In the Name of Energy Efficiency

Justice and energy poverty in the energy transition of Swedish housing

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Jenny von Platten

DOCTORAL THESIS

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Abstract
The energy transition of housing is accelerating in parallel with economic inequality reaching historically high levels. There is thus an opportunity to reduce inequalities in living conditions, but also a risk that the costs of the transition are unequally distributed and aggravate existing inequalities. In order to seize the opportunity for a just transition, and in tandem enable a meaningful introduction of energy poverty to the Swedish political agenda, the aim of the presented thesis is to explore how the energy transition of Swedish housing is affecting social justice and vulnerability to energy poverty. This is done by novel conceptualisations, that draw on existing theory particularly relevant for the current context, of what a just energy transition of Swedish housing entails, and how energy poverty can be understood in the Swedish context; but also by adding empirical rigour to the discussion in analysing how costs and burdens of the transition have been shared between income groups, and how vulnerabilities to energy poverty are distributed among households.

Overall, the findings show that the strong focus on energy efficiency in transition policy tends to structurally burden low-income residents. This could be seen in how low-income residents, who were shown to have low per capita energy use for housing, had carried a disproportionate cost burden for energy retrofitting over the past years; in how new policy imposing cold rent in the worst-performing buildings predominantly affected low-income households, and consequently elevated the risk for energy poverty in an already vulnerable part of the housing stock; and in how flexible energy use is consistently assumed to be an ability equally distributed across society. By incorporating flexibility in the conceptualisation of energy poverty, it could be determined what characteristics of a household contribute to their ability to dodge the current energy price peaks, but also who are most likely to be winners and losers in future energy systems increasingly reliant on demand-side flexibility.

In conclusion, the findings in this thesis show that injustices have occurred in the energy transition over the past decade; that these injustices are structural and not coincidental; and that there are risks of injustices continuing to occur and inequality being built into future energy systems. By disclosing the implications of past decisions, the presented thesis provides credible accounts of the need for increased integration of social perspectives in energy policy, and offers practical support for more just pathways ahead. As such, it challenges dominating transition narratives that, in the name of energy efficiency, structurally have put low-income households at the frontline of the energy transition of Swedish housing.

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MADE IN SWEDEN

Part of you pours out of me
in these lines from time to time

— Joni Mitchell,
A Case of You

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Abstract

The energy transition of housing is accelerating in parallel with economic inequality reaching historically high levels. There is thus an opportunity to reduce inequalities in living conditions, but also a risk that the costs of the transition are unequally distributed and aggravate existing inequalities. In order to seize the opportunity for a just transition, and in tandem enable a meaningful introduction of energy poverty to the Swedish political agenda, the aim of the presented thesis is to explore how the energy transition of Swedish housing is affecting social justice and vulnerability to energy poverty. This is done by novel conceptualisations, that draw on existing theory particularly relevant for the current context, of what a just energy transition of Swedish housing entails, and how energy poverty can be understood in the Swedish context; but also by adding empirical rigour to the discussion in analysing how costs and burdens of the transition have been shared between income groups, and how vulnerabilities to energy poverty are distributed among households.

Overall, the findings show that the strong focus on energy efficiency in transition policy tends to structurally burden low-income residents. This could be seen in how low-income residents, who were shown to have low per capita energy use for housing, had carried a disproportionate cost burden for energy retrofitting over the past years; in how new policy imposing cold rent in the worst-performing buildings predominantly affected low-income households, and consequently elevated the risk for energy poverty in an already vulnerable part of the housing stock; and in how flexible energy use is consistently assumed to be an ability equally distributed across society. By incorporating flexibility in the conceptualisation of energy poverty, it could be determined what characteristics of a household contribute to their ability to dodge the current energy price peaks, but also who are most likely to be winners and losers in future energy systems increasingly reliant on demand-side flexibility.

In conclusion, the findings in this thesis show that injustices have occurred in the energy transition over the past decade; that these injustices are structural and not coincidental; and that there are risks of injustices continuing to occur and inequality being built into future energy systems. By disclosing the implications of past decisions, the presented thesis provides credible accounts of the need for increased integration of social perspectives in energy policy, and offers practical support for more just pathways ahead. As such, it challenges dominating transition narratives that, in the name of energy efficiency, structurally have put low-income households at the frontline of the energy transition of Swedish housing.

Sammanfattning

Energiomställningen av bostadsbeståndet accelererar i takt med att ekonomisk ojämlikhet når historiskt höga nivåer. Det finns därför goda möjligheter att minska boenderelaterad ojämlikhet samtidigt som omställningens kostnader riskerar att snedfördelas och förstärka befintliga ojämlikheter. I en ansats att ta vara på möjligheten till en rättvis omställning, och för att samtidigt få till en meningsfull inkludering av energifattigdom i svensk energipolitik, ämnar föreliggande avhandling stärka kunskapen kring hur energiomställningen av det svenska bostadsbeståndet påverkar social rättvisa och sårbarhet för energifattigdom. Detta har gjorts genom konceptualisering, byggd på befintlig teori av särskild relevans för rådande förhållanden, av vad en rättvis energiomställning av bostadsbeståndet innebär samt hur energifattigdom kan förstås i den svenska kontexten; men även genom att empiriskt studera hur kostnader och bördor har fördelats mellan inkomstgrupper och hur sårbarheter för energifattigdom är fördelade mellan hushåll.

Helhetsbilden från resultaten visar att det starka fokuset på energieffektivisering inom energipolitiken tenderar att strukturellt belasta låginkomsttagare. Detta påvisades i hur låginkomsttagare, som visade sig ha låg energianvändning per person för boende, hade burit en oproportionerligt stor andel av kostnaderna för energieffektiviserande renovering; i hur nya krav på kallhyra i byggnaderna med lägst energiprestanda primärt nådde låginkomsttagare och således ökade risken för energifattigdom i en redan utsatt del av bostadsbeståndet; och i hur flexibel energianvändning alltjämt antas vara en förmåga som är jämnt fördelad i samhället. Genom att inkludera flexibilitet i konceptualiseringen av energifattigdom erhölls resultat kring vilka hushållsprofiler som bidrar till förmågan att parera rådande elpristoppar, men även kring vilka som är troliga att bli vinnare och förlorare i framtida energisystem alltmer beroende av efterfrågeflexibilitet.

Sammanfattningsvis visar resultaten i avhandlingen att orättvisor har skett i energiomställningen under det senaste decenniet; att dessa orättvisor är strukturella och inte slumpmässiga; och att det finns fortsatt risk att orättvisor uppstår och att ojämlikhet byggs in i framtida energisystem. Genom att blotta effekterna av tidigare beslut presenterar föreliggande avhandling starka argument för behovet av ökad integrering av sociala perspektiv inom energipolitiken, och ger praktiskt stöd för mer rättvisa vägar framåt. På så sätt utmanas de dominerande narrativen kring omställningen som, i energieffektiviseringens namn, strukturellt placerat låginkomsthushåll på frontlinjen av energiomställningen av bostadsbeståndet.

Populärvetenskaplig sammanfattning

Det pågår en omfattande omställning av samhället för att minimera effekterna av globala klimatförändringar. I Sveriges klimatomställning står minskad energianvändning i boendesektorn högt upp på den politiska agendan då sektorn står för en väsentlig del av den nationella energianvändningen. Det råder ingen tvekan om att byggnader behöver energieffektiviseras för att minska den totala energianvändningen såväl som att göra dem mer motståndskraftiga mot klimatförändringarnas extrema kyla och hetta. Men en så pass omfattande energiomställning av bostadssektorn är kostsam, och för att omställningen till ett mer hållbart samhälle ska vara rättvis krävs att kostnaderna fördelas på ett sätt som inte leder till ökad ojämlikhet. Detta är särskilt viktigt med hänsyn till de senaste decenniernas ökande ekonomiska ojämlikhet i Sverige. Den här avhandlingen har därför studerat fördelningen av kostnader, risker och sårbarheter mellan socioekonomiska grupper i energiomställningen av svenska bostäder.

Forskningsresultaten visar att det överlag tycks saknas ordentligt hänsynstagande till sociala perspektiv och rättvisa i de policys och åtgärder som nu når bostadsbeståndet. I studierna av *lägenhetsbeståndet* framkom det att låginkomsthushåll, med i genomsnitt låg energianvändning per person för boende, har fått bära en oproportionerligt stor andel av kostnaderna för energieffektiviserande renovering i form av hyreshöjningar mellan 2013 och 2019. Med en generell brist på hyresrätter till överkomligt pris innebär den här utvecklingen en alltmer utsatt situation på bostadsmarknaden för hushåll med låga inkomster.

Samtidigt har även ekonomiska incitament för minskad energianvändning riktats särskilt mot dessa hushåll. Detta har bland annat gjorts genom att ställa krav på införande av kallhyra i utbyte mot den dominerande varmhyran, där uppvärmningskostnaderna ingår, i flerbostadshusen med lägst energiprestanda där låginkomsthushåll är överrepresenterade. Med kallhyra ökar risken för att drabbas av ett pressat tillstånd där hushåll kan tvingas välja mellan att ha råd med en tillräckligt varm bostad eller andra nödvändigheter, så kallad *energifattigdom*. Tack vare varmhyra och en rad andra gynnsamma faktorer har svenska hushåll tidigare varit relativt skonade från sådan problematik. Men här visar resultaten hur policy för energiomställning nu leder till en ökad risk för energifattigdom i just de delar av beståndet där många hushåll redan är ekonomiskt utsatta.

Med anledning av ökande elpriser under 2022 studerades också energifattigdom närmare i det svenska *småhusbeståndet*. Hushållens varierande förmåga att undvika energifattigdom studerades med hänsyn till deras förmåga att vara flexibla med sin energianvändning, då flexibilitet kan vara ett sätt att undvika elpristoppar. Det framkom att ett flertal faktorer påverkar hushållens flexibilitet, och således deras sårbarhet för energifattigdom. I hushåll med lägre flexibilitet finns en förhöjd risk att drabbas ekonomiskt av energifattigdom, och andra nödvändiga utgifter kan då bli lidande. I hushåll med högre flexibilitet, och därav relativt god möjlighet att undvika pristoppar, riskerar energifattigdom istället att framträda i form av kompromisser med komfort, genom att exempelvis ha ett för kallt inomhusklimat, eller med bekvämlighet, genom att exempelvis utföra energikrävande aktiviteter såsom tvätt och disk på obekväma tider när priserna är lägre.

Resultaten i den här avhandlingen pekar på ett växande behov av att integrera sociala perspektiv inom energipolitiken och att skifta fokus från teknik till sociala strukturer. Nuvarande tillvägagångssätt lägger stor vikt vid *energieffektivitet* med fokus på flerbostadshus från miljonprogramstiden, vilket generellt placerar behovet av åtgärder hos låginkomsthushåll där den tekniska effektiviteten i bostäder och apparater tenderar att vara lägre. Däremot saknas perspektiv för att begränsa total *energianvändning*, som brukar vara högre i hushåll med högre inkomst trots en generellt högre energieffektivitet på teknisk utrustning. Framförallt saknas tillräcklig förståelse för, eller åtminstone hänsyn till, hur sociala strukturer och social ojämlikhet påverkar, och förstärks av, nuvarande strategier i omställningen. Att bredda synen på vad som krävs av en energiomställning och lägga mer fokus på åtgärder för minskad total energianvändning hade inte bara kunnat leda till en miljömässigt effektivare omställning, utan även till en mer rättvis sådan.

List of Publications

This doctoral thesis is based on the following papers, which will be referred to by their roman numerals in the text. The papers are appended at the end of the thesis.

I. *Renovating on Unequal Premises: A Normative Framework for a Just Renovation Wave in Swedish Multifamily Housing*
J. von Platten, K. de Fine Licht, M. Mangold, and K. Mjörnell
Energies, vol. 14, no. 19 (2021)

II. *The renewing of Energy Performance Certificates—Reaching comparability between decade-apart energy records*
J. von Platten, C. Holmberg, M. Mangold, T. Johansson and K. Mjörnell
Applied Energy, 255, 113902 (2019)

III. *A matter of metrics? How analysing per capita energy use changes the face of energy efficient housing in Sweden and reveals injustices in the energy transition*
J. von Platten, M. Mangold and K. Mjörnell
Energy Research & Social Science, vol. 70, 101807 (2020)

IV. *Energy efficiency at what cost? Unjust burden-sharing of rent increases in extensive energy retrofitting projects in Sweden*
J. von Platten, M. Mangold, T. Johansson and K. Mjörnell
Energy Research & Social Science, vol. 92, p. 102791 (2022)

V. *Energy inequality as a risk in socio-technical energy transitions: The Swedish case of individual metering and billing of energy for heating*
J. von Platten, M. Mangold and K. Mjörnell
IOP Conference Series: Earth and Environmental Science, vol. 588, 032015 (2020)

VI. *Energy poverty in Sweden: Using flexibility capital to describe household vulnerability to rising energy prices*
J. von Platten
Energy Research & Social Science, vol. 91, 102746 (2022)

Contribution to the Publications

Paper I
All co-authors contributed to the ideation for this paper. I wrote all parts of the first draft of the manuscript except for the section on philosophical theory which was written by Karl de Fine Licht. The manuscript then underwent minor revisions by all co-authors.

