no further complicated financial or value translation. One insurer emphasized that qualitative methods help prioritize which business types or asset categories warrant deeper investigation. However, insurers face a critical tool limitation: inability to classify business sectors (i.e., mobility, agriculture, or hospitality) within risk models, forcing manual classification and reducing automation potential.

Forward-looking models used by Dutch insurers produce portfolio-level risk distributions but not asset-specific scores, creating a resolution gap as insurers need building-level outputs to price individual policies yet receive only aggregated portfolio risk profiles.

Hazard Coverage and Differentiation
Most available CRA tools provide limited hazard coverage according to the interviewed insurers. Re-insurance market models focus on storms and differentiated flood types, which is a recent improvement from earlier single-category flood modeling. Heat stress, wildfires, and earthquakes remain poorly modeled or absent. At the same time, some tools do not differentiate land surface types (sand vs. asphalt surfaces) even though land surface type materially affects pluvial flood and heat impacts. This contributes significantly to the insurance gap mentioned by Romao et al. (2025) as climate-attributable insured losses have grown at 6.5% annually (2012–2022), nearly doubling in a decade, yet catastrophe models have not kept pace with surface-level granularity demands.

"Climate risk is never a showstopper.”

Some existing insurance products embed climate risk in their premium (e.g., property insurance, construction all risks (CAR) insurance, and home contents insurance) rather than offered as standalone climate coverage. CAR insurance covers the construction phase and starts during detailed design, while property insurance is mandated by banks for mortgage lending. Critically, some climate hazards remain uninsurable, for example:
- Primary dike failures are uninsured because the impact is too catastrophic for insurers.
- Heatwaves are classified as life insurance, not object insurance.

Groundwater and drought-related hazards, such as foundation rot, are predominantly uninsured due to their predictability in many instances. The certainty of location conflicts with the uncertainty principles inherent in insurance (Doll et al., 2022).

Local Calibration Requirements
Dutch insurers insist on local scenario alignment by incorporating the latest KNMI'23 climate scenarios and Dutch flood management infrastructure or they are rejected outright. Global tools that classify the Netherlands as high flood risk without accounting for defenses are deemed unsuitable. Insurers also demand 25-meter to 50-meter resolution for climate risk maps, exceeding the 90-meter resolution that leading commercial platforms currently offer.

4.2.3 WHAT DECISIONS ARE BASED ON CRA OUTPUTS?

Premium Setting and Contract Terms
Climate risk does not currently alter the solidarity-based[5] premium system in the Netherlands, where premiums are calculated collectively nationwide rather than risk-differentiated by location. However, insurers include the location-specific climate risks in the risk-based premiums.

European evidence shows rising climate losses between 1980 and 2024; extreme weather events caused economic losses estimated at €822 billion in the EU, with over €208 billion (25%) occurring between 2021–2024 alone. Critically, only 19.5% of economic losses from these extreme climate events in the EU were insured (1980–2022), revealing a substantial climate protection gap (AON, 2025; European Environment Agency, 2025; Munich RE, 2026). Dutch insurers acknowledge the accelerating pace of damages but cannot yet systematically price it into premiums for solidarity-based frameworks. Nevertheless, the risk-based premium is determined based on historical claims in that location, which may not accurately represent the climate hazards specific to it.

[5] Solidarity-based insurance framework refers to the treatment of risk premium as the same across the whole of the Netherlands regardless of the site's physical attributes.

Contract Renewal and Adaptation Negotiation
When CRA outputs flag an asset high risk (red category), insurers negotiate with property owners to implement climate adaptation measures. If owners decline, insurers may decide not to renew the contract rather than charge higher premiums. Insurers have never rejected initial insurance coverage due to high climate risk, reflecting regulatory acceptance obligations, but non-renewal provides an exit mechanism for persistent high-risk exposures.

Early Involvement in Development
The underwriters expressed a desire to participate early in real estate development processes to advise on site-specific risks and avoid future claims escalation. However, whether this consultation is a paid service or aspirational remains unclear. This reflects insurers' dual role: many Dutch insurers also function as investors and mortgage lenders, complicating their responsibilities but simultaneously creating incentive alignment regarding long-term asset resilience.

4.3 REAL ESTATE DEVELOPERS (LARGE AND SME)

Real estate developers occupy a pivotal position between public planning frameworks, investors, and end-users, yet their use of climate risk assessment tools is highly uneven. There are small firms that do not use any dedicated CRA tool and rely instead on zoning plans, word of mouth, experts, and municipal ambitions. Some large developers integrate national climate maps, proprietary tools, inhouse tools, and stress tests into early feasibility and design decisions. Across various sizes, developers consistently report that climate risk is rarely the sole factor to render a project unviable; financial feasibility, environmental constraints (including nitrogen rules), and market demand remain more decisive.

4.3.1 HOW REAL ESTATE DEVELOPERS USE CRA TOOLS

During the interviews, one medium-sized developer disclosed that they did not utilize any CRA tools. However, they adhered to municipal and provincial climate adaptation and mitigation objectives. To evaluate locations, they employed a self-developed Excel-based framework to assess projects based on climate adaptation, circularity, and nature conservation, employing qualitative levels for scoring. Similarly, another developer in the same category did not use a dedicated CRA tool because they assumed that climate risks had already been addressed in the municipal environmental plans *(omgevingsplan[6])* and zoning plans *(bestemmingsplan).* Their site selection criteria instead emphasized regulatory feasibility, distance to Natura 2000 areas, and nitrogen emissions, while they obtained climate information indirectly through their personal relationships within municipalities or provinces.

Large real estate developers demonstrated more structured use of tools and data, especially at area level. One large residential developer reported a three-step process when acquiring land: first, they used public national climate risk maps and the Spatial

[6] The Environmental Plan (omgevingsplan) is a plan in which a municipality translates higher-level policy into concrete local rules. It is broader and replaces the older system of separate zoning plans (bestemmingsplan). The Environmental Plan can govern not only land use but also building and environmental regulations, water, soil, noise, and other local conditions that affect the physical environment. By law there is space in the Environmental Plan for climate risk requirements, but it does not automatically oblige developers to conduct a climate risk assessment unless another rule or the local Environmental Plan requires it.

Assessment Framework *(Ruimtelijk Afwegingskader)* to identify general area-level risks; second, they commissioned engineers to prepare initial designs that integrate municipal and waterboard requirements (e.g., storing 60 mm of rainwater on site), biodiversity objectives, and other spatial standards; and finally, they ran stress tests on the new design to compare it with the baseline situation. Another large developer combined the results of their proprietary tool with an in-house EU Taxonomy adaptation tool based on open-source methodologies to screen parcels quickly (e.g., using a postal code checker) before committing to a detailed design.

In the development process, it appears that developers typically start their CRA with publicly available national climate risk maps as a foundational layer. Subsequently, they incorporate their selection of either open-source or commercially acquired tools to fulfill both physical climate risk and broader sustainability objectives, particularly in larger projects.

Tool Simplification Imperative

Developers consistently express a preference for streamlined assessment processes that deliver actionable outputs without methodological complexity. This user group requirement has driven demand for tools that consolidate multiple data sources into unified platforms while maintaining scientific credibility. However, the tension between comprehensive risk characterization and operational simplicity remains unresolved, so many developers are willing to skip analytical depth in exchange for accelerated assessment timelines.

4.3.2 WHICH OUTPUTS DO DEVELOPERS PRIORITIZE?

Developers repeatedly emphasize the need for simple, decision oriented outputs rather than complex model documentation. For example, one medium-sized developer established an in-house framework that generates qualitative rankings of climate adaptation measures and categorizes them as basic, extra, or high-level. These rankings are utilized in internal discussions with design teams and municipalities. However, the firm acknowledged the limitations of this framework because of its inability to facilitate straightforward comparisons between projects or between different investment levels due to its predominantly qualitative nature. Small and medium developers express a clear preference for easy to read scores or traffic light style rankings over dense technical reports, particularly when the goal is to show investors the difference between implementing climate adaptations and doing nothing. Meanwhile, large developers using multi-hazard platforms highlight that cross-theme scoring across biodiversity, mobility, health, and climate dimensions is attractive because it leads directly to concrete design solutions.

Time and integration into existing workflows are also critical. One prominent developer's in-house adaptation framework is specifically designed to provide a practical climate assessment from a postal code entry within 20 minutes. This enables informed decision-making before the design phase, thereby facilitating the timely progress of the project. Developers stress that climate risk tools need to align with EU Taxonomy and ESG reporting templates so results can feed directly into financiers' ESG reporting while remaining simple enough that project teams do not become "*apathetic*" when faced with these complex processes. Although this concern primarily affects large-scale firms, it is increasingly relevant for small and medium-sized enterprises (SMEs) as they are integral to larger actors' real estate chain. Consequently, these investors are compelled to incorporate their suppliers' compliance into their ESG reporting.

"We check the water plan section in the municipality's zoning plans to see how risky the area is and if the developers' plans match."

Regulatory Compliance Metrics
The primary focus of the developer's priorities is to demonstrate compliance with regulatory requirements, rather than conducting a comprehensive risk assessment. This focus on compliance manifests through a preference for tools and methodologies that directly align with regulatory requirements. Notably, developers exhibit resistance toward climate-risk labeling systems, viewing these as potentially detrimental to asset valuation due to market misinterpretation of the underlying metrics. Their skepticism reflects broader concerns about how simplified risk communication might negatively impact property marketability and investor perception.

