Appendix 2. Channels of impact (physical climate risk, climate adaptation, climate mitigation)

References in the channels of impact (in superscript) are presented in Appendix 3.

Domain	Physical Climate Risks					
Type	**Drier**		**Wetter**	**Increase Sea Level**	**Warmer**	**Extreme Weather**
Risk	**Urban Area** • Subsidence • Pole rot • Water stress • Salinization	**Rural Area** • Subsidence • Pole rot • Wildfires • Salinization	• River flooding • Rainfall flooding • Heavy precipitation • Mold • High river levels	• Coastal flooding • Coastal erosion • Salinization • Inland river flooding	• Heat stress • Heat waves • Smog	• Hail • Storm • Fall wind
Households	• Homeowners will experience higher damage, repair and maintenance costs due to climate change[F11] * • Not all (climate) risks are correctly priced into todays' market[F1, F2, F21,]					
	• Houses with foundation problems sell for less[F3, F4, F5] • Wildfires cause a house price discount[F6] • Increase in mortgage delinquency rates after a disaster[F7] • Less availability of water for gardening or green roofs caused by drought will have a negative impact on price*		• There is a price discount after a flood[F21, F22, F23, F24] • The price discount disappears after several years[F11, F21, F24]	• There is a price discount for houses that are affected by a high risk due to a future sea level rise[F22]	• Air pollution and ozone concentration have a positive effect on house prices[F28, F29] • High levels of smog cause more heat related diseases which increases health costs*[F30]	• Extreme hail breaks solar panels causing damage costs and lower solar yield* • Home buyers and sellers are affected by temporary extreme weather events and over- or underestimate price[F32]
Regions	• Subsidence of houses in surrounding area negatively impact the house[F8] • Low river levels make areas not accessible and therefore impact sectors negatively* • Salinization reduces biodiversity, disrupts ecosystem functions such as drinking water[F9] • Higher sandy areas will have less water supply certainty[F10] , which has an impact on house prices or new construction locations*		• There is a price discount of houses that are in a known high-risk flooding area [F21, F22, F23, F24] • The risk of water-transferable diseases increases* • The risk of high-water levels in streets is elevated by the capacity of drainage systems*	• There is a price discount for houses that are in areas affected by a future sea level rise[F24, F25] • Homeowners in an area known for sea level rise are leveraged more[F25] • Salinization leads to a scarcity of drinking water** • Areas vulnerable to a sea level rise are at risk of land loss[F16]	• Heat stress in city areas lead to a loss in productivity[F17, F19, F20] • Heat stress leads to price discount caused by a lower desirability for homes in affected areas*	
Macro	• Governments will face increased expenses for the maintenance of infrastructure and water management* • Climate shocks have an impact on GDP growth[F12, F13, F14, F15, F16, F17, F18], unemployment[F14, F18] and productivity[F17, F19, F20] • Correct pricing of current risks might lead to negative home equity which negatively affects the labor supply*					
	• Drought-related diseases increases by more exposure to particulate matter and UV*		• Increased costs for maintenance and adjustment of water systems*	• Leads potentially to stranded assets* • Migration out of areas leads to a decline in GDP and negative impact on house prices* • Higher costs for protecting the Netherlands might lead to lower tax income and rating[F26] • Indirect damage to labor market and housing market is caused by affected infrastructure*[F27]	• Heat stress increases work-related injuries and affects labor supply[F31] • Heat stress increases heat-related health problems and drives up health costs*	• Increased costs of sudden maintenance and temporary shutdowns of public facilities*