Paper II
This paper is based on the master's thesis written by me and Carolina Holmberg, who is also a co-author. The idea for the master's thesis was presented to us by our senior co-authors, and the paper was later written by me with substantial guidance from the other co-authors. Based on the preparatory work during our master's thesis, I conducted all data analyses.

Paper III
The idea for this paper was presented to me by my supervisors, and all data analyses were carried out by me under continuous discussion with my supervisors. I wrote the first draft of the manuscript and then made minor revisions in accordance with the input from my co-authors.

Paper IV
All co-authors contributed to the design of this study. I conducted the data analyses and wrote the first draft of the manuscript which I then revised after discussion with my co-authors.

Paper V
I came up with the idea for this paper, conducted the data analyses, and wrote the first draft of the manuscript in close dialogue with my co-authors. I then revised it after input from my co-authors.

Paper VI
I designed this study, carried out all data analyses, and wrote the first and final drafts of the manuscript.

Other Related Publications

Using machine learning to enrich building databases: Methods for tailored energy retrofits
J. von Platten, C. Sandels, K. Jörgensson, V. Karlsson, M. Mangold and K. Mjörnell
Energies, 13(10), 2574 (2020)

Sharing indoor space: stakeholders' perspectives and energy metrics
N. Francart, M. Höjer, K. Mjörnell, A. Sargon Orahim, **J. von Platten** and T. Malmqvist
Buildings and Cities, 1(1), 70-85 (2020)

Determining the Impact of High Residential Density on Indoor Environment, Energy Use, and Moisture Loads in Swedish Apartments-and Measures for Mitigation
A. Abdul Hamid, **J. von Platten**, K. Mjörnell, D. Johansson, and H. Bagge
Sustainability, vol. 13, no. 10 (2021)

The effect of weighting factors on income-related energy inequalities: The case of Sweden's new building code
J. von Platten, M. Mangold and K. Mjörnell
IOP Conference Series: Journal of Physics, vol. 2069, no. 1, p. 012102 (2021)

Balancing Social and Economic Sustainability in Renovation with an Affordable Option for Tenants? A Pilot Study from Sweden
K. Mjörnell, **J. von Platten**, and K. Björklund
Sustainability, vol. 14, no. 7 (2022)

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There are many things that go into a doctoral thesis.

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There is the academic environment. My day-to-day colleagues at RISE have given me a context filled with support, laughter, and inspiration; you have all been so important for my well-being. And my colleagues at Lund University have, despite my absence, always made me feel welcome, included, and like a natural part of the division. I will carry the memory of our trip to Visby with me for a long time; as it turned out, taking the ferry to Gotland led me to many beautiful things.

A doctoral thesis is finally built on love and support. To my friends and family – thank you for offering me your care; your time; your calls; your words; your arms; your homes; your cooking. I have been carried by all of your different kinds of love.

All these things, all these people, have gone into my research and are manifested in the presented thesis. Time and again, I find myself writing thoughts, words, and phrases that I have heard from a colleague or a loved one; sometimes it is just something that was said in passing; sometimes ideas thoughtfully and eloquently spoken in heartfelt conversations. Most importantly, my self-doubts are eased knowing that you are all in me, and in everything I do. Comforted by this notion, I look forward to continuing my path within research, committed by the fact that there is still so much to learn – and unlearn.

Jenny
Gothenburg, October 11th 2022

1. Introduction

Climate change is imposing urgent needs for mitigation and adaptation, which is triggering overdue action and policymaking across societal sectors. With housing being a sector responsible for significant greenhouse gas emissions and energy use in many countries, substantial efforts are currently being put into a transition to achieve decarbonised and energy efficient housing stocks [1].

This action is needed and ultimately inevitable; but housing is more than a commodity in need of performance optimisation. Housing is a human right that is currently being distributed across societies with historically high levels of economic inequality [2, 3]. The transition towards more sustainable housing stocks will bring about many benefits, but also burdens that in some way must be shared across these societies. While the energy transition of housing holds an opportunity to decrease socioeconomic and housing-related inequalities, the accelerating nature of the situation thus risk causing compromises with social justice [4]. In addition, new energy policy and changes in the energy system risk causing new vulnerabilities to energy poverty – an issue from which Swedish households, in large, previously have been spared.

To ensure a just transition that seizes the opportunities for reduced inequality, it is thus crucial to promote, and scrutinise, the inclusion of social perspectives in transition policymaking. In a targeted contribution to this cause, the aim of the presented thesis is to explore how the energy transition of Swedish housing is affecting social justice and energy poverty; and, followingly, how socioeconomic inequality is being affected in the name of energy efficiency.

1.1 The Swedish Energy Transition of Housing

Despite relatively low levels of socioeconomic inequality, Sweden is the OECD country that has experienced the highest increase in income inequality since the 1980's [5]. In general terms, this can be explained by governmental policies such as deregulation of capital, a shrinking welfare state in favour of privatisation, austerity measures, and the abolition of redistributive taxes such as property taxation [6, 7]; in 2016, the amount of redistribution in Sweden was among the lowest in Western Europe [8]. The housing market experienced severe marketisation and liberalisation in the early 1990's that have since then continued [9, 10]. Unlike many other European countries, Sweden lacks a social housing sector [11], and, instead, a universalist approach is employed where public housing companies have the mission to provide 'housing for all' [12, 13]. In combination, the increased socioeconomic inequality and the increasingly deregulated housing market have led to a reproduction of inequalities [10] that are particularly evident in multifamily housing as residential segregation [14], over-crowdedness [15] and a general lack of affordable housing [16, 17]. This is, in brief, the setting where an accelerating energy transition is now being rolled out.

An energy transition can be defined in many ways; it can be about changing energy systems, changing modes of energy supply or demand, or improving the energy efficiency of systems and of system components [18, 19]. Some argue that transitions, unlike transformations, merely entail minor steps of change, whereas some only use the term transition for completely reinvented systems [20]. In this thesis, however, the term 'energy transition' will be used as an umbrella term to gather policies and measures [21] that are being carried out to reduce energy use and/or improve energy efficiency and performance in the housing stock.

1.1.1 Policy Development

Energy transition policy in the context of housing usually aims for decarbonisation and improved energy performance [22]. However, the Swedish housing stock has been continuously and almost completely decarbonised since the oil crises in the 1970's which has led to efforts now primarily being put into improved energy performance [23]. Against this background, the presented thesis focuses on the energy transition of Swedish housing in terms of measures for improved energy efficiency and reduced overall energy use, rather than the phase-out of fossil energy sources.

While there inevitably is a plethora of various policy measures for this cause, this thesis, directly and indirectly, scrutinises a few policy measures that have been relevant in time and in their implications. Given the context of increasing economic inequality, this primarily entails recent policy with some imposition of requirements and/or costs that are to be distributed among residents in the Swedish housing stock. This was deemed important as every instance of cost distribution involves a possibility to either aggravate or reduce economic inequality, and thus has implications for justice in the energy transition of housing.

Among relevant measures are national as well as EU-imposed energy policies. As part of the European Green Deal, there is the policy initiative of the 'Renovation Wave' aiming to substantially increase annual renovation rates and foster deep energy retrofits [1]. In the ongoing revisions of directive 2010/31/EU on the energy performance of buildings, induced by the 'Fit for 55' legislative train, minimum requirements for energy performance of multifamily buildings are anticipated [24]. While details of these requirements remain to be determined at the national level, increased renovation rates and minimum requirements in any form will impose energy retrofits with potential rent increases which inevitably becomes a matter of cost distribution, and thus a matter of justice with socioeconomic implications. This policy development is directly addressed in Paper IV, and indirectly in Paper III.

There is also a general development towards price incentives for end-user flexibility and reduced energy use. Within the EU, this recently entailed challenging the Swedish warm rent system by demanding implementation of individual metering and billing of energy for heating, i.e., cold rent, in the worst-performing multifamily buildings [25, 26]. As warm rent means that energy costs for heating are included as a fixed component of the monthly rent, it serves as an effective protection against energy poverty. In combination with a relatively well-insulated housing stock, a strong social welfare system, and support systems against energy supply disconnections, energy poverty has previously not been an issue in Sweden [27], and there is neither research nor policy specifically targeting energy poverty in the Swedish context [28]. But this new transition policy risks changing these beneficial circumstances and create new vulnerabilities to energy poverty in multifamily housing. This policy is addressed in Paper V.

Another price incentive for reduced energy use is dynamic pricing of electricity to promote demand-side flexibility, which is currently being promoted by Swedish authorities [29]. Regardless of how dynamic pricing structures are designed, new price models for energy can cause new issues to arise, such as energy poverty, and also create winners and losers in the energy transition with significant implications for socioeconomic inequality and justice. These risks are particularly prominent in single-family housing where energy bills tend to be higher than in multifamily housing. This policy development is addressed in Paper VI.

In addition, the war in Ukraine is significantly affecting the EUs energy market with palpable implications for households. Not only is the ongoing energy crisis contributing to further acceleration of the EUs energy transition, but it is likewise changing vulnerabilities to energy poverty in Sweden as energy prices continue to rise, which Paper VI also explores. This situation has significantly altered the contextual circumstances for, and thus the implications of, the research conducted for this thesis between 2019 and 2022. Therefore, how the findings should be viewed in light of current events will be further explored in the discussion chapter (Chapter 6).

How policy measures are distributed across socioeconomic groups is important for a just energy transition of housing in general. But under the prevailing circumstances, with rapid changes and policy measures alongside increasing socioeconomic inequality, distributive implications of transition policy become particularly important to consider, and scrutinise, to ensure a just transition. This reasoning of justice in the Swedish energy transition of housing is further explored and conceptualised in Paper I.

1.1 Problem Formulation

The challenge at hand is thus the risk of the accelerating energy transition being carried out in an unjust manner that contributes to increased social inequalities.

Inevitably, the housing sector needs to become more energy efficient as a means to reduce overall energy use, to keep residents' energy costs down, and to protect them from poor thermal comfort. All these needs are pressing, and the two latter are particularly important considering rising energy prices and increased instances of extreme weather events due to changes in the climate.

But their urgent nature does not eliminate the fact that this transition can, and should, be an opportunity for reduced social inequality which entails that benefits and burdens are fairly distributed [30]. In the context of housing, energy retrofitting can improve indoor comfort and reduce energy poverty, but could also spur rent increases [31-33]. Similarly, dynamic pricing in the shape of individual metering and billing for heating, or dynamic electricity pricing, could allow households to reduce energy costs, but could also cause increased costs for those unable to adapt [34-37]. This, in turn, risks having implications for vulnerability to energy poverty among households [38]. In addition, a just transition is important for the sake of building legitimacy, and thus long-term support, for transition policy and thus society's overall capacity for sustainability [39, 40].

While these challenges within the energy transition of housing have been recognised in the scientific community [41-43], they have so far been overlooked in Swedish energy policy.

1.3 Gap in Policy and Research

Sweden is a forerunning country in terms of energy transitions globally; in 2021, Sweden topped the World Economic Forum's Energy Transitions Index for the fourth year in a row [44]. Yet, this forefront position is not reflected in Swedish energy policy's consideration of social perspectives in general and a just transition in particular. In a recent study from 2022, themes and keywords in the Swedish Energy Agency's official strategies, agendas, and funded projects were analysed [45]. In the Energy Agency's future strategy, there is no mention of the word 'justice'. In Sweden's Integrated National Energy and Climate Plan [46], covering themes such as Sweden's current energy policy, general objectives, and an outline of government-supported research programmes, the word 'justice' was not mentioned either; the word 'equality' was however mentioned 14 times, but only in relation to gender [45].

This is also reflected when analysing 129 projects funded by the Energy Agency from 2009 and onwards, where none of the granted projects focused on 'social justice' or 'class' [45]; this showcases how a lack of justice considerations within the Energy Agency transfers to a research gap in the Swedish scientific community. While there is a growing body of research in Sweden analysing justice considerations and implications of smart technology, renewable energy, and decision-making in energy transitions, there is still a lack of research particularly studying justice in the energy transition of housing.