Climate Adaptation as Site Planning Constraint
Climate risk assessment outputs primarily inform spatial allocation decisions within development sites. When high physical climate risk characterizes portions of a development area, the standard response involves transferring high-risk zones to non-residential uses (typically green infrastructure or nature areas), while concentrating the built development on lower-risk locations. This approach reinforces a risk-avoidance behavior by treating climate adaptation as a site planning constraint rather than an opportunity for innovative resilient design.

> "For climate adaptation, you need to have adequate financial status."

4.3.3 WHAT DECISIONS ARE BASED ON CRA OUTPUTS?

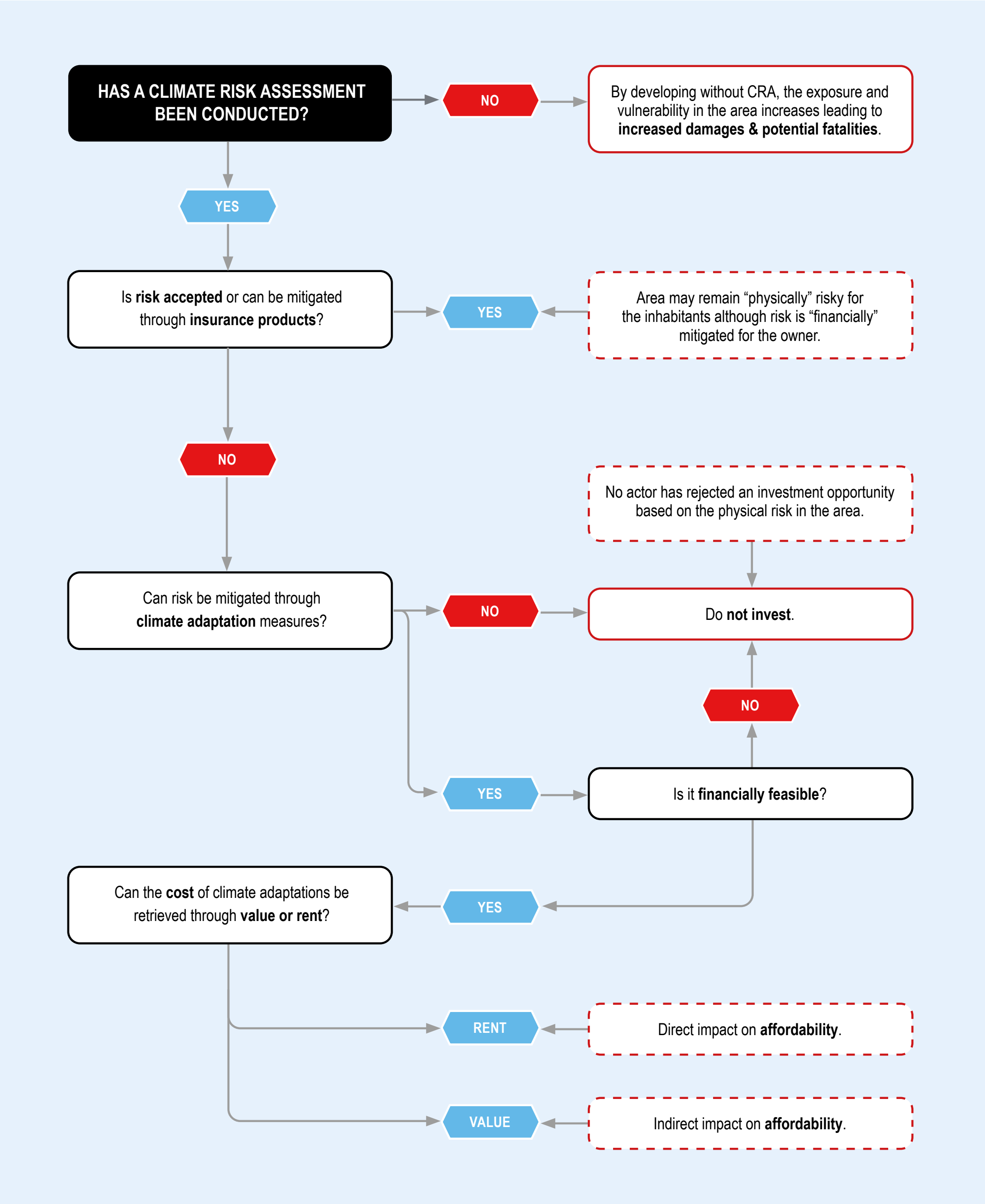
Prioritizing Climate Adaptation Measures
For developers, CRA outputs primarily influence how and where to build, not whether to build at all. Large developers describe using area-level assessments and stress tests to shape the spatial layout. One large area developer explicitly separates "space" adaptations (e.g., designing on-site storage for heavy rain events) from "technical" building-level measures, and uses climate assessments early on to test whether such measures can remain financially feasible within project budgets. Multi-hazard screening outputs are used to prioritize which adaptation measures should be taken immediately and which can be deferred to a later phase based on the composite scoring and the combined assessment of climate, biodiversity, or other factors.

CSRD Reporting Versus Local Adaptation
Finally, sector-level interviews reveal a structural tension between project timelines and adaptation ambitions. Some developers mentioned that they typically aim to commence construction within approximately five years of the project acquisition. However, climate adaptation negotiations with municipalities and water boards can extend beyond this timeframe, resulting in some projects either being dropped or having to scale back adaptation measures to avoid delays. In practice, many developers prioritize meeting corporate sustainability reporting-driven requirements and other national planning guidelines over exceeding minimum local adaptation requirements. This reinforces the current pattern in which CRA tools influence spatial design and compliance narratives but rarely drive transformative shifts in development locations. It also creates a disconnect between an organizations' reported climate awareness and the actual adaptive capacity embedded in their built environment.

One developer described their attitude to reporting versus adaptation as follows: *"We don't really assess the climate risk in the locations we acquire because we assume that the climate risk was considered in the environmental plan and the zoning plan ... Therefore, there should not be any climate risk if the government allowed building in that location."* This demonstrates the regulatory authority that municipalities wield through planning instruments, even when enforcement mechanisms remain limited.

Large Dutch developers reported performing stress tests in new development areas before and after the design phase to compare baseline conditions with new designs and assess whether adaptation measures can achieve the intended risk reduction. However, developers noted that *"climate adaptation discussions can take longer"* than their typical five-year development timelines, so that they *"sometimes have to skip climate adaptation measures"* to maintain project momentum.

Figure 5: *Financial Dilemma in Climate Adaptations. In the absence of a CRA during area development, assets and users are exposed to hazards, thereby exacerbating the damages resulting from the unassessed risks. At the same time, CRAs prompt climate adaptation decisions. Decisions on the extent of adaptation are significantly influenced by the project's financial performance, the developer's financial standing, and/or the return on investment.*



Financial Feasibility

At the same time, climate risk seldom leads to outright rejection of projects. Developers of all sizes stated that they had never declined a development solely due to climate risk. It appears that financial stability and meeting the growing housing demand are prioritized over climate considerations. Furthermore, developers assume that if municipalities grant environmental and zoning permits then the climate safety of the location is ensured. In contrast, one developer experienced a financial loss when the provincial government designated their newly acquired site as a flood retention area. This oversight occurred because the firm had not conducted a climate risk assessment, which underscores the potential pitfalls of relying solely on planning instruments.

4.4 REAL ESTATE SUSTAINABILITY CONSULTANTS

4.4.1 HOW SUSTAINABILITY CONSULTANTS USE CRA TOOLS?

Real estate consultants in the Netherlands deploy climate risk assessment tools on behalf of clients rather than for internal portfolio management, creating a service-driven model distinct from investors, insurers, or developers. The interviews revealed that real estate sustainability consultants perform assessments across at least five primary client-driven use cases: ESG and due diligence reporting, EU Taxonomy alignment, BREEAM certification support, general climate risk understanding, and TCFD/CSRD integration.

Some consultants operate with a dual-tool strategy for Dutch assets: local open-source tools for the Netherlands-based properties supplemented by global/international tools for global portfolios. This geographic segmentation reflects Dutch clients' strong preference for open-source, nationally standardized tools that enable cross-city comparability. Consultants tend to prefer national level maps for the sake of consistency rather than municipal climate risk maps that apply different methodologies in each city. They frequently outsource building-level assessments to specialized firms.

When regulatory compliance drives assessment requests, consultants face a temporal constraint: EU Taxonomy requires that once an asset owner or investor becomes aware of climate risk, they must implement adaptation solutions within five years. This

deadline transforms CRA from an informational exercise into a compliance trigger, creating urgency around both assessment timing and adaptation planning.

Large-scale real estate sustainability consultants perform extra validation for their assessment results, meaning that they depend on several resources rather than one CRA tool. This quality control step is absent from investor and insurer workflows. If discrepancies emerge, consultants further investigate publicly available maps to confirm whether risk remains elevated. This validation reflects consultants' reputational exposure: unlike internal investor assessments, consultant reports circulate to external auditors, regulators, and transaction counterparties, demanding higher defensibility standards.