* Hypothesis

Domain	Climate adaptation					
	Protective measures					
Policy types	**Climate-proof housing construction**	**Make existing homes climate proof**	**Nature-based solutions**	**Climate-proof spatial planning**	**Reduce financial risk for homeowners**	**"Accommodate and retreat" measures**
Policy measures	*How and where to build which types of homes? (Building guidelines, local building codes, location restrictions based on water and soil conditions ('Water en Bodem sturend' [A72]), floating or higher ground homes)*	Airconditioning, shading measures, measures stimulating rainwater harvesting, install drainage system/remove electric equipment in basement	Urban greening (green roofs, parks), rain gardens, constructed wetlands, reforesting, rainwater management	Higher ground water levels, strengthening dikes (technical solution), more flexible water system	Climate-informed mortgages, flood insurance, informing households about risk, foundation restoration loans	Elevated/floating buildings, raise ground elevation, internal migration within NL, "depoldering", salt-tolerant agriculture, lower LTVs mortgage providers
Households	Households may have more difficulties finding homes due to flood-safe building codes* Households are confronted with slightly higher housing prices due to higher awareness.* Limited impact of increased construction costs on home prices [A47, A81]	Some climate-proofing measures increase the investment costs for individual homeowners* Owners of heat-resistant homes receive a housing market premium [A12]	Homeowners near attractive green and blue spaces experience a property value increase (and hence lower LTVs*) [A13, A25, A29, A30, A31, A32] Water-rich areas increase property values and reduce LTV ratios of affected households [A23] but this is not the case for water retention areas [A26, A22]	Engineered flood protection raises property values and reduces LTV ratios of affected households, [A71] but the impact depends on the design [A28, A71] Groundwater level increases can stabilize some housing values by reducing foundation restoration costs, while potentially increasing groundwater issues in nearby homes * [A14]	Higher insurance costs alter household locational choices* Information about risks alters household risk perceptions, leading to different locational choices* [A80]	Lower maximum LTVs for homebuyers are making it harder to buy a house in risky areas, and more difficult to sell a house* Households may have more difficulties finding homes due to increased housing deficit*
Regions	Building higher leads to economic densification [A52, A53] Flood-safe housing construction increases housing variety [A50] (floating homes, strict building codes) but might be not inclusive, [A43] causes less construction, [A56] outmigration Climate-proof homes may become more popular, which may lead to a larger price premium for climate-proof homes* [A42, A48, A49, A63]	Subsidizing adaptation increases resilience especially for low-income households [A69, A74] Adaptation measures increase inequality between current homeowners and renters (or prospective buyers)* High investment costs for landlords/housing associations, resulting in higher rents for renters*	Local urban greening projects increase prices of owner-occupied homes and privately rented homes, which fuels green gentrification and affordability problems for newcomers [A1, A2, A3, A4, A5, A6, A7, A8, A9, A11, A16, A17] Adaptation through urban greening increases housing comfort [A10] Urban greening in areas with predominantly social rental housing might result in more prospective renters (and potentially longer waiting lists)*	Coastal and flood protection infrastructure raises local housing prices [A36, A38] Improved water quality increases regional housing prices Elevated groundwater levels threaten farming communities* [A15] Grey and green infrastructural measures are associated with local housing price increases. [A60, A61, A62, A63]	Insurance can help reducing financial risks for homeowners, [A54] but too high premia can make areas less attractive [A55] Subsidies increase adaptation by homeowners. [A70] This could help especially financially-constrained households who are less able to adapt. [A62] Mandatory flood insurance causes lower property prices and outmigration [A58, A76] Information about risks might suppress demand in risky areas, resulting in lower property prices and outmigration	Allowing for natural sedimentation through "depoldering" helps to create new economic activities [A79] Drought- and salt-tolerant agriculture and preventing salinization prevents decline of rural housing market* [A18, A19, A33, A34] Promoting interregional migration increases risks of gentrification and inequality [A51] Expensive floating homes contribute to gentrification Lower maximum LTVs for homebuyers in risky areas suppress demand, resulting in a downward pressure on housing prices and increase in vacant/abandoned properties
Macro	Climate-proof housing development (e.g., with strict climate standards and on the most suitable soils only) increases housing shortage* [A35, A41] Limited availability of fresh water in suitable locations might hinder home construction, therefore increasing housing shortage (resulting in an upward pressure on housing prices)* [A66, A82]	Adaptation in owner-occupied homes reduces mortgage default rates*		Protective infrastructure prevents housing market collapses due to extreme flood events [A21] Protection of low-lying areas invites additional or more expensive coastal housing construction ("levee" effect)* [A37]		A national strategy to selectively implement flood protection causes economic activities to re-locate to safer areas, while vulnerable households stay behind [A20, A44, A45, A75] While a retreat strategy might increase the housing shortage,* [A46] it's also uncertain if NL can keep on building new homes in low-lying areas. [A75]