Regarding energy poverty, official Swedish energy policy documents consistently refers to social policy as the political sphere for dealing with such issues. In Sweden's National Strategy for Energy Efficient Renovation, it is briefly stated that:

> "Sweden makes no distinction between energy poverty and general poverty, and therefore does not use the concept of energy poverty. The issue is managed within the context of social policy and there are no instruments in place which are specifically aimed at this issue." [47]

In Sweden's Integrated National Energy and Climate Plan, it is similarly said that:

> "Sweden makes no distinction between energy poverty and poverty in general. As a result, the term energy poverty is not used, and there are no targeted policies to deal with it. The issue is addressed within social policy." [46]

There is thus no tangible acknowledgement of energy poverty in the Swedish policy sphere. Instead, the protective elements of social policy, such as housing allowances and prohibition against energy disconnects, are thought to sufficiently take care of a problem that ultimately has not been studied or fully understood in the Swedish context [27]. Followingly, there has been no prior research conducted on energy poverty in Sweden apart from research analysing or comparing energy poverty between different countries [48] and EU surveys [49, 50].

Finally, a new regulation for dynamic pricing on the electric grid to promote demand-side flexibility was recently passed [29]. In the impact assessment for the new regulation, it was stated that (i) the regulation will impose new tariffs for most households, (ii) households that do not adapt their electricity use in accordance with the new tariffs will experience increased costs, and (iii) automated control equipment can make the adaption convenient and is available from around 250€ [51]. Yet, despite stating that there is a substantial risk for increased electricity costs unless an investment of 250€ is made – which for many households is a significant expenditure – the Energy Markets Inspectorate conclude that they do not find any implications for negative impacts on social equality [51].

Thus, there are evident gaps in Swedish energy policy that to some extent are reflected in Swedish energy transition research. Owing to current developments in terms of socioeconomic inequality, energy markets, and energy policy, this gap can no longer be overlooked; there is a critical need for research with a social science perspective to better inform policymakers on justice implications of the energy transition of Swedish housing.

1.4 Aim and Research Questions

Against this background, the aim and the research questions of this thesis have been framed as follows:

Aim: To advance the knowledge and conceptual understanding of how the energy transition of Swedish housing is affecting social justice and vulnerability to energy poverty.

RQ I: What criteria need to be met for the energy transition of Swedish housing to be just?

RQ II: What distributive implications has the energy transition of Swedish multifamily housing had thus far?

RQ III: How is the energy transition affecting future vulnerabilities to energy poverty in Swedish housing?

While RQ I is of normative character, with the aim to conceptualise what a just energy transition of Swedish housing entails, RQ II and RQ III look backward and forward in time, respectively. RQ II focuses on distributive implications, or burden-sharing, whereas RQ III focuses on energy poverty. Figure 1 shows how the appended papers fit with the research questions, methodological approaches, and different themes within the research.

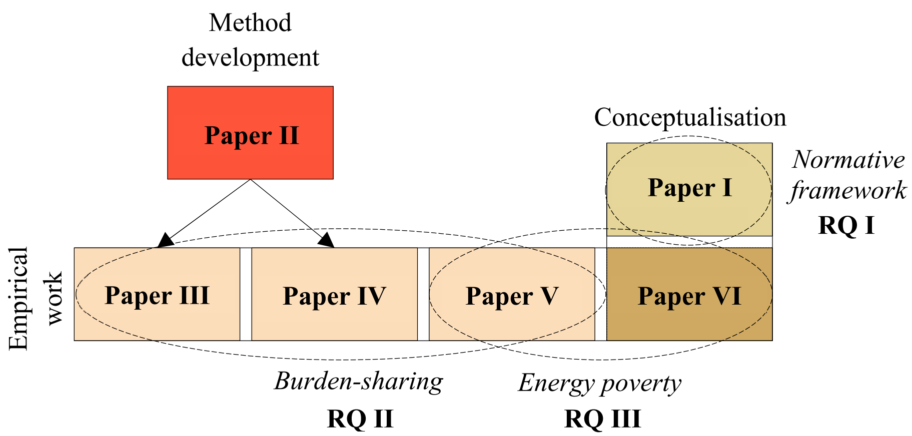

Figure 1.1. An overview of the methodological approach in the appended papers (method development, conceptualisation, and empirical work), as well as their connection to the themes and research questions in the thesis.

Paper I and Paper VI both have a methodological approach containing conceptualisation, where they aim to conceptualise a suitable understanding of a just energy transition of housing and of energy poverty for the Swedish context, respectively. Paper III-VI all have elements of empirical analyses in the methodological form of quantitative data analysis. Finally, Paper II develops the method needed for the empirical analyses in Paper III and Paper IV.

1.5 Delimitations

In relation to the aim and research questions, there are some delimitations to the scope of the research. First, while the aim is to explore justice in the energy transition of Swedish housing as a whole, many of the papers are limited to multifamily housing. This is because these papers have some connection to policy implementation, which over the past years to a greater extent has been imposed in multifamily housing than in single-family housing due to extensive renovation needs in the multifamily housing stock. Single-family housing is only analysed in Paper VI, which focuses on energy poverty, as energy poverty tends to be a more prominent issue in single-family housing than in multifamily housing owing to how heating costs are paid.

Second, the focus on measures for improved energy efficiency and reduced overall energy use means that analyses are strictly limited to energy use and therefore do not consider greenhouse gas emissions. While there indeed are significant differences between the climate, and environmental, impacts of various energy sources, accounting for these differences has not been part of the scope of the presented thesis. Moreover, this is less of an issue in multifamily housing, i.e., the main foci of the thesis, where district heating provides around 90% of the energy used for heating.

Third, when analysing implications for socioeconomic inequality, household income is used as a proxy for socioeconomic status. Although socioeconomic status is built up by several parameters, such as educational level, employment, etc., it is primarily income inequality that has been increasing in Sweden over the past decades, thus making income a relevant unit for analysis.

Finally, in the study of how the energy transition of Swedish housing is affecting social justice and vulnerability to energy poverty, only chosen aspects of, and policies in, the transition are analysed. While this does not provide a full evaluation of the energy transition’s implications, it is likely, and partly assumed, that the findings point in the direction of general trends and patterns that also underpin the parts of the energy transition that lie outside the scope of this thesis.

1.6 Structure of Thesis

The presented thesis is structured as follows. Given the normative dimension of the research, a chapter on scientific positioning (Chapter 2) follows this introductory chapter. After that, the theoretical concepts applied in the research are presented in Chapter 3, followed by a chapter on the two-parted research methodology consisting of conceptualisation and empirical analyses (Chapter 4), as showed in Figure 1. The results are then presented in Chapter 5, and are further discussed, interweaved, and contextualised in Chapter 6. Finally, the conclusions are presented in Chapter 7 along with brief answers to the research questions and recommendations for future avenues of research.

2. Scientific Positioning and Reflections

Researchers applying perspectives of justice are often asked to thoroughly declare their underlying normative standpoints and assumptions. I intend to do the same. However, I would like to start by revealing some of the implicit normative assumptions embedded in dominating energy transition research and policy. Although there is often a consensus around why, and how, the energy transition of housing should be carried out, there is a plethora of assumptions behind the framing of problems and thus the design of solutions. And by no means does consensus eliminate normativity.

2.1 The Normative Dimensions of Energy Transitions

In general, sustainability transitions subscribe to the Anthropocene narrative, i.e., the story of how humankind has pushed the Earth into an unnatural state where human influence has grown to a similar magnitude as natural forces [52]. This is the premise for our need and responsibility to act for a more sustainable future, and it permeates sustainability transitions from the global to the local scale, as well as energy transitions of countries and their housing stocks. Being deeply embedded in the natural sciences [53], there are however ontological assumptions of the Anthropocene narrative that often remain overlooked in academia as well as in policy, albeit their non-negligible normative implications [54-56]. Recognising that there are many ontological assumptions to scrutinise, I will here focus on what has been referred to as the post-social and the post-political ontologies of the Anthropocene narrative [55] to showcase that what is often presented as "*the only way ahead*" in energy transitions is, in fact, a decision actively made.

Today, there is a general understanding that societal traits within the fossil fuel economy, such as social inequality and excess consumption, have significantly contributed to changes in the environment and climate. Yet, the formulation of problems and solutions within the Anthropocene narrative is predominately situated in the natural sciences, often overlooking the structural societal changes needed for a more sustainable future [54]. This constitutes the core of the post-social ontology of the Anthropocene. Herein lies a paradox of recognising humans, *Anthropos*, and human societies as drivers for climate change, yet assuming that solutions will mainly stem from technical innovation.

This paradox extends to a fallacy of generalisation in the Anthropocene narrative where *humanity* is given responsibility for changes in the environment and the climate that have been caused by a *minority*; these changes have been brought about by technological development that some argue has been directly enabled by uneven distribution of labour and resources [54, 57-59]. This general lack of recognising inequalities in terms of contributions to climate change, as well as abilities to support a transition away from harming activities, constitutes another central trait of the post-social ontology of the Anthropocene narrative [55]. Although inequalities are increasingly accounted for, where e.g. international agreements tend to rely on the principle of *common but differentiated responsibilities* [60], the general narrative of the Anthropocene fails to acknowledge inequality as a core causal element of the current climate crisis [54, 55]. Failing to acknowledge inequality as a contributor to contemporary problems will inevitably limit the attention given to inequality in the design of pathways for more sustainable futures. In the housing sector, this post-social ontology is e.g. reflected in the way the energy transition discourse focuses on "energy use in buildings"; here, the human agency that drives energy use in buildings remains hidden, and the asymmetrical access to housing, living space and associated energy use between groups in society is left unrecognised.

Moreover, the strong focus on technology and artefacts in energy transitions has made transition pathways such as ecological modernisation and green growth the dominating ways ahead [61]. These transition pathways subscribe to the growth imperative [61], meaning that similar means that brought us here are being relied upon for transitions toward more sustainable futures. These market-based and technology-oriented pathways have come to de-politicise energy transitions [62], despite the politically conditioned inequalities that have given rise to, and that risk emerging from, sustainable transitions. This is where the post-political ontology of the Anthropocene narrative has emerged as a response to the urgency of action. This de-politicisation occurs when ideological contestation and struggles, i.e., democracy, are replaced by techno-managerial planning in the name of urgency, expressed as follows by [63]:

> "There is no contestation over the givens of the situation, […] there is only debate over the technologies of management, the timing of their implementation, the arrangements of policing, and the interests of those whose stake is already acknowledged, whose voice is recognized as legitimate." [63]

The growth imperative is so deeply embedded that it is often invisible; yet it constitutes a central normative consensus in energy transitions worldwide [64]. When it comes to energy transition policy in housing, the green growth narrative is hegemonic [65]. Within the EU, policy almost exclusively aims at improving the energy efficiency of housing [22], i.e. "greening" housing, so that housing stocks and living space per capita can continue to grow in a hope for decoupling; this decoupling has however been challenged in the housing sector [66] as well as in the wider economy [67-71]. It is this narrative and techno-economic reasoning that makes improved energy performance of the worst-performing buildings (where low-income households often are overrepresented) the main strategy in this energy transition. This is not a coincidence, but a direct outcome of the normative consensus of green growth as transition pathway, and the reliance on market mechanisms to produce desirable outcomes.

More so, visions of future societies become restricted when technology is believed to solve problems rooted in societal asymmetries of power and resources, as the technological focus diverts attention "*away from the social and cultural norms, practices and power relations that drive environmental problems in the first place*." [72]. This leads to transition narratives focused on environmental, rather than social, change [54, 55, 63, 73], perhaps missing opportunities for more just and socially sustainable societies.

Yet, few engineers and natural scientists declare their assumptions when researching new or more energy efficient technologies – although such assumptions are often rather bold. They include, but are not limited to, assumptions of social and environmental sustainability being possible to achieve within a growth economy; of democracy being subordinate to the urgency of transition; and of improved energy efficiency to surpass rebound effects. Ultimately, all of these are embedded assumptions that are rarely spoken and that, in fact, often lack empirical evidence [68, 69, 74].

I have only touched upon some of the underlying and often hidden assumptions of energy transitions here; covering all of them would be a thesis of its own. The takeaway should nonetheless be that a majority of energy transition research subscribes to assumptions of what is possible and what is desirable, but when these assumptions align with the general consensus, they rarely have to be spoken out loud. I would even argue that they might not always be recognised by the researchers themselves. An important contribution from the social sciences to sustainability research is thus to reveal and challenge implicit assumptions in transition research [55], as our understanding of problems directly impacts the solutions we implement [75].

2.2 Normative Positioning

I will here disclose my main standpoints and assumptions as a researcher and discuss how I believe these have influenced my research. This entails (i) my normative position for a just energy transition, (ii) my assumption that no transition will be just by default (challenging the post-political ontology of the Anthropocene), and (iii) my assumption that responsibilities and capabilities in the energy transition of housing are heterogenous (challenging the post-social ontology of the Anthropocene).