4.4.2 WHICH OUTPUTS DO CONSULTANTS PRIORITIZE?

Risk Scales and Adaptation Recommendations

Consultants prioritize outputs that translate directly into client deliverables. The most delivered format is a qualitative scale from very low to very high physical climate risk, color-coded from green to red. This simplicity aligns with investors' sophistication levels: most consultants reported that clients and their investors do not request detailed explanations of what "high" or "low" risk entails as this categorical label suffices for portfolio-level decisions. However, consultants must combine risk ratings with adaptation cost estimates to satisfy EU Taxonomy requirements. By using a local CRA tool that recommends adaptation measures, they integrate these with their risk labels to develop implementation roadmaps, enabling the consultants to show their clients how climate risk can be reduced within the five-year compliance window. This dual output—risk assessment plus actionable risk mitigation pathway—distinguishes consultant deliverables from investor or insurer outputs that focus primarily on risk quantification.

4.4.3 WHAT DECISIONS ARE BASED ON CRA OUTPUTS?

Client Transaction and Holding Decisions

Sustainability consultants report that their clients increasingly reject investments due to transition risks (non-conformity with CRREM pathways or TCFD requirements) rather than physical climate risk. This trend reveals a hierarchy of risk concerns because regulatory non-compliance has immediate consequences (i.e., inability to access green finance or BREEAM rating downgrades), while physical climate risk remains contingent and temporally distant.

When assessments flag an asset as high risk, consultants recommend adaptation measures, but client implementation depends on financial feasibility and investor demands. Developers avoid climate adaptation measures unless investors explicitly require them, prioritizing project profitability over voluntary resilient investments.

Regulatory Reporting and Compliance

Sustainability certification like the Greenlabel Standards Area Label or, more internationally, BREEAM provide another compliance-driven use case. Consultants conduct climate risk assessments to help clients earn BREEAM credits under the Resilience category, which evaluates both adaptation to climate change and design durability. BREEAM's five-level rating system (from Pass to Outstanding) creates competitive pressure because higher ratings increase asset value and ESG appeal (BREEAM, 2025).

Informing Liquidity Reserves
The advice that consultants give to banks and asset owners based on climate risk assessments inform the liquidity planning. Institutions should maintain cash reserves to respond to climate events rather than relying solely on insurance or physical adaptation. This financial cushioning approach reflects uncertainty about insurance availability and the effectiveness of climate adaptation measures.

4.5 MUNICIPALITY

4.5.1 HOW DO MUNICIPALITIES USE CRA TOOLS?

Dutch municipalities deploy climate risk assessment tools primarily to fulfill mandates under the Delta Plan on Spatial Adaptation (DPSA), which requires all local governments to conduct standardized climate stress tests and develop implementation agendas. Whereas investors and insurers assess climate risk for individual assets or portfolios, municipalities use CRA tools for territorial planning and mapping climate vulnerabilities across entire jurisdictions to guide zoning decisions, infrastructure investments, and development permits (MoIE & MoEA, 2017).

Large municipalities usually conduct stress tests that combine publicly available national data with locally refined datasets. The municipality of Amsterdam, for example, has created its own Climate Adaptation Dashboard website which shows results from stress tests (mainly for heat stress and short-term extreme rainfall), while using national government maps for flood risk. Amsterdam's flood risk metric uniquely combines water depth with the percentage width of water coverage relative to building location, although each department within the municipality uses different tools under the coordination of a central Climate Adaptation Program.

Municipal CRA workflows integrate climate risk into multiple planning instruments. Climate stress-test outputs inform environmental visions *(omgevingsvisies)*, zoning plans *(bestemmingsplannen)*, and water plans *(waterparagrafen)* that developers and investors must consult before initiating projects. Multiple developers and investors interviewed noted that they rely heavily on municipal zoning plans and water plans to determine climate risk, effectively outsourcing initial risk assessment to municipal authorities rather than conducting independent

evaluations. One investor stated: *"We check the water plan section in the municipality's zoning plans to see how risky the area is and if the developers' plans match."* This reliance positions municipalities as gatekeepers of climate risk information, though it also creates dependencies: when municipal maps are outdated or incomplete, downstream actors inherit those data gaps. This is especially true for smaller municipalities that lack the capacity and means to create their own climate risk metrics. In such cases they would be relying on provincial zoning plans, general national-level guidelines (i.e., *Landelijke maatlat*), or even the ambitious plans of the real estate developer.

4.5.2 WHICH OUTPUTS DO MUNICIPALITIES PRIORITIZE?

Spatial Risk Maps and Hazard-Specific Metrics

Municipalities prioritize geospatial outputs that visualize climate risk across their districts. For example, Amsterdam decides on climate adaptation interventions based on its municipal climate risk maps. These maps incorporate the hazard data with vulnerability, exposure, and adaptability data in one score. Here, the short-term rainfall vulnerability data which results from stress tests

> "I didn't want to live anywhere else than this location and I had to accept the risk, whatever it was."

differentiate between land surface types—rainwater calculations differ for rain falling on green areas versus asphalt—reflecting municipal responsibilities for public space management. For urban heat risk, the city includes building characteristics (mainly building height) to determine shading effects. The result is then combined with socio-economic indicators and public-space specifics to show the final score, ranking neighborhoods from high risk (red) to low risk (green). This granularity exceeds what most commercial tools provide and reflects the operational precision that municipalities require for infrastructure planning.

Unlike investors who receive categorical risk labels (A-F scales), municipalities require quantitative metrics to design interventions. For flood risk, municipalities use depth estimates (in centimeters) and return periods (1-in-30, 1-in-50, 1-in-100-year events). Sometimes digital twinning is also used to detail climate risk assessments, adding sewage system capacity to flooding calculations and tree species specifications to heat models. However, performing stress tests for drought risk remains complex and challenging, revealing persistent methodological gaps even in advanced municipal assessment programs.

4.5.3 WHAT DECISIONS ARE BASED ON CRA OUTPUTS?

Zoning and Development Approval

Climate risk maps directly impact municipal land-use decisions through the *Ruimtelijk Afwegingskader* (Spatial Consideration Framework). This framework categorizes land into zones ranging from 0 to D, with “preferred development areas” (labeled as gray 0) and “no, unless” areas (labeled as red D) which require additional justification and risk mitigation measures. However, interviews with developers reveal that even "no, unless" zones (marked as purple D in the framework) remain open for construction if adaptation measures are incorporated. Political and housing-supply pressures limit municipalities' ability to enforce strict exclusions based solely on climate risk, particularly given the Netherlands' acute housing shortage.

One large developer stated: *"We build on all six areas and colors defined in the framework, even if they are 'no, unless' areas. The purple zones in the Spatial Consideration Framework are also okay for us to build in."*

Municipal zoning plans incorporate water plans *(waterparagrafen)* that specify which flood management requirements developers must meet to obtain building permits, such as requirements to retain 60mm of rainfall per hour on-site to be discharged at a rate of 1 mm/h in Amsterdam. Developers consistently check these water plans to understand climate risk expectations, treating them as more authoritative than independent assessments.

Infrastructure Investment Prioritization
Municipalities use stress tests at multiple project stages, and their climate risk outputs are used to prioritize capital investments in green-blue infrastructure, sewer upgrades, and public space redesign. Amsterdam's coordinated approach involves multiple departments within the municipality and the waterboard, creating specialized climate risk maps without using externally purchased CRA tools. This reflects municipal capacity disparities: larger cities like Amsterdam and Rotterdam develop their own high-resolution maps, while smaller municipalities rely entirely on national datasets (Amsterdam Weerproof, 2024; Rotterdam WeerWord, 2025).

4.6 HOMEOWNERS/HOMESEEKERS

4.6.1 HOW DO HOMEOWNERS AND HOMESEEKERS USE CRA TOOLS?

Dutch homeowners and homeseekers represent the least systematic users of CRA tools among all stakeholder groups. Unlike professional actors who integrate CRA into structured workflows, homeowners conduct *ad hoc,* self-directed assessments through publicly available maps and simple internet research.

Survey data from Funda's[7] 2025 research among platform visitors indicate that only about 20%-30% of respondents are currently worried about climate risks for their own home. The majority are not concerned, usually because 73% believe their residence is not in a risk area and roughly a quarter consider the risks or potential damage to be minor. At the same time, more than half of active homebuyers say they do take climate-related risk factors into account during their search, which indicates a gap between homeowners' low perceived risk and buyers' more forward-looking attention to specific hazards (Funda, 2025).

Climate risk assessment typically occurs late in the home-buying process, often after bidding or even purchase, reflecting the intense pressure of the Dutch housing market, where competitive bidding leaves minimal time for thorough due diligence. Multiple interviewees prioritized location over risk avoidance, with some acknowledging that their enthusiasm for specific properties overrode risk considerations. This reveals that location preferences and market dynamics consistently override climate risk concerns in home-buying decisions.

The 2021 Limburg floods appear to have heightened climate risk awareness among some buyers. One homeowner reported looking for flood maps in their neighborhood after these floods. This behavior reflects a pattern of increased interest following raised awareness among buyers and owners. A Dutch Central Bank survey showed that at-risk homeowners became more aware of flood risk between 2021 and 2023, with 17% of at-risk owners identifying floods as the main threat to their property in the second survey round compared to previous lower levels (Jansen, 2023).