* Hypothesis

Domain	Climate Mitigation				
Policy types	**Energy-efficiency norms**	**Pricing policies**	**Subsidies**	**Financing measures**	**Policies to enable a municipal-led transition to zero carbon housing stock**
Policy measures	- Hybrid heat pump as norm from 2026 (in progress, no approval) - Phasing-out of rental homes with E, F and G labels per 2030 (in progress, no approval)	- Increase of tax on natural gas by +5.23ct/m3 between 2023-2030, decrease of tax on electricity by -5.23ct/kWh (uncertain***) - EU ETS2/-BRT from 2027^^ (adopted)	- ISDE: subsidy for homeowners investing in energy efficiency improvements** (implemented) - SVVE: ISDE equivalent for owners' association (implemented)	- Affordable energy savings loans via "Warmtefonds" (implemented) - Extra borrowing capacity for renovation purposes^^^ (implemented) - Differentiation of Nibud norms by energy label from 2024 (approved)	- Wet Gemeentelijke Instrumenten Warmtetransitie: law providing municipalities with the tools to guide transition of homes to net zero (proposal) - Wet Collectieve Warmtevoorziening: legal framework for collective heat grids (proposal) - Transitievisie Warmte: all municipalities need to have a policy document providing a first direction for the phasing-out of natural gas in the built environment (implemented)
Households	Financial business case				
	Homeowner needs to invest in energy-efficiency measures regardless of business case	Higher energy tax on natural gas improves financial business case, a.k.a. provides financial incentive to improve energy efficiency	Subsidies improve financial business case of energy-efficiency measures	Affordable loans (lower than market rates) improve financial business case of energy-efficiency measures	
	Investing in energy-efficiency improvements results in lower energy cost, but... Financial business case with current policy mix often is still negative, according to recent studies[M20]: -Insulation to "standard" is financially beneficial for 47% of all homeowners of homes built before 1992. Low income households in large homes have a bigger chance of income losses[M25]. - Renovation to energy label C is, on average, financially beneficial, upgrade to B and A not[M66]. - The last mile, from A to nearly zero-energy buildings is far from financially beneficial[M66]. - The financial business case of insulation and heat pumps is more positive for households with above-average energy use. Above estimates are based on theoretical energy use. The actual energy savings are often lower, which is partly due to the rebound effect[M30]: after renovation, homeowners start heating their homes at higher temperatures, cancelling out 27% of the energy savings[M33]. This means that households to some extent prefer to increase their living comfort (by increasing the temperature) instead of achieving extra energy cost savings. - This is confirmed by cross-sectional data on household energy consumption by energy label: the difference in energy consumption of households in a label D versus label G home is on average not sufficient to outweigh the initial investment costs, even at 2022 price levels[M67].				
	Available financial resources:				
	Stricter energy efficiency standards in general mean homeowners need more budget to renovate their home	Higher energy taxes are regressive[M6]	(Targeted) subsidies help to relieve financial constraints.[M17]	Affordable loans help to relieve financial constraints.	
	- Some homeowners lack the financial means for renovating their home[M23]: around 14% of homeowners lack the financial means (both lacking savings, and insufficient borrowing capacity) to upgrade the insulation of their home to energy label B level and a hybrid heat pump; an investment which on average amounted EUR 24,000 in 2020[M19].				
	Non-financial impacts				
	- Non-financial hurdles homeowners experience to renovate homes are: limited time, capabilities and knowledge to organize the renovation, lacking transparency about the quality of contractors. Homeowners also dread the lower living comfort during the renovation activities[M15,M19,M33,M45] . - Non-financial benefits of investing in energy efficiency: higher living comfort[M45,M61]. - Disagreements among members of Homeowners' Associations (VvEs) about when and how to renovate apartments[M68] .				Municipalities take multiple actions to help and unburden homeowners with the renovation of their home (incl. advice from "Energieloket" and coordination of regional renovation via "Programma Aardgasvrije wijken").

(regional and macro-level impacts on next page)

Regions

Price premium of energy-efficient home

Stricter norms and higher energy taxes will increase the relative price of an energy-efficient home.

Subsidies and affordable loans (below market rates) will -all else equal- lower the relative price of an energy-efficient home.

Municipal plans with a concrete timelines to phase out natural gas will -eventually- increase the relative price of an energy-efficient home.

There is a price premium for energy efficiency on the housing market[M8, M13, M14, M24, M28, M43, M39, M42, M48]. For example, one recent study finds that home buyers are currently willing to pay around EUR 37,000 on average more for a home that is upgraded from energy label G to A[M67].

Grid congestion

Mitigation policies steer the transition to a zero-carbon housing stock. This will come alongside increased grid congestion problems in virtually every region of the Netherlands[M69].

Other

The effect of standards on homeowners will differ across regions. There are 23 municipalities in the Netherlands in which the percentage of homeowners with insufficient funds for renovation measures is relatively high[M46]

Municipalities currently still lack the power (legal frame) to fulfill their requested role in the transition to a net-zero housing stock. This limits their ability to, among other things, scale-up the use of heating networks, which from a societal perspective often is a very cost-efficient alternative to natural gas, especially in older neighborhoods in inner cities.

Macro

Effect on inequality between low- and high-income households

Channel 2 - via higher energy prices (significant impact): low-income households are more vulnerable to higher energy prices.[M65]
Based on 2022 energy price levels, low income households spend on average about 10%-16% of their disposable income on energy, compared to approx. 2-3% for high-income households[M18].

Channel 1 - Distribution of home equity (limited effect): changes in the price premium of an energy-efficient home will affect the distribution of home equity among homeowners. The effect on inequality between low and high income households is expected to be limited, since low income households own only 3.3% of all owner-occupied homes and approx. 4.0% of all owner-occupied homes with a (very) bad energy label (labels D to G)[M18]

Other impacts of climate policies

- Contributes to timely transition to net-zero housing stock (in line with legally-binding EU climate goals).
- Reduces geo-political risks due to the phasing out of natural gas.
- Intensifies capacity constraints at municipalities and grid operators[M70].
- Missing insights: effects on, among other things, GDP, employment, government budget

* existing owner-occupied homes.
** subsidy for, among other things, insulation, hybrid heat pump, solar panels. Subsidy amount for insulation doubles when homeowners invest at least in two measures at once.
*** based on coalition agreement.
^^ separate and upstream emissions trading system covering, among other things, fuel combustion in buildings.
^^^ Max. Loan-to-Value up to 106% instead of 100%, and max. extra borrowing capacity via Nibud norms of EUR 20,000 for homes with label E, F and G.