First, in all steps of this research, my normative position has been that the energy transition of Swedish housing should be just in terms of its distribution of benefits and burdens so that it contributes to reduced, rather than increased, social inequalities. These values are to me embedded in the understanding of a holistically sustainable transition. This normative standpoint has affected my research in the way that I have constantly been receptive to potential injustices when choosing research topics and forming research questions. Moreover, it has influenced my will to reach out with research results as a means to raise awareness and promote a just energy transition. But although these actions within my role as a researcher have been influenced by personal values, I am confident that my personal values have not influenced the scientific rigour and objectivity in the design, execution, or interpretation of my research.

Second, I have consistently worked under the assumption that the energy transition of housing will not be just or reduce social inequalities by default. Although I frame it as an assumption, this statement is supported by empirical evidence worldwide; both in terms of the direct social injustices occurring in energy transitions [76] as well as in terms of the general inability to decouple energy use and environmental impact from economic growth [64], thus failing to ensure environmental and subsequently social sustainability across space (globally) and time (inter-generationally). Thus, the lack of evidence for hegemonic structures to produce socially and environmentally sustainable outcomes constitutes a strong argument for a re-politicisation of energy transitions [77], and a critique of the post-political ontology of the Anthropocene narrative. I hold the position that unless decisions and measures are implemented with explicit concern for social justice and equality, there are significant risks that the energy transition of Swedish housing ends up reproducing existing inequalities. Technology is not politically neutral [77], and technically-driven solutions, such as policies and regulations for energy retrofitting, should not be presented as such.

Third, I challenge the post-social ontology of the Anthropocene narrative by putting social inequalities at the centre of my analyses; this primarily entails peoples' unequal contributions to the total energy use in housing and their unequal abilities to adapt to, and pay for, transition measures. I align with the scientific community that sees inequality as an enabler for the technological development and industrialisation that has put us in this urgent situation of action [54], and against that background, inequality should not be overlooked in measures for mitigation and adaptation.

Finally, I believe that it is important to bear in mind the unprecedentedness of the current climate crisis and the lack of empirical evidence of effective solutions. The fossil fuel economy has led to a natural as well as a social crisis, and I think we must seriously question whether core elements of the fossil fuel economy – such as techno-economic management and the growth imperative, both deeply connected to social inequality – will constitute sufficient modes of transition; at the very least, we must acknowledge that we are assuming that they will. Acknowledging assumptions allows for a humble approach to the framing of problems and solutions, and a constant (uncomfortable) questioning of one's own belief systems; this is ultimately needed if we are to continue to learn, and primarily, to unlearn.

2.3 Reflections of an 'Undisciplined' Researcher

Before entering the theoretical body of this thesis, I finally want to emphasise the fact that while the presented thesis to a great extent explores and employs questions of justice, and other themes primarily situated in the social sciences, I have my formal educational background in the engineering disciplines. In a way, this makes me an 'undisciplined' researcher [78, 79].

Branching out from the engineering disciplines can in part be explained by my personal interests and values, but there are external factors demanding such trajectories as well. The global climate crisis is a wicked problem that demands complex solutions; in many cases, this entails collaboration between, and integration of, disciplines. The need for cross-, multi-, trans-, and interdisciplinary research is not controversial but rather a common conception upon which there is large consensus across academia and in policymaking contexts.

Yet there is still much resistance to, and obstacles for, research and researchers combining disciplines within academia. I will not list all the challenges here, as they are many and multifaceted. But I would like to share a few reflections to dismantle and forestall some of the fear that non-intradisciplinary research seems to provoke.

I am still new to the fields I am studying. But then again, at some point I will have to be if I am to branch out from my initial discipline. If we are to meet the complex problems of our time with non- intradisciplinary research and researchers, many of us will have to start off in a tentative manner; at the end of the day, the PhD journey is in itself the epitome of being new to something, regardless of if one enters a new discipline or not. While our work of course must withstand scrutiny, such as the peer review process and public defences, there will also inevitably have to be room for undisciplined novices within academia.

Because, ultimately, being new is not only a drawback potentially compromising with scientific rigour. In this thesis, being new means that my lack of formal education within philosophy and justice theory has contributed to an increased focus on the instrumental value of principles of justice rather than their theoretical anchoring. While this somewhat limits the philosophical discussion of what a just energy transition of housing entails, it simultaneously holds the benefit of making the research more readily accessible and applicable for policymakers.

Moreover, branching out means that I lean towards being a generalist rather than the specialist researchers often are expected to be (again, an undisciplined researcher). Being a generalist makes you broad; this can be seen in the vastly different approaches applied in this thesis, ranging from exhaustive quantitative analyses to conceptualisations of a just transition and energy poverty. This broadness, that is inherent to generalists, implies that the research will perhaps not be of methodological excellence, but it will explore realistically anchored issues and be tailored to pressing societal needs; in other words, it will be problem-oriented rather than theoretically driven. This is also confirmed in the way research from this thesis has been utilised to inform policymaking in several instances.

I interpret the meaning of an undisciplined researcher as a scholar that challenges several boundaries and norms within academia. I do this in the way I have entered a new scientific discipline; in the way I enthusiastically engage with media and societal actors; in the way I have included artwork in my research communication; and, perhaps most evidently, in the way I chose to dedicate an entire chapter of my thesis to reflections on norms and assumptions within academia.

I believe there is not one way to be a researcher or to conduct research. Most importantly, I believe we are in need of some light bending and breaking of the old patterns and rules to solve today's multifaceted societal challenges. In other words, it is about time we become undisciplined.

3. Theoretical Concepts

The aim of this chapter is to describe in more detail what theories to draw from when conceptualising what a just energy transition of Swedish housing entails. Different theories, or different fields within academia, dealing with just energy transitions will be briefly introduced to finally summarise which of these theories have been applied, and how, in the presented thesis. Common for the applied theories is that they all view energy transitions as highly political and socially embedded, and thus in constant need of scrutiny to ensure social justice.

3.1 Just Transitions and Energy Justice

Justice is a concept with many different meanings to it. According to some, justice depends on the process through which an outcome is achieved, regardless of the actual outcome [80]. According to others, an outcome is just only if it has certain characteristics, such as meeting some pre-defined criteria of distribution [81]. Within the context of sustainable transitions, the concept of *just transitions* has come to comprise the justice implications of transitions for people whose livelihoods depend upon the fossil fuel economy on the one hand, and for people who risk experiencing other burdens of a sustainable transition, or a lack thereof, on the other [82]. The just transition movement originated among trade unions in the 1970's and 1980's in a call for green jobs to replace jobs in closing industries [82, 83]; as such, this movement dealt with a conflict between social and environmental sustainability that came to be explicitly situated within the *environmental justice* movement [84]. In general, the scholarship around environmental justice concerns the political economy and ecology of climate change, and the implicit asymmetries in terms of burdens of, and responsibilities for, environmental pollution and degradation [85].

Environmental justice has in turn influenced *climate justice* [86]; an academic field that has come to evolve from studying the uneven distribution of effects of climate change to dealing with the issue of burden-sharing in regard to policies and measures for climate change mitigation and adaptation [87]. Not far from these scholarships lies *energy justice*, a field where social implications of energy systems and energy transitions are considered all the way from production to consumption of energy. Today, environmental justice, climate justice, and energy justice scholarships all deal with just transitions in various ways and influence how just transitions are defined and evaluated [84].

In particular, the energy justice scholarship offers theoretical as well as practical tools for the evaluation of justice implications of energy transitions [88]. The academic field of energy justice has a foundation in what has been called the *triumvirate of tenets* consisting of distributive, procedural, and recognition justice [41, 88, 89], and promotes interdisciplinary approaches to energy transition studies [90]. Through the lens of energy justice, scrutiny has been brought upon energy policies, embedded values in the construction of new energy systems, energy transition pathways, energy development projects, and many other aspects of contemporary endeavours in the energy sector [42, 90-93]. While energy justice covers topics such as energy efficiency, energy subsidies, and energy poverty, eight guiding principles have been suggested in order to apply energy justice as a practical decision-making tool: availability, affordability, due process, good governance, sustainability, intergenerational equity, intragenerational equity, and responsibility [88]. As such, issues of affordability and energy poverty are part of the energy justice scholarship [94-97] alongside questions of just energy transitions in general, and distributive implications in particular; this suggests that all three research questions in the presented thesis to some extent are situated within the field of energy justice. In the following sections, the particular justice considerations utilised in the thesis will be further described.

3.2 Distributive Justice

Owing to the context of increasing economic inequality, the presented thesis has put much focus on burden-sharing, or the distribution of costs and burdens, in the Swedish energy transition of housing. The distribution of burdens, rather than benefits, becomes particularly important to study in light of increasing inequality, as energy transition policy should not worsen the situation for the worst-off or increase existing socioeconomic inequalities. Therefore, theories of distributive justice have been limited to the distribution of burdens under the following demarcations:

i. between income groups, as this is of higher concern for socioeconomic inequalities than the distribution of costs and burdens between, e.g., residents, housing companies, and governments,

ii. within Sweden, as energy transition policy mainly is enforced at the national level, and

iii. within the current generation, as we are primarily concerned with the burden-sharing and the inequalities within the existing population.

Moreover, although distributive justice is applied as a tool to reveal how burdens of the energy transition of housing are being distributed, this does not mean that there are no compensatory measures existing outside of energy transition policy. However, distributive implications of the energy transition must nonetheless be investigated in order to determine whether existing compensatory measures, such as social welfare subsidies, are sufficient or not.

The following two sections will briefly introduce some of the principles of distributive justice that have been relevant for, and applied in, the research.

3.2.1 Fundamental Normative Theories

Distributive justice is outcome-based, meaning that it is the outcome of how a certain benefit or burden is distributed that determines whether the distribution was just or not; this is in contrast to procedural justice accounts, that instead focus on the means through which the distribution was decided and carried out [81]. There is, however, a plethora of normative theories relevant for the distribution of benefits and burdens in the context of the energy transition of Swedish housing, which each have their own criteria for what constitutes a just outcome. One such theory is sufficientarianism. According to this normative theory, an outcome is just if, and only if, everyone is over a pre-determined sufficiency threshold [98, 99]. In the context of housing, this could imply that everyone has access to housing of an adequate standard, such as sufficiently energy efficient housing, sufficiently spacious housing, or sufficiently affordable housing.

Another commonly applied normative theory within social justice is egalitarianism, which requires everyone to be equally well off in order for an outcome to be considered just [100, 101]. In the energy transition of housing, this could imply that everyone should be equally comfortable in their indoor environment, or that the general standard of housing should be equal across societal groups.

Utilitarianism and prioritarianism are two normative theories that judge an outcome based on whether the total value has been maximised or not. While both theories consider an outcome to be just when total value has been maximised, they count increases in values differently. In utilitarianism, everyone's increase in value counts equally [102, 103]; in prioritarianism, on the other hand, every incremental increase in value counts for more for the least well-off [104, 105]. In the context of the energy transition of housing, this could mean, e.g., that subsidies for improved energy efficiency would be skewed more towards the worst off if policies were to align with prioritarianism, whereas they would be at least somewhat less skewed when distributed in accordance with utilitarianism.

In short, these different normative theories showcase the many ways in which "justice" can be achieved, and thus the importance of selecting a normative theory or standpoint against which an outcome can be evaluated. As conceptualising a just energy transition of Swedish housing was part of the aim of the presented thesis, it is described in Chapter 4 how these fundamental normative theories was utilised and combined in Paper I to answer RQI.

3.2.2 Burden-Sharing Principles

Apart from developing new and tailored criteria for a just energy transition of Swedish housing, some of the appended papers draw on existing burden-sharing principles commonly applied in climate policy. While there are several burden-sharing principles that could be utilised, the ones deemed to be most relevant for burden-sharing across socioeconomic groups, within a country, and within a single generation, are the polluter-pays principle and the ability-to-pay principle, which are utilised to answer RQ II. The benefit of using existing principles is that they are often designed for, and readily applicable in, policy contexts, and they are often generally recognised and endorsed. Thus, developing a new conceptualisation for a just energy transition of Swedish housing (RQ I) and utilising it alongside already existing burden-sharing principles (RQ II) allows for evaluations of justice that are likely to be generally accepted.

Polluter-Pays Principle

The polluter-pays principle holds that an agent responsible for pollution should also be responsible for paying for the remedy of the damage caused by the pollution [106, 107]. This principle is commonly applied in international environmental agreements such as the *1992 Rio Declaration on Environment and Development* [108], and is also imperative in policy such as trade with greenhouse gas emission permits and CO_2 taxes [109].