"I didn't consider any climate risks when we were looking for a home. I think if you consider climate risk in your search for a home you end up shooting yourself in the foot."

In practice, homeowners and buyers rely almost exclusively on simple, publicly available web tools rather than specialized CRA platforms. Based on the interviews, most homeseekers who checked climate risk reported only looking at elevation or flood maps before purchase, typically as a one-off search near the end of their house-hunting process. This narrow, map-based use contrasts with the multi-tool, multi-stage CRA workflows seen among institutional investors and insurers.

4.6.2 WHICH OUTPUTS DO HOMEOWNERS AND HOMESEEKERS PRIORITIZE?

For this group, usability and concreteness are of greater importance than methodological details. Public risk maps that clearly delineate risk areas for flooding or foundation issues, complemented by straightforward qualitative indicators of risk level, constitute the primary outputs that households may consider. Real estate professionals interviewed by Funda stress that buyers and owners want property-specific information that answers intuitive questions (Funda, 2025), underlining a desire for clear recurrence-interval style metrics rather than abstract climate scenarios. Beyond hazard visualizations, homeowners value highly practical outputs such as checklists for identifying signs of

[7] Funda is a leading online real estate platform in the Netherlands for buying, selling, and renting homes.

foundation damage (e.g., uneven floors, sticking doors, and cracks in walls or windows) and concrete adaptation tips like keeping valuables out of basements in flood-prone areas. Compared with professional users, they show little interest in complex scores or loss models, but strong interest in actionable, building-level guidance.

4.6.3 WHAT DECISIONS ARE BASED ON CRA OUTPUTS?

Limited Influence on Purchase Decisions

Despite checking climate risk information, homeowners rarely reject properties based on assessment findings. Instead, they prefer to manage identified risks through expert consultation or adaptation measures after purchase. Research indicates that homes in flood-prone areas with expected subsidence exceeding 10cm by 2050 sell for only 1.5% less, suggesting climate risks remain insufficiently reflected in market prices (Deelen et al., 2025; Hofmann et al., 2025).

"My enthusiasm for some houses made me disregard the risk value in my bid so I made a high offer regardless of my knowledge of the risk because I wanted to buy this specific house."

Absence of Intermediary Guidance

Climate risk receives no attention during the transaction process from banks or property valuators. All the homeowners interviewed indicated that their real estate agent, bank, and valuators never disclosed any climate-related risks to them during the property transactions. Furthermore, these homeowners expressed uncertainty regarding whether their insurance policy covered flood damages. This information gap is deep as more than 40% of Dutch consumers mistakenly assume flood damage is covered by insurance, while homeowners express uncertainty about actual insurance coverage for climate-related damages (AFM, 2023).

"I assessed the climate risk only after bidding for the house. I only had a 3-day window between the bid and final offer to check everything about the house."

5

Dutch Real Estate Market Realities

This chapter delves into the perspectives of Dutch real estate actors regarding the perception, selection, and utilization of climate risk assessment tools, without addressing the design or evaluation of adaptation strategies themselves. When adaptation measures are discussed, they are framed as downstream applications of climate risk analytics rather than the core object of analysis.

5.1 DECISION-TRIGGER HAZARDS

In this report, a decisive climate hazard is one that is prioritized in the climate risk assessment process, and if the risk associated with this hazard is high, a decision must be made. This aligns with the IPCC framework, which defines high-risk hazards as those combining both high probability and high impact. In practice, 47% of municipalities globally identify at least one such high-risk hazard, with corresponding adaptation actions being implemented for 67% of these cases (Palermo et al., 2025; Treville et al., 2025). Therefore, it is important to examine these decisive hazards from an agent perspective.

Flooding and rainfall emerge as the climate hazards most consistently described as decisive across Dutch real estate actors. This pattern mirrors broader European findings where flood/sea-level rise accounts for 23% of vulnerabilities for the buildings sector and heavy precipitation represents 17%. Globally, floods appear in 78% of municipal risk assessments and droughts in 79%, although Dutch actors prioritize water-related hazards even more strongly due to the country's topography (Treville et al., 2025). Financial actors and consultants repeatedly single out various forms of water hazards (fluvial, pluvial, and sea level rise) as the hazards that most directly influence location choices, design requirements, and insurance terms. For insurers, rainfall is explicitly named as the most decisive hazard because of the increasing frequency and scale of damages observed in recent years. However, flood risk tolerance varies by investor profile. One Dutch institutional investor managing renovation projects drew a hard line, stating that flood risk is unacceptable because it is *"out of our hands, destructive, and we cannot take measures to reduce it,"* while heat risk is tolerated because it is widely shared across the market. In contrast, global investment managers negotiate flood risk through adaptation requirements rather than outright rejection.

This reveals that the level of risk that investors are willing to accept is relative to their peers, and their perceived ease of mitigating that risk significantly influences their investment strategies.

Heat and drought receive more mixed attention. Several developers consider heat important, particularly those working on urban densification and city centers. However, other developers and some investors treat heat and drought as secondary, noting that they do not directly damage buildings in the same way as flooding. Consultants point out that heat risk is especially relevant for commercial buildings with air conditioning and for specific vulnerable user groups (e.g., senior housing), while foundation rot from drought is mainly a concern for older buildings. Treville et al., 2025 confirms that for food and agriculture sectors, droughts constitute 20% of vulnerabilities and extreme heat 17%; while for water supply, droughts account for 30% of vulnerabilities, suggesting sectoral rather than universal importance. Insurers confirm that heat is often excluded from their models and from object-level property insurance and is instead treated as a life-insurance concern.

Beyond the four core hazards (flooding, rainfall, heat, and drought), several actors mention additional risks that are either underrepresented in current tools or considered decisive in specific contexts. Investors express a need for better data on earthquakes and wildfires, which are not well covered in Dutch tools. Several developers (especially those working outside the Randstad region) highlight biodiversity loss as increasingly decisive, even though it is not on the classic climate-hazard list. Some developers mention nitrogen emissions as a de facto decisive constraint, even though they are considered a transition risk rather than a physical climate hazard.

For homeowners and homeseekers, flooding dominates risk perception almost entirely. Most interviewees in this group checked only elevation or flood maps before buying, and some explicitly stated that flooding was *"the worst"* hazard while they saw heat as a future or age-related concern. Funda's 2025 survey of Dutch homeowners confirms this pattern: 70% of home buyers are aware of foundation problems and 58% consider flood risk during their search, indicating a perception gap between owners (retrospective) and buyers (forward-looking. Many actors check foundation risk and subsidence although these risks are often not labeled as "climate risk." This narrow focus contrasts with the broader hazard lists used by professional actors and suggests that public tools and communication may reinforce flood-centric perceptions while underplaying heat, drought, and other compound risks.
In conclusion, in a low-lying country such as the Netherlands, water-related climate hazards are inherently significant. However, the decisive hazards are highly contingent upon the asset's location, type, year of construction, and user group.

5.2 TOOL TRANSPARENCY

What Is the Black Box?

Black box models describe systems where internal mechanisms remain hidden, leaving only inputs and outputs visible to users. In climate risk assessment, this manifests as tools where methodological logic, computational processes, and parameter assumptions are concealed, proprietary, or too complex for end-users to scrutinize. Opacity is now systemic in contemporary CRA. Arribas et al. rank transparency as one of three critical effectiveness constraints, tracing this to the financial sector's reliance on proprietary tools developed by service providers competing through methodological secrecy rather than transparency (2022). This opacity obscures users' ability to evaluate methodologies, compare tools, or understand the causal mechanisms driving specific risk outputs.

The theoretical significance extends beyond technical concerns. When model logic is not evident, whether through proprietary design or inherent complexity, trust in decision-making erodes, particularly when models inform resource allocation and adaptation investments. Kythreotis et al. describe this as a "fuzzy black box" situation for policymakers attempting to translate climate risk assessments into coherent adaptation policy (2024). The inability to scrutinize assumptions or validate reasoning pathways breaks the feedback loop necessary for scientific credibility and institutional learning, leaving practitioners unable to explain to colleagues, boards, or regulators why tools identify specific risks or how adaptations reduce them (Kuzma et al., 2023).

> “Lack of common definitions and standards for climate-related data and products.”

Market Transparency

Empirically, the definition of “transparency” varies depending on the actor's scope and data requirements. Regional investors and consultants prefer open-source, government-mandated data for credibility with local stakeholders and cross-city comparability. In contrast, global institutional investors prioritize methodological documentation from commercial platform vendors. A global real estate investment manager who had previously used an established probabilistic vendor switched to a newer commercial

platform because it was more transparent about data and methodology, reflecting demand for tools that document how diverse data sources are combined even if underlying calculations remain proprietary. This preference reflects broader market dynamics where transparency means different things: institutional alignment for local actors and methodological clarity for global managers. Studies also warn that inadequate governance and knowledge asymmetries between tool providers and users can hinder decision quality (Arribas et al., 2022), justifying Dutch actors' insistence on transparency. Consultants likewise stress that open national maps allow comparisons between cities and locations within the same country and are easier to explain to asset owners and banks than proprietary commercial models.

Nonetheless, many users do not fully investigate the data and methods behind the commercial tools they use even when this information is available. One large investor noted that even though they could obtain detailed documentation from a global vendor, they were *"not very keen to understand how the risk calculations were made"* because it seemed too complex and part of the supplier's competitive advantage. Insurers, for their part, are highly dependent on their own claims data to create risk models. Other investors and some insurers reported that they trusted tools with a strong brand, long track record, or wide use in the market, and reported satisfaction with high-level descriptions of data sources and modeling approaches.

The above contrast reveals a dual standard. Strategic users (banks and regulators) demand methodological transparency for compliance and benchmarking, while operational users (asset managers and real estate agents) prioritize functional transparency, outputs that "make sense" and can be integrated into risk models, over a detailed understanding of every underlying dataset. Research distinguishes these tools as "decision-useful" instead of "disclosure-useful," suggesting that transparency requirements differ by use case and are not universally high or low (CDSB, 2021).

5.3 CONFLICT BETWEEN GLOBAL AND LOCAL DATA

Many interviewees highlight tensions between international climate risk tools and Dutch local data, especially for flood-related hazards. Investors and insurers mentioned global models which classify large parts of the Netherlands as high flood risk because they do not fully incorporate dikes, dunes, and other flood-protection measures. In contrast, Dutch public maps and frameworks explicitly embed these defenses and use nationally agreed return periods, leading to much lower risk classifications for the same locations. This discrepancy creates confusion and forces users to choose which representation of risk they consider more credible for Dutch assets.

These conflicts are not only about flood protection infrastructure but also about granularity and conventions. Several actors note that international tools often work with coarse spatial grids and generic return periods, while Dutch datasets use finer resolution and specific return periods such as 1-in-30, 1-in-50, or 1-in-100 years. Investors and consultants observe that this leads to different numerical outcomes and different visual patterns of risk on maps, even when assessing the same hazard. Some investors report struggling to explain to international capital providers why local Dutch maps show relatively low to moderate risk whereas global vendor tools suggest very high risk. This has resulted in instances in which developers lost international clients due to the contrast between low-risk national flood maps and high-risk international ones. This mismatch is not unique to the Netherlands, for example the EU's PROTECT initiative notes that cross-border comparability is hindered by a *"lack of common definitions and standards for climate-related data and products,"* while the UNEP FI identifies the lack of granular, consistent, and comparable ESG data as a primary barrier to effective climate risk disclosure (Climate X, 2023; UNEP, 2025). Dutch actors' struggles to reconcile global and local tools reflect this unresolved standardization challenge at the international level.

Professionals respond to these conflicts in different ways. Consultants and some investors tend to treat Dutch public data as the reference for assets in the Netherlands and use global tools mainly for international portfolios or for providing a consistent global comparison. When writing ESG, EU Taxonomy, or TCFD reports, consultants sometimes compare outputs from global tools to Dutch maps to check for major inconsistencies so that they can provide an explanation that reconciles both perspectives. Others consciously avoid high-coarse global datasets for Dutch assets altogether, arguing that they are not suitable without local adjustment and that they undermine trust among local stakeholders.

Overall, the interviews suggest that Dutch real estate actors navigate a hybrid landscape in which global and local tools are both used, but their outputs must be actively interpreted, reconciled, and contextualized rather than taken at face value.

5.4 BUNDLING THE PHYSICAL CLIMATE RISK

Across stakeholder groups, physical climate risk is rarely assessed in isolation; instead, it is routinely bundled with other risk dimensions in broader decision frameworks. Bundling aligns with the IPCC risk framework, requiring integration of physical hazard data with socioeconomic exposure and adaptive capacity. Financial institutions operationalize this through transmission pathways, making bundling a conceptual requirement for translating climate science into financial risk metrics (Higuera Roa et al., 2025; UNEP, 2025).

Investors describe climate risk as one component within a composite Total Risk view that also includes macro-economic conditions, market dynamics, and asset-specific factors, and they emphasize that the return on investment remains the decisive criterion. In practice, climate risk scores or loss estimates are fed into internal valuation models or regression frameworks alongside non-climate variables, rather than being used as separate gatekeeping thresholds. At the EU level, this bundled treatment of risk is also visible in lending practices, where banks apply relatively favorable credit terms to green and transitioning firms and tighter standards for high-emitting firms, effectively embedding climate risk within the broader credit risk and pricing frameworks (Köhler-Ulbrich et al., 2025).

This bundling occurs at both the methodological and the organizational level. Some investors and global managers use climate modules that are embedded within wider multi-risk platforms, which simultaneously consider physical climate hazards, transition risks, economic forecasts and ecological indicators. Asset managers and consultants similarly report that physical risk assessments are conducted in combination with, or are immediately translated into, indicators required for ESG, EU Taxonomy, GRESB, or net-zero strategies, thereby linking physical risk to transition and reputational risk in reporting. For these actors, the key output is not a standalone climate label but an integrated picture of how climate risk affects portfolio performance, compliance, and strategic positioning. The Euro Area Bank Lending Survey 2025 results suggest that these integrated platforms and reporting logics are already reflected in credit conditions, with physical and transition risks jointly influencing margins, collateral requirements and loan eligibility, rather than being handled as isolated add-ons, demonstrating that bundling is now embedded in EU credit practices (ECB, 2025).

> “How likely is it that my house will flood—once in 100 years or once in 100,000 years? That's quite a difference.”

Bundling also takes place across spatial scales. Several investors, insurers, and consultants combine location-based assessments (e.g., area-level maps) with building-level evaluations to derive a single score or qualitative judgment per asset. For example, some asset managers use a two-step approach in which national or municipal maps provide an initial area risk classification followed by a building-specific assessment that incorporates selected characteristics such as height, renovation history, or use type. The resulting risk label or color scale is then used in internal portfolio dashboards, investment proposals, and ESG reports, often without separating the relative contributions of location and building factors.

Some insurers and investors emphasize that climate risk is only part of the overall risk assessment, and that other considerations frequently override climate-related concerns even when high risk is identified. Consultants observe that, in reporting contexts, physical risk metrics can be overshadowed by transition and financial indicators that are more familiar to decision-makers and more directly linked to existing targets. As a result, bundling risk supports integration into mainstream processes but can also dilute the visibility and influence of physical climate risk within those processes. This explains why climate mitigation is prioritized over adaptation measures because the latter are directly linked to the physical climate risk.

Finally, this integrated treatment of risk also introduces ambiguities. Several interviewees note that when physical climate risk is embedded in composite indicators or multi-risk models, it becomes difficult to trace how much weight it ends up carrying in final decisions, thus undermining the physical climate risk on their assets. Moreover, 80% of companies disclose at least one TCFD-recommended climate risk metric, while only 4% disclose all eleven, and Strategy and Risk Management pillars remain underreported. Furthermore, only 37% of EU financial institutions have integrated climate risks into internal capital models that include probability of default calculations, suggesting that bundling often results in climate risk being acknowledged but not systematically weighted (UNEP, 2025).

5.5 ADAPTATION VS. MITIGATION

During the interviews, stakeholders expressed confusion as to how to clearly differentiate between climate mitigation and adaptation measures. The adoption of sustainability reporting terminology and the market term “sustainable transition” has led to a predominant focus on climate mitigation within market publications and among stakeholders. This confusion is further compounded when actors use the term “risk mitigation” to imply “risk aversion.”

To clarify, climate mitigation refers to measures taken to reduce the speed of climate change through reducing GHG emissions produced by an asset or an activity, while climate adaptations are the measures implemented to reduce the impact of the changing climate on that asset or area, eventually making this asset climate resilient (European Environment Agency, 2024).

Climate mitigation measures can be easily noticeable (i.e., double glass insulation to keep heat from escaping or using renewable energy instead of fossil fuel). The outcome of these measures can be weighed in metric tons of gas, so their norms and standards are measurable. Parallelly, there is a considerable amount of literature and international frameworks that provide the know-how, if not well-established agreements, about calculating climate-mitigation measure investments and outcomes (e.g., CRREM and LEED). Asset managers and consultants report using CRA partly to feed EU Taxonomy alignment, ESG, and climate-related financial disclosures, whereas mitigation indicators (e.g., emissions and energy performance) are still more pivotal than adaptation indicators. EU banks report easing impacts on credit standards and terms for firms and buildings with strong climate and energy performance, but tightening impacts for high-emitting firms and low-efficiency buildings. Physical climate risk information is still emerging, with banks identifying it as a tightening driver for real estate lending but gradually integrating it into systematic adaptation incentives (Köhler-Ulbrich et al., 2025).

Conversely, climate adaptation measures pose significant challenges in terms of measurement. The impact of these measures is closely intertwined with the occurrence of climate disasters. For instance, how can the effect of an artificial wadi be measured if no flooding occurs? The inherent uncertainty surrounding future climate events, coupled with the ambiguity of climate data, further complicates the implementation of effective climate adaptations. Adaptation is often perceived as a newer and less standardized field and is frequently portrayed as still being in the process of establishing its role in decision-making. This perception has led to reduced investor willingness to invest in climate adaptations.

Across the interviews, physical climate risk assessment clearly emerges as less mature than mitigation-focused practice, but its importance is increasing. Many investors, insurers, and asset managers described a recent shift from a primary emphasis on mitigation (energy performance, emissions, and net-zero pathways) to adding adaptation as a second pillar in their climate approach. In practice, adaptation is usually positioned as a value-adding or risk-reducing measure rather than a hard condition for investment. Investors and consultants use climate risk assessments to identify high-risk locations or assets and then propose adaptation measures, but these proposals are commonly weighed against financial returns, timing, and other risks.