One common objection to the polluter-pays principle is that it fails to account for the difference between pollution from excessive consumption and consumption needed to meet basic needs [30, 110], i.e., pollution from meeting the criteria of sufficientarianism. In terms of energy use, basic needs could, e.g., entail the energy use needed to keep one's home sufficiently warm. Another objection of a more practical nature is the challenge of identifying the polluter [30]; in this thesis, pollution will be interpreted as the energy use for building services such as heating and ventilation, as there inevitably will be emissions from any energy use, even from renewable sources [111, 112]. In the case of housing, the polluter could be considered to be either the housing owner or the resident, or both. Although it is the housing owner that makes decisions regarding a building's energy efficiency and energy system, the polluter is in the presented thesis interpreted as being the resident. The reason for this choice is the same as the reason for choosing to study the distribution of costs and burdens between resident groups, i.e. that households are of main concern when aiming to analyse, and reduce, socioeconomic inequalities; however, it is also motivated by the fact that households constitute the smallest societal entity to which costs are likely to trickle down. Thus, even if costs for transition policy were to be put on housing owners, it is reasonable to assume that these costs would eventually be passed down to the residents.

In Paper III, the polluter-pays principle is applied as an interpretative lens when comparing two different ways of measuring energy use in housing: kWh per square meter and kWh per capita. By raising the question of whether to consider *buildings* as polluters (kWh per square meter) or *residents* as polluters (kWh per capita), this burden-sharing principle is used to demonstrate how the distributive implications of transition policy can go from just to unjust simply by changing the way pollution is measured. Not only does this showcase the subjectivity in seemingly objective evaluations, but it also highlights how embedded assumptions, such as a common notion of a preferred way to assess energy use in housing, can affect the distributive implications of transition policy.

Ability-to-Pay Principle

The ability-to-pay principle holds that the burden of paying for transition policy for the common good should be borne in a progressive manner, i.e., to a greater extent by those who have higher ability to pay [87]. Such reasoning is often applied in progressive taxation schemes, where there is a clear distinction between cost and burden [113]; the idea is that the financial burden should be equal across socioeconomic groups, meaning that the actual cost will have to increase with increasing income in order for the cost burden to remain equal [114]. This principle holds elements of utilitarianism in its quest to maximise total utility, or minimise total harm, if the burden is to be equally distributed [115]. Moreover, the ability-to-pay principle is more concerned with utility, or social values, rather than remedy as is the case in the polluter-pays principle. Although these burden-sharing principles approach the question of cost distribution from very different angles, it is however likely that they in many cases would lead to the same outcome given that ability to pay tends to be strongly correlated with level of pollution, or in this case, energy use [116, 117].

In Paper IV, the ability-to-pay principle is applied as an interpretative lens to evaluate the distributive implications of rent increases from energy retrofitting among different income groups in the multifamily housing stock. The contribution of the paper is twofold: the first part seeks to investigate whether there *is* a cost burden from energy retrofitting, and the second part analyses how such a cost burden, if it exists, has been *distributed* across income groups. The ability-to-pay principle thus becomes a tool for normative evaluation of the distribution of the cost for energy retrofitting, i.e., the cost of a key instrument in the energy transition of housing.

One objection to this application of the ability-to-pay principle could be that energy retrofitting does not constitute a transition policy for the common good, but rather for the interest of the housing owner and the residents who benefit through reduced costs and potentially improved indoor environment. However, as national and international implementation of energy transition policy is accelerating and

Sweden is now anticipating minimum requirements for buildings' energy performance, common goals of reduced greenhouse gas emissions and energy use are, arguably, the main reason for the imposition of energy retrofits. This perspective is further supported by the generally high standard of housing in Sweden, meaning that other benefits of energy retrofitting, such as improved indoor environment, are, or at least have been, somewhat limited and perhaps of inferior importance compared to climate objectives.

In this thesis, I have thus primarily viewed energy retrofitting as an instrument to achieve national and international targets of reduced climate impact, meaning that the ability-to-pay principle becomes applicable when analysing cost distributions across socioeconomic groups within Sweden. Applying the ability-to-pay principle in this context thus implies that the cost for energy retrofitting should be progressively carried by higher income households, i.e., these households should bear a larger share of the actual costs than lower income households.

3.3 Vulnerability to Energy Poverty

The final research question, RQ III, is concerned with how the energy transition of Swedish housing is affecting vulnerabilities to heating-related energy poverty among households. Energy poverty in a Swedish context is explored and conceptualised in Paper V and Paper VI, and in order for the methodological approach in these papers to be understandable to those not familiar with the topic of energy poverty, the following two sections will describe different ways in which energy poverty has been conceptualised in the literature.

3.3.1 Energy Poverty and Energy Vulnerability

The understanding of energy poverty has evolved from initially seeing it as a fixed state that could be quantitatively defined, to now viewing it more as a vulnerability that can be identified and defined through numerous risk factors. The first definition of heating-related energy poverty stated that households spending more than 10% of their disposable income on energy for heating were living in a state of energy poverty [118]. This expenditure-based definition then evolved into a definition saying that households at the intersection of a low energy performance of the dwelling, low income, and high energy prices suffered from energy poverty, sometimes referred to as the energy poverty triad [119]. There has also been a growing understanding that energy poverty cannot always be detected through expenditure-based indicators, as households could also be under-consuming energy to keep energy costs down; this has been referred to as *hidden* energy poverty [120, 121].

Eventually, the research field moved beyond strict definitions and began to consider energy poverty not as a fixed state, but as a situation to which households can have varying susceptibilities. The energy vulnerability framework by Bouzarovski and Petrova [122] views energy poverty in the light of changing circumstances, such as rising energy prices or a loss of household income, as well as in differences in energy demand. The latter is an important aspect as it can reveal vast differences between households that at a first glance appear to have similar susceptibilities to energy poverty; for example, a person with a chronic illness might require a higher indoor temperature to feel comfortable than someone with good health, just as a person spending a large part of the day at home might have a higher heating demand than someone spending much time at work, school, or in other settings [122].

In Sweden, there is neither an official definition of energy poverty nor has the problem been closely studied. When the concept has been discussed, ways of understanding energy poverty in Sweden have mainly centred around security of supply to avoid situations of power scarcity [27] as well as power cuts [123]. Both these types of power shortages are likely to hit vulnerable households harder; the former as power scarcity is likely to drive up energy prices and thus limit the energy access of low-income households, and the latter as power cuts are likely to have more severe effects in households with limited ability to invest in either additional façade insulation for improved thermal inertia, or one's own energy production or storage.

In Paper V, the distributive implications of a new energy transition policy, that demands the deployment of cold rent in the worst-performing multifamily buildings, are analysed from an energy poverty perspective. This new policy aims at giving households economic incentives to reduce their energy use for heating by replacing a static price model with a more dynamic one. This can thus be viewed as a basic form of demand-side management through dynamic pricing to promote end-user flexibility. Paper V utilises a rather simple conceptualisation of energy poverty in the multifamily housing stock where a high risk for energy poverty is said to be present when:

i. the energy performance of the dwelling is low,
ii. household income is low, and
iii. when heating is measured and billed individually, i.e., cold rent.

This is thus similar to the energy poverty triad, with the difference being that the risk factor of high energy prices has been exchanged for cold rent. In the context of Swedish multifamily housing, cold rent is indeed a higher risk factor for energy poverty than high energy prices, as warm rent effectively eliminates households' trade-offs between heating and heating costs. More so, increasing energy prices will not instantly affect the warm rent; rather, the warm rent will have to be adjusted to increasing energy prices in the yearly negotiations held between landlords and tenants' associations.

Paper VI, on the other hand, goes further in its conceptualisation of energy poverty by combining the energy vulnerability framework with another theoretical concept: flexibility capital. Due to its higher level of complexity, this conceptualisation is part of the methodology, and the approach will be further described in Chapter 4. However, the following section introduces flexibility capital and explains how it is connected to energy poverty.

3.3.2 Flexibility Capital

In the previous section, it was briefly mentioned how the implementation of cold rent can be viewed as a form of dynamic pricing to promote demand-side flexibility. While flexibility can be considered a component to Paper V, it is however a main theme in Paper VI. The increasing reliance upon demand-side flexibility is a central concern regarding the energy transition's implications for energy justice in general, and energy poverty in particular [43, 124]. Demand-side flexibility is today considered a crucial part of future energy systems to maintain balance in the electric grid as more intermittent electricity generation is being integrated [125, 126]. While demand-side management and flexibility in households can be achieved in many ways, such as through smart and automated technologies or external control of e.g. heat pumps, there is currently a development in Sweden towards more dynamic pricing, i.e., price variations on electricity throughout the day and/or week, to limit peaks in electricity demand. This general development was solidified in 2022 when a new regulation promoting time-differentiated tariffs on energy and power was enforced by the Swedish Energy Market Inspectorate [127].

In an effort to conceptualise justice implications of future energy systems, Powells and Fell [128] argue that with increased dependence on, and thus value of, demand-side flexibility, flexibility will increasingly become an ability that can be capitalised upon and thus be viewed as a form of capital in itself [128]. They call this ability *flexibility capital* and assume that its embeddedness in sociotechnical contexts makes it unevenly distributed across society by default [128]. Thus, assuming that flexibility capital is held in different forms and to different extents among households, Powells and Fell [128] propose a framework for conceptualising households' varying vulnerabilities in future energy systems, which can be seen in Figure 3.1.

In their framework, the interaction between flexibility capital and financial resources is explored. Although flexibility capital indeed interacts with several dimensions of inequality, Powells and Fell [128] argue that the interaction with affluence is the most evident one. In the two upper quadrants, households are relatively affluent but have differing flexibility capital. In the top-left quadrant, flexibility capital is lower, which means that households are likely to face increased energy costs in future energy systems; however, the economic burden of these costs will remain limited due to the access to financial resources. In the top-right quadrant, flexibility capital is higher, meaning that households can economise on demand-side flexibility, although it will not be financially necessary for them. This means that these households can choose to participate voluntarily and conveniently in flexibility efforts for economic gain, and it is also likely that these households utilise smart and automated technological equipment to realise flexibility in a convenient manner. This is also indicated by the two gradient bars in Figure 3.1, showing how affluence affects the level of technologically derived flexibility and voluntary flexibility, respectively.

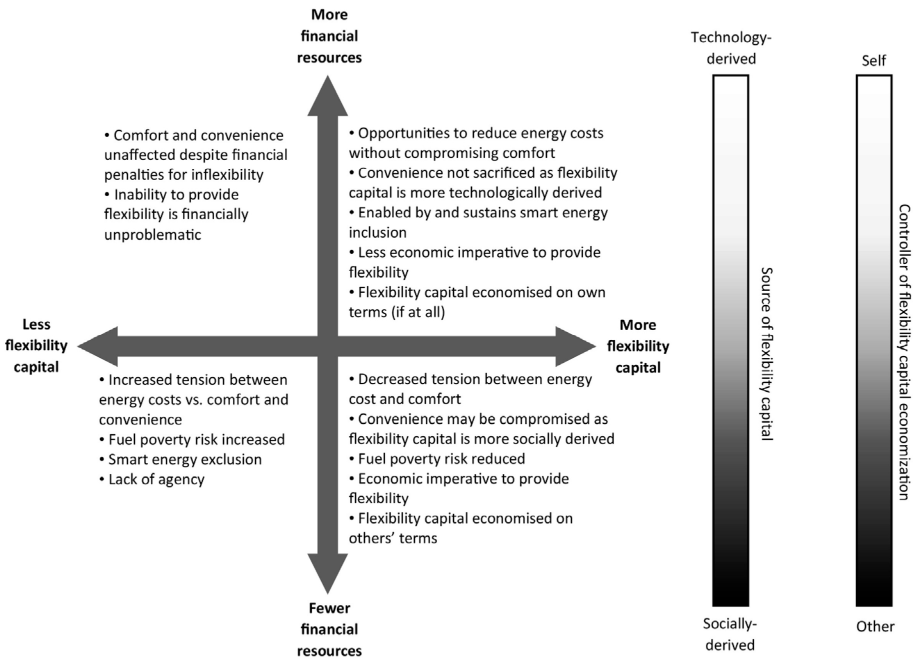

Figure 3.1. Conceptual framework showing how financial resources and flexibility capital interact to create resilience and vulnerability in smart energy systems. Source: Powells and Fell [128].

In the two lower quadrants, affluence is relatively low which alters the nature of engagement with demand-side flexibility. In the bottom-left quadrant, low affluence in combination with low flexibility capital causes tension between energy costs and other expenses, which contributes to an increased risk for energy poverty. Flexibility capital is higher in the bottom-right quadrant, but low affluence makes participation in demand-side flexibility less voluntary and more of a means to alleviate energy poverty. There is thus a risk that such participation occurs at the expense of comfort and convenience as flexibility tends to be more socially derived, i.e., more behaviour-related, when affluence is lower.

The different understandings of energy poverty described in this section were combined in Paper VI to create a novel conceptualisation of energy poverty in the Swedish context. In the following methodological chapter, it will be described in more detail how, and why, the energy vulnerability framework was combined with the framework by Powells and Fell [128].