Factors like time and budget constraints, combined with strong external pressure on decarbonization metrics, lead to a scenario in which mitigation actions often take precedence over adaptation in practice. Interviewees also noted that most tools do not yet transparently show the before-and-after effects of adaptation measures on risk levels, which makes it harder to build a robust business case for adaptation based solely on CRA tools outputs.

5.6 REQUIREMENTS AND DATA GAPS

Interviewees identified a range of functional requirements for climate risk assessment tools as well as recurrent concerns about missing data and methodological limitations. Investors, insurers, and consultants emphasized the need for tools that provide sufficiently granular and up-to-date information to support asset- and portfolio-level decisions in the Dutch context. This includes detailed spatial resolution, coverage of relevant hazards, and the ability to link hazard information to specific building types and characteristics. Practitioners also expect tools to align with reporting needs under ESG, EU Taxonomy, CSRD, and similar frameworks, for example by generating risk labels or quantitative indicators that can be incorporated into standard templates and internal dashboards.

Tool providers and insurers also indicated gaps in local modeling that complicate this picture. Some global tools have started differentiating between flood types (e.g., rainfall, river, and sea level) and incorporating major defense structures. However, they still lack detailed modeling of land-surface types (e.g., asphalt versus sand), or micro-topographic and drainage conditions that Dutch municipal tools consider, even though these factors significantly impact pluvial flood and heat risks in urban areas. At the same time, users reported several persistent data gaps and modeling issues. One recurring concern is that some widely used national hazard maps are outdated, which limits their accuracy and prediction capabilities. Insurers and investors highlighted the limited coverage of certain hazards as well, especially wildfires, earthquakes, and smaller, more frequent events in both national and global tools, which prompted investors to consult international sources on these

risk dimensions. Research indicates that climate risk assessment requires an ongoing and continuous process, known as iterative risk management, a process that involves periodic updates as methodological advancements, data availability, and climate projections evolve (Palermo et al., 2025; UNEP, 2025; Valkenburg & Viguurs, 2023).

Several actors criticized CRA tools for the insufficient representation of building-level characteristics and adaptation measures. Funda's consumer survey briefly captures this sentiment; the platform's users want to know *"how likely is it that my house will flood—once in 100 years or once in 100,000 years? That's quite a difference"* (Funda, 2025). Investors and asset managers observed that global models often account for major flood defenses but ignore building-specific features such as elevation, construction materials, or local retrofits, leading to risk estimates that do not reflect on-site adaptation efforts. Some users therefore rely on separate engineering studies or tenant feedback. In some cases, tenants reported severe heat problems while the CRA tools did not flag high heat risk, leading asset managers to question the tool and rely more on measurements or complaints than on risk modeling tools. This mismatch undermines trust in some tools and reinforces the view that adaptation decisions still depend heavily on professional judgment.

This critique highlights a gap in the vulnerability component of climate risk. The IPCC framework defines vulnerability as the "tendency to be adversely affected," encompassing sensitivity and a lack of adaptive capacity (IPCC, 2023). However, most commercial tools only provide hazard-exposure estimates and treat all buildings in a flood zone identically. Vulnerability is multifaceted and varies depending on the extent of the hazard and the affected sector. While current literature rarely assesses vulnerability dynamics, Dutch respondents' call for tools that reflect building-specific adaptation measures thus demands a theoretically complete risk assessment, not mere data enhancement (Higuera Roa et al., 2025; Palermo et al., 2025).

Finally, current tools only partly meet requirements related to scenarios, uncertainty, and comparability. Several investors called for multiple climate scenarios, including pessimistic pathways, and more explicit treatment of uncertainty, rather than a single deterministic label. Others wanted better comparability of results between cities and between countries, which is hampered by differences in data sources, modeling approaches, and return-period conventions across tools. As a result of this incompatibility, practitioners often treat risk labels and scores as useful but approximate indicators and continue to rely heavily on professional judgment, local knowledge, comparisons with other sources, or risk dialogue.

5.7 RECOGNITION-TO-IMPLEMENTATION GAP

Across stakeholder groups, interviewees consistently described climate risk as an important consideration but not a standalone decision trigger. Investors emphasize that the decisive factor for investment remains the overall risk–return profile, with climate risk treated as one component within a broader assessment that also includes market conditions, vacancy risk, and asset quality. Several investors stated explicitly that they had never rejected an investment solely because of high physical climate risk, even when tools labeled assets or locations as high or very high risk. In such

cases, climate risk information may influence price negotiations, holding period assumptions, or requests for adaptation measures, but cannot be used as the sole means of determining whether a transaction will proceed.

Insurers and asset managers reported a similar pattern. For insurers, climate risk is integrated into underwriting and premium calculations, yet they rarely refuse coverage purely on physical climate grounds; instead, high risk prompts advice on adaptation or, in some cases, non-renewal if no measures are taken. Asset managers noted that climate risk assessments were routinely included in portfolio reviews and investment proposals, but that economic and financial risks remained more dominant in steering capital allocation. Even when assets are reclassified into higher risk categories over time, decisions to divest, retrofit, or maintain positions are usually justified on multiple grounds, with climate risk representing just one contributing factor rather than the primary rationale.

Developers and municipalities also indicated that climate risk seldom operates as an absolute constraint. Developers acknowledge physical risks and may adjust designs in response to municipal requirements or investor expectations, but they rarely abandon projects purely because of climate risk. They typically consider other barriers such as permits, nitrogen constraints, or financial feasibility more decisive. One developer indicated that they would reconsider their investment decisions if the investors demanded climate adaptation measures after permits were granted. This is because adjustments to permits are both costly and time-consuming. At the same time, municipal officials described using climate stress tests and zoning instruments to steer development away from the highest-risk areas and to impose adaptation requirements, yet political, legal, and housing-market pressures limit the extent to which climate risk alone can block development.

Climate risk influences decisions unevenly among homeowners and homeseekers. Some respondents reported having rejected specific properties due to perceived flood risk or elevation, but many others either never checked climate risk or chose to proceed despite unfavorable information because of location preferences and the tight housing market. All the homeowners interviewed reported that their real estate agents and appraisers *(taxateurs)* never discussed climate risk with them, while their bank showed no concerns when they applied for mortgages—apart from the foundations rotting, which is an indirect impact of climate change. Overall, the interviews suggest that climate risk currently functions as a moderating and sometimes negotiable factor in Dutch real estate decisions, more often shaping conditions, pricing, and design choices than serving as a strict go/no-go criterion.

The interviews revealed a clear pattern of recognizing adaptation needs but not implementing them. Asset managers and insurers reported cases in which assets received a high-risk label (e.g., specific flood types or heat), but no adaptation followed because of economic and market risks dominated, or because the tool output was perceived as too uncertain or insufficiently operational. One of the barriers to recognition-to-implementation identified in literature is that the current adaptation efforts are primarily expected to remain incremental and do not adequately address the underlying causes of exposure and vulnerability. Furthermore, inadequate planning and mismanagement of climate risks can have far-reaching consequences, including maladaptation. Dutch real estate actors' behavior—conducting assessments but deferring action—reflects these global patterns (Higuera Roa et al., 2025; Treville et al., 2025).

A few investors and insurers use climate risk assessments to inform portfolio strategy, for example, by selling assets in very high-risk locations or favoring assets where adaptation measures can reasonably reduce exposure. Several investors stated that if an assessment showed very high risk, they would discuss adaptations with developers or fund managers and possibly ask for design changes. However, climate risk alone seldom led to canceling a project, because as one pension fund representative mentioned, physical climate risk *"is never a showstopper."*

5.8 TOOL FRAGMENTATION, STANDARDIZATION, AND ADAPTATION

The ideal tool would be a one-size-fits-all solution: a single, globally standardized CRA methodology that could simultaneously serve portfolio-level transparency for regulators, asset-specific quantification for underwriting, scenario analysis for stress testing, and actionable adaptation guidance for developers. Standardization enables efficiency, cross-portfolio comparison, reduced duplication, and economies of scale. However, practitioners encounter a structural mismatch. For example, a tool assessing flood risk across portfolios using 90-meter resolution cannot provide the 25m–50m granularity and building-specific information necessary for asset-level adaptation decisions. Other global tools classify flood zones uniformly, unable to incorporate locally specific flood defenses like dikes. The standardization which is required for institutional transparency destroys asset-level precision (Macnaghten, 2022; Siebert, 2022).

Rather than adopting unified standards, the sector has fragmented as Dutch practitioners simultaneously use open-source national maps (local credibility), commercial platforms (global coverage), municipal stress tests (compliance), in-house models (internal assessment), and consultancy tools (client reporting). This creates three problems. First, incomparability: different tools employ different data sources, hazard definitions, and vulnerability assumptions, which renders their results incommensurable. Second, validation burden: practitioners cannot assume any tool is correct, so they construct informal hierarchies of evidence, comparing outputs across sources and validating against local expertise. Finally, decision paralysis: when tools conflict, practitioners lack principled decision rules and fall back on subjective judgment, the very approach that standardization aims to eliminate (van Bommel et al., 2023).