4. Research Methodology

To fulfil the aim of advancing the knowledge of justice implications in the energy transition of Swedish housing, the research methodology has been twofold. One part focuses on conceptualisation; what does it mean for the energy transition of Swedish housing to be just, and how can energy poverty be understood in a Swedish context? These questions must be answered in order to make any statements regarding how the energy transition is affecting social justice and vulnerabilities to energy poverty. The second part focuses on quantitative analyses of distributive implications of the energy transition thus far, and of the nature and distribution of energy poverty vulnerability. This part of the work constitutes the empirical evidence that is to be evaluated and judged against the conceptual understandings of social justice and energy poverty. In this chapter, the reasoning behind these methodological choices is further developed and their general execution is outlined.

4.1 Conceptualisation

As there has been a lack of attention to considerations of both social justice and energy poverty in Swedish energy policy, novel conceptualisations of these issues were needed. In both cases, conceptualisation was conducted by drawing on, and combining, existing theoretical concepts of particular relevance for the current Swedish context.

4.1.1 A Just Energy Transition of Swedish Housing (RQI)

To answer RQI regarding what criteria that need to be met in order for the energy transition of Swedish housing to be just, a normative framework consisting of ordered principles was developed. The approach of developing a new framework, rather than utilising existing principles and guidelines within, e.g., the energy justice literature, was preferred in order to (i) get a normative framework particularly tailored to the Swedish context, and to (ii) draw on several different fundamental normative theories to generate a framework that is likely to be broadly accepted and legitimate, thus facilitating application in policymaking contexts.

The framework was developed by drawing on the fundamental normative theories for the distribution of benefits and burdens described in section 3.2.1. The theories were combined and ordered with regards to the current Swedish context, particularly with consideration to: (i) increasing economic inequalities, (ii) an increasingly precarious housing market, and (iii) a generally high standard of housing with low prevalence of energy poverty.

These contextual factors suggest, among other things, that a reduction of socioeconomic inequality in the transition can be achieved through prioritarianism, where the worst-off are the least burdened by transition policy, and that sufficientarianism can ensure a sufficient housing standard and protect the basic needs of the worst-off, such as housing affordability. More details of this reasoning can be found in Paper I, but the main take-away is that benefitting the worst-off becomes particularly important under current circumstances, and increases in well-being and resources should be deemed more valuable among the worst-off than in the rest of the population.

Moreover, ideas were pulled from the energy justice literature on essential justice considerations within energy systems and energy transitions, such as procedural, distributive, and recognitional justice. While distributive justice is covered by the outcome-based normative theories, procedural justice is important to, e.g., ensure tenant influence in renovation processes. Moreover, recognitional justice is needed to guarantee that vulnerable minority groups, such as tenants in particularly precarious or illegitimate housing situations, are considered in procedures as well as in the distribution of benefits and burdens.

Combining these different theories of justice with regards to the Swedish context resulted in the following normative framework for a just energy transition of Swedish housing, developed in Paper I to answer RQ I:

(1) Not discriminate against people on morally irrelevant grounds, such as their ethnic, religious, sexual (etc.) orientation (**the equal treatment principle**).

(2) Prioritise the needs of the worst-off, with an increase in priority the worse off they are (**the priority principle**).

(3) Produce the maximum benefit (in terms of well-being, capabilities, and resources) per resource unit (**the efficiency principle**).

(4) Use a transparent procedure where decisions are made by reasonable, fair-minded, well-informed, and cooperative people, among which are those who are (potentially) negatively affected, under equal terms, and where the decisions being made can be appealed (**the principle of procedural fairness**).

The four principles are ordered and depart from fundamental rights of equal treatment (*the equal treatment principle*), to whom to prioritise (*the priority principle*), to distributing the transition's benefits and burdens in a way that produces the maximum good (*the efficiency principle*), to finally ensuring procedural fairness in transition decision-making (*the principle of procedural fairness*). While the priority principle emphasised the need to prioritise the worst-off, the efficiency principle stops the priority principle from giving the worst-off *absolute* priority; ultimately, there will be instances in policymaking where absolute priority will simply yield too large losses in final values (such as energy savings), and thus be deemed inefficient. Where this line is drawn will have to be determined in individual cases, preferably through a fair process involving the concerned agents in accordance with the principle of procedural fairness.

The research approach of combining theory with context thus managed to generate a framework that can be readily applied in Swedish policymaking[1] where conceptualisation, as well as implementation, of justice perspectives in general have been overlooked. In Paper I, the framework is employed to evaluate justice implications in the implementation of the Renovation Wave – where minimum requirements for energy performance are anticipated – in Swedish multifamily housing.

4.1.2 Energy Poverty and Vulnerability in Sweden

With no prior conceptualisation of energy poverty in the Swedish policy landscape, a significant contribution of the presented thesis is to translate this concept to the Swedish context in order to (i) allow for analyses of the nature and the extent of the problem, as well as to (ii) initiate a dialogue on energy poverty-related issues in the Swedish policy landscape. Considering that warm rent is still dominating in multifamily housing, where the risk for energy poverty was conceptualised as an imposition of cold rent, the work presented here is limited to single-family housing where current risks for energy poverty are considered to be more prevalent.

Given that energy poverty-related issues primarily emerged in Swedish single-family housing as energy prices peaked during the winter of 2021/22, it was decided to view energy poverty in Sweden through a vulnerability lens rather than as a fixed state. The attention given to changing circumstances within Bouzarovski and Petrova's energy vulnerability framework [122] offers a suitable understanding of where problems may emerge in situations of price peaks, energy scarcity, or extreme cold spells; all of which are previously rare events that risk having increased implications for households within the near future.

Moreover, given this attention to circumstances that in various ways lead to energy price peaks, flexibility capital was included in the conceptualisation as it allows consideration of households' varying abilities to dodge price peaks and thus limit economic tension from energy poverty. Such consideration is also relevant for the development towards more dynamic pricing to promote demand-side flexibility; as such, flexibility capital not only helps to understand varying abilities to dodge currently observed electricity price peaks, but also manages to capture

[1] In fact, the normative framework was utilised as policy support in a project for Boverket in 2021.

vulnerabilities that may emerge in future energy systems more reliant on demand-side flexibility and dynamic pricing.

The concepts of energy vulnerability and flexibility capital were combined in a modified version of the conceptual framework developed by Powells and Fell [128] shown in Figure 4.1. Here, socially, or behaviourally, related flexibility capital is put along the horizontal axis, whereas inverted energy vulnerability, expressed as ‘ability to pay for heating’, is put along the vertical axis. Since the correlation between technical flexibility and financial resources is strong, the differentiation between the two axes in the framework is increased by only adding social flexibility capital to the horizontal axis, and leaving technical flexibility capital completely to the gradient bar.

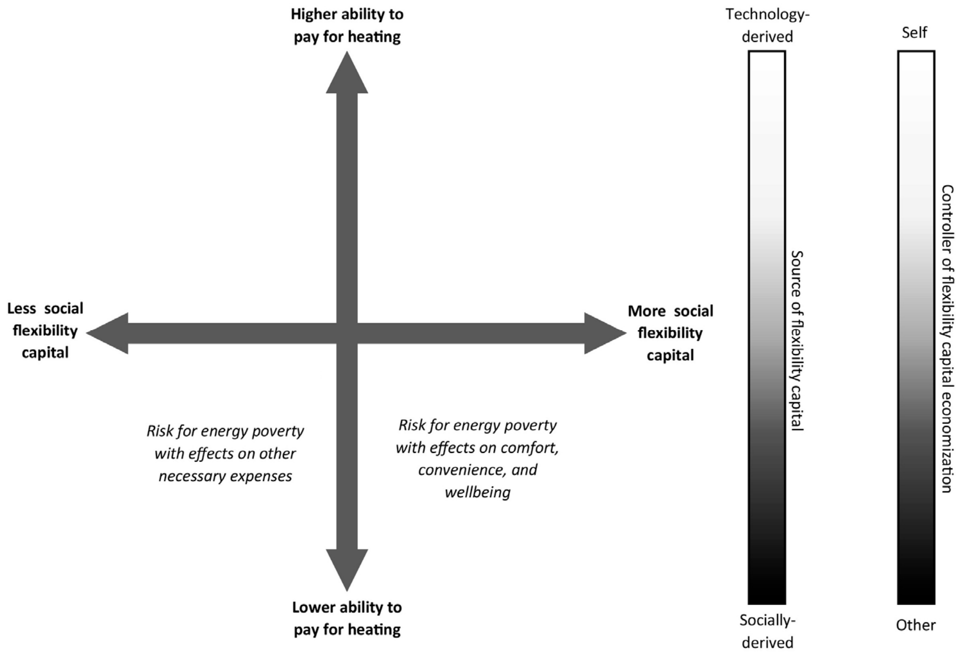

Figure 4.1. A customised version of Powells and Fell’s conceptual framework to understand and analyse energy poverty in Swedish single-family housing.
Source: Powells and Fell [128].

This way of conceptualising vulnerability to energy poverty in Sweden provides two different ways of viewing energy poverty. In the lower left quadrant, energy vulnerability is high and flexibility capital is low, meaning that there is an elevated risk of energy poverty causing financial stress for the household; here, there is a high probability of observing the ‘heat or eat’ dilemma [129, 130]. In the lower right quadrant, energy vulnerability is high but flexibility capital is also relatively high, meaning that households have abilities to dodge price peaks and curb severe financial effects of energy poverty. However, there is instead an elevated risk of hidden energy poverty, where households make compromises with their well-being or every-day life in order to keep heating costs down.

This conceptualisation was developed in Paper VI, where the modified framework was also used in quantitative analysis to investigate what factors affect households' vulnerabilities to energy poverty along the framework's two axes.

4.2 Quantitative Evaluation

To answer RQ II, empirical evidence of distributive implications of energy transition policy in the housing sector had to be collected. While justice can be studied and evaluated in various manners, such as through interviews to explore people's experiences of procedural inclusion, the study of distribution is quantitative in its nature. In the presented thesis, the main focus has been to study differences in distributive implications – of energy transition policy and of risks for energy poverty – between socioeconomic groups at the national level, and thus the anticipated effects on national socioeconomic inequality. Using quantitative methods to study differences between income groups was thus an appropriate methodology to analyse overarching correlations, general trends, and systematic practices in the energy transition of Swedish housing.

The strength in the quantitative analyses has primarily laid in their national coverage. By studying distributive implications at the national level, random patterns of distributive implications in individual buildings, neighbourhoods, or cities have not limited the analyses and interpretations; instead, it has been possible to study the general, systematic, and national implications of energy transition policy. It will here be explained what quantitative analyses have been utilised in the different appended papers.

Mirroring the conceptual work of the thesis, the quantitative analyses have focused on justice – however limited to distributive implications – as well as vulnerability to energy poverty. In Paper III and Paper IV, quantitative methods are utilised to study distributive implications viewed through the polluter-pays and the ability-to-pay principles, respectively. Common for these papers is that they both evaluate development over the past decade, which was enabled by data processing methods built in Paper II. When comparing energy use in housing measured as kWh per square meter with kWh per capita in Paper III (polluter-pays principle), differences between income groups are analysed using both analysis of variance (ANOVA), as well as multivariate linear regression analysis. While ANOVA is a suitable method to study statistically significant differences between income groups, regression analysis is powerful as a means to determine the impact of household income while also controlling for other influencing factors. In combination, these statistical methods can thus determine whether there (i) are differences in kWh per square meter and kWh per capita between income groups (ANOVA), and (ii) whether these differences can be explained by differences in income or by other confounding factors, such as differences in living space per capita (regression analysis).

Similar methods are used in Paper IV when studying rent increases from energy retrofitting and their distribution among income groups (ability-to-pay principle). A challenge in this paper was to isolate the rent increases that could specifically be allocated to energy efficiency measures; especially since Swedish rent regulation in general does not allow rent increases from such measures. An assumption in this paper was thus that any observed rent increase from energy retrofitting was an *indirect* rent increase, enabled through the inclusion of other measures that allow for rents to be increased; these are often cosmetic measures such as installing an electric towel dryer, or upgrading to a more modern kitchen or bathroom [131]. Thus, while there is expected to be much variation in included measures between individual renovation and energy retrofitting projects, national quantitative analyses allow for the observation of patterns of systematic inclusion of measures that enable rent increases in energy retrofitting projects. To study such systematic patterns, ANOVA is used to compare rent increases in renovation projects with and without energy performance improvements, and regression analysis is used to detail the impact of energy performance improvement on rent increases, while also controlling for other influencing variables. Having investigated whether there is a cost burden for energy retrofitting, Paper IV finally analyses the distribution of energy retrofits between different income groups.

In studying new requirements for individual metering and billing of energy for heating in the worst-performing multifamily buildings, Paper V spans over both conceptual themes of distributive justice as well as vulnerability to energy poverty. In a straight-forward manner, this paper draws a connection between energy performance of housing and residents' income, and analyses the distribution of this new energy transition policy between income groups. Since the policy removes warm rent, a strong protection against energy poverty in multifamily housing, this paper can be said to investigate the distributive implications of a policy that increases households' vulnerability to energy poverty.

Finally, two logistic regression analyses are used in Paper VI to investigate how various sociodemographic variables affect energy poverty vulnerability along the two axes in the customised framework in Figure 4.1, namely energy vulnerability and flexibility capital. Beyond conceptualising energy poverty in a Swedish context, this paper thus analyses characteristics contributing to energy poverty vulnerability in households, and also explores households' asymmetrical benefits and burdens in future energy systems.

4.2.1 Data

Multifamily housing: National Building-Specific Information (NBI)

For the quantitative analyses described in the previous section, two different sources of data have been used. For Papers III, IV and V, primarily dealing with analyses of distributive justice, a database developed within this thesis' research project, National Building-Specific Information (NBI), was utilised. The NBI database is a national building-specific database of Swedish multifamily housing consisting of several integrated national registers, of which an overview is shown in Table 4.1. The database relies on research conducted in the theses of Mikael Mangold and Tim Johansson, where Mangold primarily focused on data quality and data interpretation [132], whereas Johansson focused on integration and merging of different national registers with varying levels of aggregation [133].

In the database, Energy Performance Certificates (EPCs) constitute the lowest unit of analysis to which other national registers have been attached. In most cases, an EPC corresponds to one building, although adjacent buildings with similar characteristics, and on the same property, are sometimes merged into one EPC; this is because properties constitute legally delineated spaces within which all buildings have the same owner. In contrast to in many other countries, Swedish EPCs are based on operational and not calculated values for energy use, which makes energy performance data relatively reliable in an international context [134].

The main attributes used from the EPC have been energy performance, energy efficiency measures, and heated floor area. Since the implementation of EPCs in Sweden in 2008, energy performance has been defined in several ways where the main difference has lied in how different energy sources are weighted [135]; to maintain transparent interpretability and general comparability among the appended papers, no weighting factors have been applied in the calculation of energy performance. This is also in line with the delimitation to solely focus on energy use and keep greenhouse gas emissions, which weighting factors often account for, out of the scope of the thesis. Thus, in all appended papers of the presented thesis, energy performance is defined as:

> *The yearly, temperature corrected energy use for heating, ventilation, and common electricity services in multifamily housing per square meter of heated floor area. Electricity used in individual households is not included.*

As both Paper III and Paper IV study energy performance improvement between buildings' first and second EPCs, methods to ensure comparability between older and newer EPCs, despite the changes that have occurred, were developed in Paper II. One of the major contributions of Paper II was the investigation and correction of different ways to determine heated floor area between old and new EPCs. Left unaddressed, these differences contributed to systematic errors when analysing energy performance improvement, and accuracy and reliability in Paper III and

Paper IV could thus be significantly improved by finding a way to correct this systematic error.

The main advantage of this database lies in its vast coverage of the Swedish multifamily housing stock. A first EPC is available for around 90% of all multifamily buildings, and the availability of buildings' second EPCs has increased throughout this thesis work, as the initial EPCs expire after 10 years and then have to be updated. In Paper II, around 10% of the multifamily buildings had a second EPC, whereas close to 40% of buildings had a second EPC in Paper IV. The vast coverage of the multifamily housing stock in the NBI database thus allows for exhaustive analyses of general trends and patterns in Swedish multifamily housing.

Table 4.1. Overview of attributes in the NBI database.

Source	Attributes	Level of aggregation	First data point	Second data point
Energy Performance Certificates (EPCs)	Energy performance Energy efficiency measures Year of construction	Building	2008–2009	2018–2021
Swedish Tax Agency	Renovation investments	Property	2013	2019
Swedish Mapping, Cadastral and Land Registration Authority	Average yearly rent per square meter Ownership	Property	2013	2019
Statistics Sweden	Residents' median income Number of residents	Property	2016	-
The Swedish Association of Local Authorities and Regions	Classifications of municipalities	Building	2020	-

Single-family housing: SOM data

In Paper VI, vulnerability to energy poverty is studied in *single-family* housing, meaning that the NBI database could not be utilised. It was thus decided to collect data in collaboration with the SOM Institute at Gothenburg University, where annual national surveys around society, opinion and media are conducted. Researchers have the opportunity to include questions in the national survey which allows access to auxiliary sociodemographic data about the respondents, as well as access to responses to other questions in the survey. The survey was out between September and December of 2021, with most responses being collected in September, and the questions that were included for Paper VI concerned households' experienced burden of heating costs as well as their self-perceived flexibility capital. The survey was thus out right before, or at the very start of, the notable increase in electricity prices, which should be kept in mind when interpreting the results; it can however be considered an advantage that the results are likely to reflect a more neutral distribution of energy poverty vulnerability that is not tinted, or exaggerated, by the energy crisis. The questions and their respective response options can be found in Paper VI.

The SOM institute ensures a statistically representative sample and undertakes several measures to increase the response rate for the survey; for a more thorough description of their survey methodology, see [136]. The part of the survey that included the questions for Paper VI was sent to 3 374 respondents aged 16–85 and had a net response rate of 49%, corresponding to a total of 1 645 responses. Out of these, 875 responses were from households living in single-family houses or semi-detached houses.

4.3 Methodological Limitations

The methodological limitations of this thesis are mainly centred around the data. While many of the more specific shortcomings in the data are discussed and handled in the appended papers, there are two major measurement errors, i.e., discrepancies between actual values and observed values, in need of further discussion; the first is a random error, and the second is a systematic error. While the random error could be left unaddressed, the systematic error induced noticeable progression in the methodology throughout the appended papers.

4.3.1 Random Errors

The first measurement error concerns the errors and variations within EPC data. Although EPCs are issued by certified experts, the human element has nonetheless been shown to contribute to random errors in energy use data [137, 138]. These random errors stem from variations in, e.g., how energy supply to a property has been assumed to be distributed across the buildings on that property, or differences in how much of the energy supply that has been assumed to be used for heating versus domestic hot water [139]. They are assumed to be random due to their human dependency, as there is no obvious reason to believe that the issuing experts would be making the same type of error.

An advantage with random errors is however that their impact on overall accuracy in quantitative analyses decrease as data quantity increases. This is because random measurement errors can be assumed to point in different directions and cancel each other out [140]. As such, random errors in large datasets usually have limited impact on the accuracy of descriptive statistics such as average values within groups utilised in, e.g., ANOVA. Given that analyses in the appended papers have primarily been conducted on large datasets, random errors in the EPCs have not been addressed; while it has not been possible to evaluate whether their impact is significant or not, it has been assumed that their implications on the overall results have been limited.

4.3.2 Systematic Errors and Methodological Progression

The second measurement error is a systematic error in the comparison of buildings' first and second EPCs, which should have been addressed in the methodological Paper II. It concerns the determination of domestic hot water use in the calculation of buildings' energy performance. In old EPCs, domestic hot water use was often determined as a specific share of a building's total water use. This meant that in buildings with higher residential density, where the overall water use was higher than average, the energy performance was negatively affected; this is because energy use for domestic hot water was underestimated, and energy use for heating and ventilation was, followingly, overestimated. In general, this had a negative impact on estimated energy performance in areas with higher residential density, and generally lower incomes. Thus, as a means to decrease the impact of residential density, and thus increase comparability between buildings, a normalised value of energy use for domestic hot water was introduced and set to 25 kWh per square meter and year [141].

In newer EPCs, analysis showed that this standardised value is consistently used. To get an accurate representation of buildings' energy performance in old EPCs, and to get an accurate comparison of old and new EPCs, energy use for domestic hot water would have to be replaced with the new standardised value in old EPCs. However, in Paper II, Paper III, and Paper V, no such correction was made. The reason was a lack of knowledge of how energy use for domestic hot water had been determined in older EPCs, and thus uncertainty regarding whether re-calculating old EPCs would generate more accurate results or not. Eventually, after further analysing the data, I decided to replace energy use for domestic hot water in old EPCs with the new normalised value for the analyses in Paper IV.

The errors that this issue causes are twofold. First, it contributes to a flawed representation of buildings' energy performance, particularly in comparisons between income groups. This primarily becomes an issue in Paper V; at the time of writing Paper V, very few multifamily buildings had issued their second EPC, meaning that predominately old EPCs were utilised to analyse how new transition policy was to be distributed across income groups based on buildings' energy performance. In old EPCs without normalised energy use for water, this meant that buildings with high residential density, where income generally is lower, were mistakenly overrepresented among policy-affected buildings.

Second, the change in how to determine energy use for domestic hot water interferes with analyses of energy performance development between buildings' first and second EPCs. If changes in energy use for domestic hot water are not corrected for, much of the difference between first and second EPCs can be allocated to changed definitions, rather than changes in buildings' energy performance. This should thus have been addressed in the methodological Paper II, and it causes problems for the analyses in Paper III. Considering that energy use for domestic hot water in general was higher in low-income housing in old EPCs, this error primarily exaggerated the energy performance improvement in low-income housing, where the new normalised value of 25 kWh per square meter and year in many cases is lower than the value used in older EPCs.

As corrections for this systematic error were not remedied elsewhere than in Paper IV, analyses for Paper III and Paper V have been updated for the presented thesis. The updated analyses include corrections of energy use for domestic hot water in older EPCs, as well as newer, and more, data as more buildings have had their second EPC issued. In the results of this thesis, it can thus be noted that figures shown in the results chapter (Chapter 5) differ slightly from figures and results presented in the appended Paper III and Paper V. However, it was found that the overall results and the general trends did not change when updating the input data and analyses.

5. Research Findings

This chapter will present the results of the conducted studies, organised as answers to the research questions in two parts: the normative and the empirical. Utilising the conceptual work presented in the previous chapter, the first part describes the outcome of applying the framework for a just energy transition of Swedish housing to ongoing policy approaches. The second part presents the empirical findings regarding burden-sharing and energy poverty vulnerability; the latter by applying the conceptualisation of energy poverty presented in Chapter 4.

5.1 The Normative (RQ I)

Paper I addresses the first research question and lays the normative foundation against which to evaluate the empirical work in this thesis. In the paper, the framework for a just energy transition of Swedish housing presented in Chapter 4 was developed and applied to identified approaches for reduced energy use in the housing sector. The identified general approaches were (i) improved technical performance and energy efficiency of housing, (ii) economic incentives for residents to adopt more energy-efficient behaviour, which can be achieved through, e.g., individual metering and billing of energy use, or price signals for improved demand-side flexibility, and (iii) more efficient use of living space in the housing stock; the latter currently being the least recognised approach in the energy transition of housing.

When applying the framework to the different approaches, a mismatch was identified between the most relied-upon approaches for energy savings in the housing stock, and the approaches that were considered most just according to the normative framework. This is shown in Table 5.1. In the first two approaches, a lack of compliance with the framework could mainly be explained by a violation of the priority principle, i.e., the needs of the worst-off were not prioritised. Both approaches put a particular focus on buildings with low energy performance where low-income households are likely to be overrepresented, meaning that the worst-off are put at the frontline of the energy transition of housing. As this entails risks of increased rent levels from energy retrofitting, and increased energy costs from dynamic pricing, there is a possibility that these approaches lead to increased socioeconomic inequality; especially considering that these risks are not being accounted for in Swedish energy policy.

Apart from the priority principle, it was also found that the principle of procedural fairness could be more difficult to meet among the worst-off as tenant-influence tends to be lower in more exposed areas. How the approaches of improved energy performance and increased economic incentives can affect the worst-off is empirically investigated in Paper IV, Paper V and Paper VI, and the findings of these papers, presented in the following section, support the conclusions of compliance in Table 5.1.

The final approach of a more efficient use of living space in the housing stock was found to be the most compliant with the normative framework, mainly because it put the wealthiest part of the population at the frontline of the energy transition. Unlike the two prior approaches, this approach targets residents with excessive energy use in the housing stock, owing to relatively large living space per capita, rather than residents with limited economic – and spatial – margins. Empirical evidence for this claim is presented in Paper III, and the following section will present the empirical work of this thesis supporting the findings of compliance with the normative framework in Table 5.1.

Table 5.1. Characteristics of approaches to reduce energy use in the housing stock and their evaluated compliance with the developed normative framework (Paper I). An indication is also given regarding how different appended papers empirically support the findings of the normative analysis.