Real estate actors respond through adaptive strategies. They construct parallel validation networks integrating separate engineering studies or tenant feedback alongside tool outputs. They negotiate tool selection, using different tools for different purposes rather than seeking universal platforms. Some institute standardization by fiat, developing in-house models calibrated to internal requirements.

Despite limitations, standardization remains essential for adaptation. It enables comparability for capital allocation, prevents biased investment flows, and allows systematic risk-based distribution of adaptation resources. Standardization further builds

institutional credibility through peer review and documented methodology rather than subjective judgment. It enables the translation of physical hazards into financial metrics, EAL, LTV adjustments, and insurance premiums, thus making climate risk operational in capital decisions. Nevertheless, practitioners need both standardized outputs (portfolio reporting and regulatory compliance) as well as asset-specific precision (actual adaptation decisions). No single tool resolves this dual requirement. Practitioners navigate this paradox through informal adaptation strategies that essentially recreate pre-standardization decision logic despite nominally using standardized tools.

Table 3: *The Impact of Tensions Within CRA Tools on Actors and the Subsequent Implications for the Dutch Real Estate Market*

Challenge	Tension	Stakeholder Impact	Implications
Decision-trigger Hazards	Stakeholders prioritize flooding and rainwater over heat, drought, and soil subsidence risk despite multi-hazard regulatory mandates.	Developers and municipalities focus on water hazards while insurers treat heat as non-material.	Hazard prioritization misaligns with comprehensive risk frameworks.
Transparency of Tools	Commercial platforms operate as black boxes while open-source tools lack regular updates.	Strategic users mandate methodological transparency for compliance, while operational users prioritize functional transparency.	Methodological opacity undermines tool credibility across decision workflows.
Global vs Local Data Conflict	Global tools ignore local attributes, whereas local tools prevent inter-city/ national comparability.	Investors toggle between scales, while developers rely on government ambitions and frameworks.	Data governance fragmentation blocks standardized risk communication.
Bundling of Physical Climate Risk	Climate risk is embedded within broader ESG, financial, and regulatory considerations rather than being a standalone driver.	Investors weigh physical risk against ROI, and banks conflate the risk with energy efficiency metrics and mitigation reporting.	Risk dilution prevents climate risk from achieving financial materiality.
Adaptation vs Mitigation	Stakeholders confuse climate mitigation measures with adaptations, treating the latter as a compliance/value issue rather than risk reduction.	Developers prioritize regulatory minimums while consultants bundle climate risk into ESG reporting.	Conceptual confusion makes climate resilience a regulatory concern rather than fostering fundamental changes in risk reduction.
Requirements and Data Gaps	Building-level adaptation data absent; address-level climate data scarce for screening.	Insurers lack sectoral classification, investors rely on developer inputs, and homeseekers skip assessment.	Reliance on subjective judgment and local knowledge, rather than data-driven modeling.
Recognition-to-Implementation Gap	Tools identify risks effectively but rarely trigger project rejection, pricing adjustment, or capital reallocation.	Despite all actors acknowledging physical risk, none reported climate-driven divestment.	Assessment decoupled from binding investment discipline.
Tool Fragmentation	Actors deploy 3-5 tools simultaneously across investment stages; no single tool meets all workflow needs.	Users validate across different platforms, sometimes maintaining in-house tools alongside other tools.	Ecosystem fragmentation sustains selective rather than systematic adoption, creating validation burden and decision paralysis.

6

Discussion on the Implications of CRA Tools

This research investigates how Dutch real estate actors select and use climate risk assessment tools across the investment lifecycle. Dutch practitioners have broadly adopted CRA tools, yet tool proliferation has not translated into substantive changes to underwriting discipline, pricing mechanisms, or capital allocation decisions. Climate risk is recognized, documented, and disclosed but rarely changes outcomes. While this paradox highlights the gap between the desired regulatory objectives and the actual methods employed to achieve them, this research identifies several interconnected mechanisms sustaining a pattern of recognition-without-action.

First, CRA tools are operationally decoupled from asset valuation. Investors conduct climate risk screening but results rarely trigger project rejection or asset value adjustments. Insurers assess climate exposure, but lack of transparency and methodological limitations prevent true pricing of risks and further widens the insurance gap. Developers integrate climate findings into site design but accept them only when financially compatible with project economics. Banks incorporate climate stress tests into capital planning yet maintain legacy credit models that limit climate risk repricing capacity. When physical climate risks conflict with project momentum, ROI expectations, or regulatory compliance timelines, these physical risks are prioritized lower on the list. This financially motivated perspective underscores the dual nature of CRA-tool functions, where compliance documentation takes dominance over climate adaptation decision-support.

Second, while these CRA tools provide a perspective on physical climate risks mainly for financial decisions, they largely dismiss the social vulnerability of the society living or working in and around the subject assets. The decision criteria and the outcome of these CRA tools are usually based on the hazards and physical features of an area, sometimes with building characteristics, but often overlook or fail to estimate other indirect or intangible indictors related to the residential or commercial population in the area like demographics, impact on health and income, or business disruption. This is evident, when, for example, insurance companies consider climate heat risk as an individual life-insurance, while homeseekers consider the same risk as a future problem that does not require immediate planning. Nonetheless, municipalities would argue that social indicators were included in their risk dashboards to determine the vulnerable urban areas where climate adaptation investments should be prioritized.

Third, standardization undermines asset-level precision, while localization sacrifices comparability. The research results confirm that global standardized tools enable efficient ESG portfolio-level reporting and regulatory disclosures, even though they do not provide the spatial resolution or building-specific knowledge necessary for actual adaptation decisions. Conversely, locally calibrated municipal tools, open-source platforms, or hybrid tools offer methodological transparency and the incorporation of locally specific climate-adaptive infrastructure, yet they produce results that cannot be compared across jurisdictions and portfolio perimeters. This structural contradiction implies that the sector will continue to fragment into complementary ecosystems, establish standardized global platforms for compliance, and develop local tools for adaptation, rather than converging toward unified standards. Policy should accept this reality and facilitate ecosystem integration rather than mandate impossible unification.

In a report issued by three major Dutch banks in 2024, Bani et al. advised the Dutch government to take the lead in incorporating climate risk into the asset value through a standardized climate risk property label similar to the energy label, thus allowing the market value of real estate assets to more accurately reflect their climate risk exposure. Banks argue that they cannot lead this change unless all banks apply the same measure simultaneously, because if one bank were to deny a mortgage seeker due to high climate risk, the borrower would switch to another bank that does not even consider climate risk in its lending practices. Nonetheless, given the current methodological and scientific gaps in CRA tools, standard climate risk labels, which are inherently complex, might be far from realistic.

In response, the Dutch Ministry of Infrastructure and Water (IenW) is investing in a tool that allows non-professional users (i.e., homeowners/homeseekers) to comprehend the climate risks on the asset level. It remains unclear whether building characteristics will be included in these assessments. This national move might also conflict with local municipality views. According to Kowalski, revealing building-level risks could inject more uncertainty into the real estate market bubble as demand for revaluation of assets based on their climate risk level will substantially increase (2025). This clearly indicates a conflict between the national government, municipalities, and market parties' approach to addressing physical climate risk.

Fourth, rather than adopting unified standards, Dutch practitioners have fragmented into parallel tool ecosystems. This created a validation burden as practitioners cannot assume that any single tool is correct, so they construct informal hierarchies of evidence. They compare outputs across sources and validate them against local and experts' knowledge. For this specific reason, sustainability consultants opt for risk dialogue *(risicodialoog)* with their clients after running the risk assessment to ensure that their client comprehends the risk and can make decisions based on the discussion. This reflects the fact that CRA tools remain incapable of showing definite outcomes that are commonly comprehensible and which users can base a decision on. Instead, they result in estimations and qualitative analysis that require explanations and discussions. This perspective-shaping practice further exacerbates the climate-risk perception gap among different parties and hinders public-private cooperation for climate adaptation.

Fifth, recognition of climate risk is not sufficient for behavioral change. All nine stakeholder groups acknowledge physical climate hazards. Investors conduct systematic screening, insurers model climate exposure, developers integrate findings into spatial planning, municipalities mandate climate stress tests, and homeowners increasingly consult hazard maps. Nevertheless, this steady recognition has not produced outcomes that proportional understanding would predict. This research reveals that institutional structures like financial return requirements, regulatory compliance timelines, insurance market regulations, or project development cycles create systematic barriers to translating risk recognition into action. This challenges the assumption that tool transparency and accessibility alone will drive climate adaptation. Institutional reform, instead of only methodological improvement, is the binding constraint on effective climate risk integration.

Sixth, while the Dutch Central Bank recommends solidarity among insurance policyholders (Doll et al., 2022), the outdated or lack of related publicly available data and the ambiguity of premium calculation methodologies hinder smaller insurance companies from competing in the market and breaks this solidarity principle. Larger and international insurance companies have more resources and more diversified risk experience that allows them not only to calculate but also to select which risks are covered, leading to highly diversified premiums that may not be accessible to low-income groups. While these insurers operate on black-box models, other factors like the ambiguous stance from the national government toward compensations for primary dike failure flooding[8] and asset owners' low awareness of climate risks contribute to widening the insurance gap and exposing a large segment of society to financial, physical, and psychological damages following catastrophic climate incidents.

Seventh, it is evident that several of the market challenges mentioned in the previous chapter are currently being addressed on a national scale. The Ministry of Infrastructure and Water has worked as the facilitator to improve risk awareness nationally and internationally. This role is manifested in supporting open-source tools and data that allow both professional and non-professional users to understand, estimate, and prepare for climate risks. For instance, the Dutch Climate Risk Portal (DCRP) has received substantial support from the national government to overcome the conflicting data between global and local flood defenses. The aim is to demonstrate to international market participants that the Netherlands is resilient against flooding and provide credible information to potential investors. Regardless of whether the DRCP will achieve its intended goal to enhance the Netherlands' climate risk profile globally, it remains an essential resource for a comprehensive repository of climate risk information within the low-lying country.

[8] *The Calamities Compensation Act* (Wet tegemoetkoming schade bij rampen – Wts) *guarantees that the government covers major flood damages (mainly from primary dike failure) but only after the disaster takes place. Whether the act applies depends on whether the Minister of Justice and Security declares the flooding a disaster, even though there are no normative standards for what constitutes a disaster.*

Finally, climate risk adaptations will remain incremental and financially constrained. Climate risk assessments rarely trigger project rejection but instead moderate prices, defer low-priority measures, or require design modifications. Financial feasibility is consistently prioritized over climate resilience. Developers make adaptation conditional on investor mandate, then investors make climate investment conditional on regulatory requirement. This sequential constraint means that absent exogenous financial incentives (e.g., green finance premiums, regulatory capital relief, or climate risk premiums sufficient to offset adaptation costs) will continue to drive incremental improvement rather than transformational adaptation.

Limitations and Pathways for Further Research

This research documents practitioner experience during the early implementation of CSRD and evolving ECB expectations (2025–2026), offering a situated snapshot in a rapidly changing field. The findings are grounded in 26 semi-structured interviews with large, climate-mature institutions and while SMEs and households are underrepresented. The analysis covers a particular cluster of widely used tools rather than comprehensive market sampling. Systematic quantitative comparison across tools on identical assets, longitudinal tracking of tool adoption and adaptation investment, and analysis of less-resourced institutional actors remain necessary to triangulate findings and assess sector-wide evolution. In addition, the gap between estimating the indirect impact of physical risk on assets and on society requires further investigation at the methodological, ethical, and scientific level.

More fundamentally, research must investigate whether the current institutional structures can generate adaptation outcomes proportional to climate hazards, or whether recognition-without-action represents structural balance rather than a temporary implementation gap. If so, the relevant policy question is not how to improve tools but how to restructure financial incentives, regulatory requirements, and time horizons to align recognition with action. This recognition-implementation research agenda is essential to move the real estate sector from compliance-driven tool adoption toward substantive climate-resilient adaptation.

7

Frequently Asked Questions

7.1 AM I USING THE RIGHT CRA TOOL?

No single tool is "right" for all purposes. Most actors use multiple complementary tools because standardized global platforms excel at generating comparable outputs for regulatory compliance and investor reporting, while locally calibrated tools (e.g., municipal data and open-source platforms) provide contextually valid assessment for operational decisions. Dutch real estate actors typically deploy one standardized platform for TCFD/CSRD disclosure combined with local tools for site-specific decisions. This reflects the structural reality: standardization and localization require different tools.

Evaluate tool credibility by asking whether providers publish their methodology and assumptions transparently and are forthcoming about the data source behind their calculations. Proprietary black-box tools obscure which hazards are analyzed in-depth and which are represented only by crude proxies. Government agencies and open-source platforms typically offer higher transparency than commercial vendors, though commercial tools excel at system integration and ease of use. You can trade transparency for usability based on your organizational capacity. A practical approach is to use commercial platforms for broad screening and supplement them with transparent open-source tools for validation.

7.2 WHAT IS MY POSITION IN THE REAL ESTATE MARKET?

Your market position as a CRA-using actor depends on your institutional capacity to conduct assessment and your willingness to act on findings. Large financial institutions have a competitive advantage: they maintain dedicated climate teams, face mandatory regulatory disclosure obligations, and have capacity to conduct parallel assessment frameworks (compliance plus operational decision-making). These institutions can leverage climate risk integration into pricing and underwriting decisions and maintain a competitive advantage over climate-unprepared competitors. Large actors who successfully translate CRA findings into financing decisions will gain a market advantage.

Mid-size developers and real estate firms occupy a transitional position: they lack internal CRA capacity but increasingly face pressure from institutional investors demanding climate documentation. Early adoption of climate assessment capacity positions mid-size firms favorably for institutional investment. SME developers rely on municipal planning engagement and external consultants: your market position depends on geographic concentration and climate-resilient regions face lower urgency than flood-prone or drought-exposed areas. Municipalities occupy a unique position: they maintain independent assessment authority and can influence private-sector adaptation decisions through transparent climate mapping and by learning from other larger municipalities. Insurers face pressure to incorporate climate into underwriting but are constrained by regulations that restrict location-based pricing differentiation.

7.3 ARE OPEN-ACCESS TOOLS THE FUTURE?

Open-source tools are likely to remain complementary rather than replaceable, for three reasons.

First, regulators demand standardized metrics across jurisdictions for systemic risk monitoring. Commercial platforms create standardized taxonomies enabling aggregation, but open-source tools lack this comparability.

Second, while developing quality CRA requires sustained investment in climate modeling, data collection, and maintenance, open-source communities cannot reliably do so without backing. Government agencies sustain these open-access tools through public funding.

Third, financial institutions need tools that integrate with existing risk management systems, credit models, and regulatory infrastructure. Commercial vendors design tools with this in mind whereas open-source tools require substantial customization to be intergraded in the user's workflow.

The future of tools is likely to be a differentiated ecosystem in which open-source platforms dominate local adaptation planning, commercial platforms support standardized disclosure (TCFD, CSRD), and government-funded infrastructure provides baseline hazard data.

Select your tool based on use case and ask: Is my primary goal from the tool to take a decision, or to conform and comply?

Can I access and verify the methodology? Does it incorporate local data accurately? Does it integrate with my systems? Open source excels at transparency and localization while commercial excels at standardization. You may need one or both.

7.4 HOW DO REAL ESTATE ACTORS USE THE CRA RESULTS?

CRA results function differently across investment lifecycle stages. During screening, standardized outputs rapidly flag high-risk properties for deeper analysis, while high-risk properties progress to due diligence rather than elimination. Developers rely on municipal approval as implicit validation but when international data conflicts with municipal assessments, local sources are prioritized because they are seen as more credible.

During due diligence, site-specific assessments inform cost estimation for climate adaptation measures but rarely trigger project rejection. Banks apply CRA primarily to collateral valuation rather than interest rate adjustment because their legacy credit models limit pricing capacity (so far). Insurers respond through policy non-renewal rather than premium differentiation due to market regulations.

During portfolio monitoring, CRA results facilitate mandatory disclosure (CSRD, GRESB, and TCFD). When portfolio concentration in vulnerable geographies occurs, the response is disclosure and reputational management rather than capital reallocation. Banks conduct stress testing without modifying lending frameworks.

The consistent pattern of events is that climate findings trigger operational adjustments (elevation, dry-proofing, and enhanced insurance) but do not substantially alter financing structures or portfolio composition. CRA functions simultaneously as decision-support and compliance documentation, and their compliance function is dominant. When findings conflict with project economics or regulatory requirements, they are frequently overridden.

8

Annex

Table 4: *List of Tools Mentioned During the Research Interviews*

Tool	Link	Access
Amsterdam Dashboard Klimaatadaptatie	https://experience.arcgis.com/experience/aec3fc23a4134a3da32c7cb2cf3b66da	Public, open source
Amsterdam Risicokaarten	https://experience.arcgis.com/experience/a9c9694c4a8a4298ab97f1a44249ed68/page/Hitte	Public
Blue Label	https://www.bluelabel.net/over-bluelabel	Proprietary
Check je plek	https://www.atlasleefomgeving.nl/check-je-plek	Public
Climate X	https://www.climate-x.com	Proprietary
CRREM	https://crrem.org/resources	Open source
Framework for Climate Adaptive Buildings	https://www.dgbc.nl/publicaties/framework-climate-adaptive-buildings	Open source
Jupiter Intelligence	https://info.jupiterintel.com/Gold-Standard-in-Climate-Risk-Analytics	Proprietary
Klimaateffectatlas	https://klimaateffectatlas.nl	Open source
Landelijk Informatie-systeem Water en Overstromingen (LIWO)	https://basisinformatie-overstromingen.nl/#/maps	Open Source, public
Landelijke maatlat	https://www.rijksoverheid.nl/documenten/rapporten/2023/03/23/landelijke-maatlat-factsheets-en-overzichtstabel	Public
Moody's	https://www.moodys.com/web/en/us/capabilities/physical-transition-risk.html	Proprietary
Munich RE	https://www.munichre.com/en/risks/climate-change.html	Proprietary
NL Green Label	https://nlgreenlabel.nl	Proprietary
NOS: Stresstest voor je adres	https://app.nos.nl/op3/stresstest-voor-je-adres	Public
Overstroom Ik	https://overstroomik.nl	Public
Rotterdam Climate Dashboard	https://rotterdam.maps.arcgis.com/home/index.html	Closed Access

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