Approach for energy transition of housing	Energy savings potential	Part of housing stock with largest potential	Recognition	Compliance with normative framework
Improved technical performance (Renovation Wave)	High potential	Greater potential and higher cost-effectiveness in buildings with low energy performance	Highly recognised and endorsed	Low compliance (**Paper IV**)
Economic incentives for more energy-efficient behaviour (or increased demand-side flexibility)	Relatively low potential	Slightly greater potential in buildings with low energy performance	Recognised but not highly endorsed	Relatively low compliance (**Paper V**) (**Paper VI**)
More efficient use of living space	Can reduce energy use for construction and operation of new buildings	Primarily affluent parts of housing stock where living space per capita is large	Unrecognised	High compliance (**Paper III**)

5.2 The Empirical

The empirical work of this thesis has firstly looked backwards and evaluated development over the past decade to analyse how burdens have been distributed between income groups. Secondly, it has looked ahead to anticipate how vulnerabilities to energy poverty are affected by the energy transition of housing and the general development towards increased demand-side flexibility. These results will here be presented consecutively.

5.2.1 Distributive Implications (RQ II)

To investigate burden-sharing in the energy transition of Swedish multifamily housing over the past decade, two studies were carried out that focused on the polluter-pays principle (Paper III) and the ability-to-pay principle (Paper IV), respectively.

Polluter-Pays Principle

In an effort to nuance the understanding of energy use in housing, Paper III compared kWh per square meter and kWh per capita in multifamily housing. These two different energy use metrics were compared between different income deciles (1-10, low to high), as well as between 2008 and 2018, to study their respective developments over time and within the income deciles. The results of these analyses can be seen in Figure 5.1(a-b). The two energy use metrics show different trends in their correlation to income as well as in their development between 2008 and 2018. In Figure 5.1(a), it can be seen that kWh per square meter in 2008 has a *negative* correlation with household income, but that the differences in energy use between income deciles have *decreased* between 2008 and 2018. In Figure 5.1(b), there is instead a *positive* correlation between kWh per capita and household income in 2008, and the differences in energy use between income deciles have *increased* between 2008 and 2018.

The diameter of the circles in Figure 5.1(a-b) is proportional to the median living space per capita in each income decile. It can be seen that the median living space per capita has decreased in the lower income deciles between 2008 and 2018. This increase in residential density in lower income housing reflects the increased inequalities in housing, and explains the increased differences in per capita energy use between income deciles in Figure 5.1(b). The development of decreased differences in energy use per square meter seen in Figure 5.1(a) is however most likely explained by measures for improved energy efficiency in the worst-performing buildings, in which the lower income deciles are overrepresented.

Together, the results in Figure 5.1(a-b) show two different ways of analysing energy use in housing with differing implications of where measures should be directed. Viewing these metrics side by side also showcases the ambiguity of distributing costs in the energy transition if costs and burdens are to be distributed according to the polluter-pays principle.

Figure 5.2(a-d) shows a geographical representation of the two different energy use metrics in 2018. In the maps, low-income and high-income areas have been highlighted to illustrate how different areas stand out in terms of energy use depending on what metric is chosen.

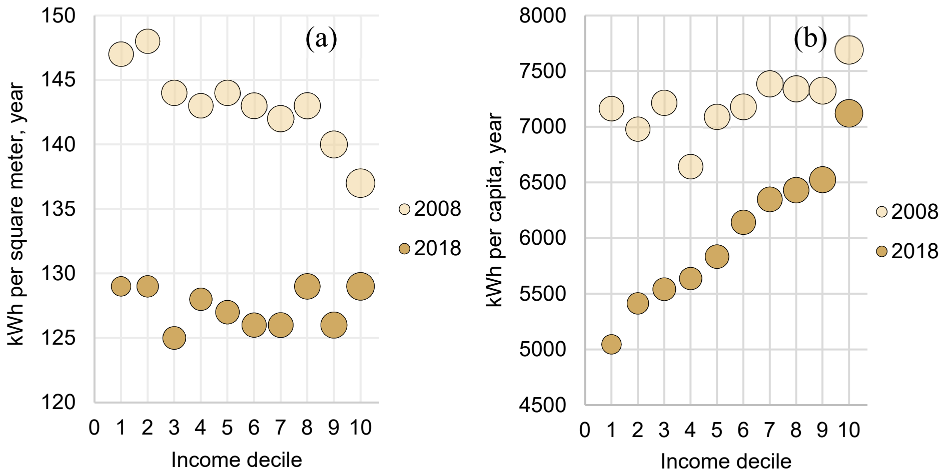

Figure 5.1(a-b). Energy use in Swedish multifamily housing in ~2008 and in ~2018 measured as kWh per square meter and year (a) and as kWh per capita and year (b) (Paper III). The diameter of the circles reflects the median living space per capita in each income decile, ranging from low to high (1-10). The figure is based on 56 716 pairs of old and new EPCs issued prior to 2022-01-01 and matched according to methods developed in Paper II. Note that these results are from Paper III, but that they differ slightly from the results presented in Paper III as this figure has been updated with more and newer data. The results include rental as well as tenant-owned housing.

Ability-to-Pay Principle

The results from Paper III reveal how the choice of energy use metric changes the perception of the polluter, but the paper does not connect the polluting activity to actual costs or expenditures. Thus, rent increases from energy retrofitting were investigated in Paper IV by comparing rent increases from renovation projects with and without energy performance improvements. These results can be seen in Figure 5.3, showing percentual rent increases between 2013 and 2019. The figure shows rent increases for buildings that have undergone no renovation, light renovation, and extensive renovation, and buildings within each of these renovation categories have been separated into three levels of energy performance improvement. In so doing, a reference level for rent increases without energy performance improvement is obtained within each renovation category, thus making it possible to identify the cost burden of energy performance improvement, or energy retrofitting, in each renovation category.

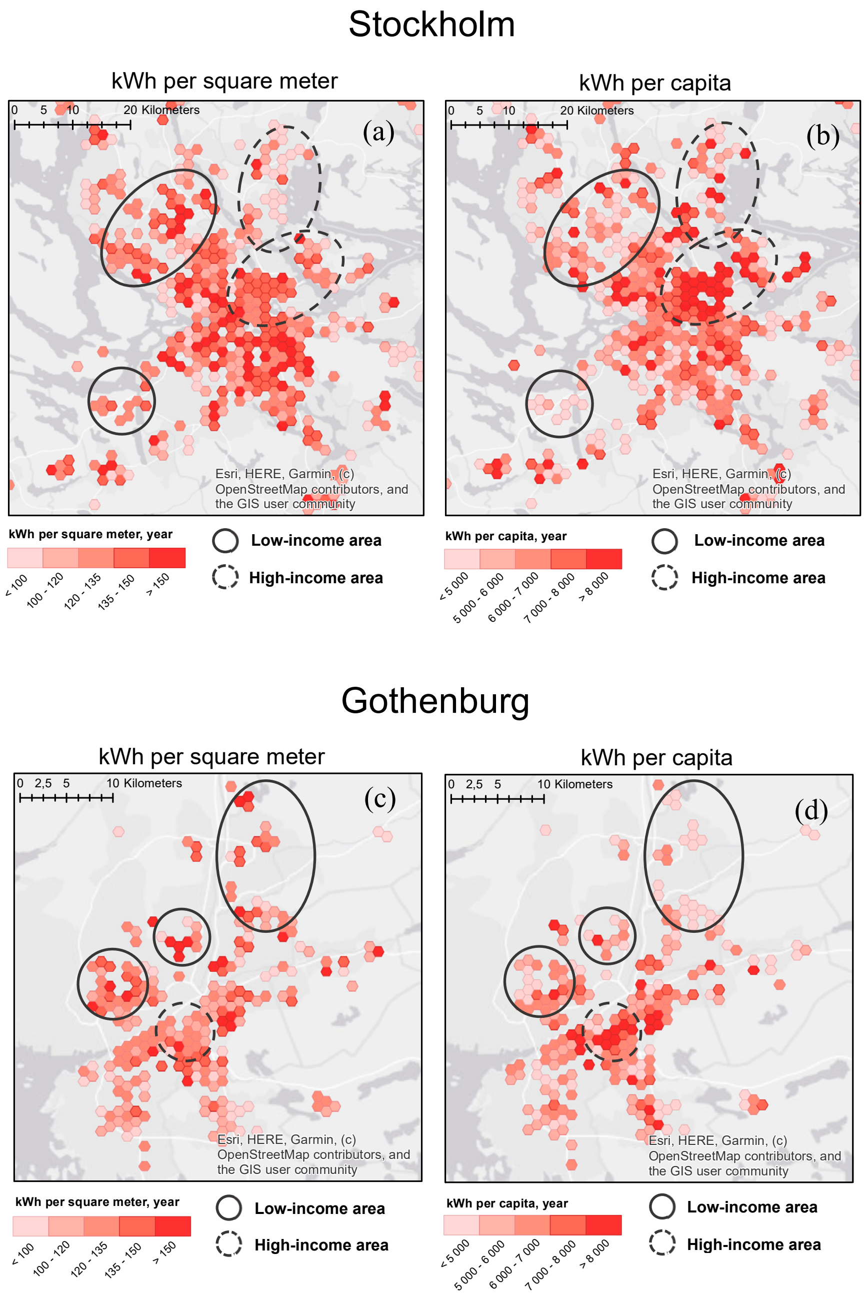

Figure 5.2(a-d). Maps showing energy use in multifamily housing measured as kWh per square meter and year (a,c) and as kWh per capita and year (b,d) in Stockholm and Gothenburg 2018. These results are from Paper III and are based on approximately 27 000 second-round EPCs issued prior to 2019-07-01.

In the 'light renovation' category, a slight yet statistically significant (ANOVA) *negative* correlation between rent increases and energy performance improvement can be seen. In the 'extensive renovation' category, there is instead a *positive* statistically significant (ANOVA) correlation between rent increases and energy performance improvement. These correlations were also confirmed in multivariate linear regression analyses (Paper IV).

With the difference between these renovation categories being the extent of the renovation investment, it can be assumed that the extent of energy efficiency measures carried out have been different as well, which in turn affects the general profitability of energy retrofitting. Although the reason for the renovation project or the type of measures carried out cannot be determined, these results reveal that in general, at the national level, there appears to be a systematic *cost burden* for energy retrofitting in more extensive renovation projects; in smaller renovation projects, energy retrofitting rather appears to entail a *cost relief* for tenants. These findings support the assumption that energy retrofitting in general is more profitable, and less likely to lead to rent increases, when energy performance improvements can be achieved through smaller investments.

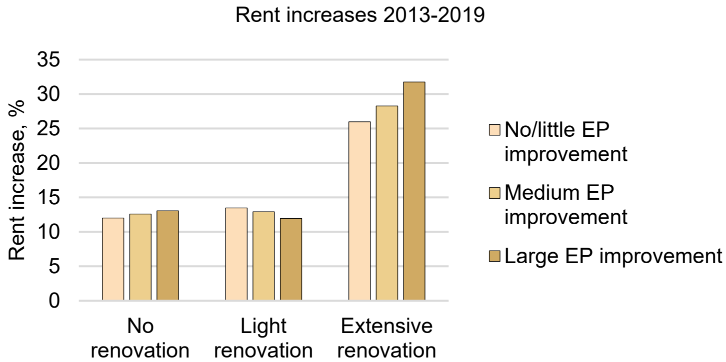

Figure 5.3. Average rent increases at different levels of energy performance (EP) improvement in different renovation categories over the period 2013 – 2019. Note that the rent increases correspond to the net change in rent levels and energy costs for heating, as the latter are included in the rent. The results are from Paper IV and based on 33 830 pairs of EPCs from rental housing only, issued prior to 2022-01-01.

Given that the cost burden for energy retrofitting was found to vary depending on the extent of the renovation project, it was further analysed how energy retrofits of different extents had been distributed across income groups. While it was found that energy retrofits entailing a cost relief for tenants had been rather evenly distributed across income groups between 2013 and 2019 (Paper IV), it was found that energy retrofits entailing a cost burden for tenants had been disproportionately carried out in low-income areas. This is shown in Figure 5.4. These results reflect the results from Figure 5.1(a) showing that energy performance has improved more in lower income areas between 2008 and 2018, where initial energy performance was the lowest. Yet, the distribution of extensive energy retrofits shown in Figure 5.4 is not merely explained by the low initial energy performance in lower income housing, but is also a testimony to public housing companies' role as forerunners in terms of energy retrofitting (Paper IV).

Regardless of the reason for the income distribution in Figure 5.4, these results show that low-income households have carried a disproportionate share of the cost burden for energy retrofitting between 2013 and 2019. This stands in direct conflict with the ability-to-pay principle and means that low-income households, who also were shown to have a low per capita energy use in multifamily housing (Paper III), are carrying palpable costs in the energy transition of Swedish housing. In combination, the results from Paper III and Paper IV thus suggest that the burden-sharing over the past decade has violated both the polluter-pays principle and the ability-to-pay principle.

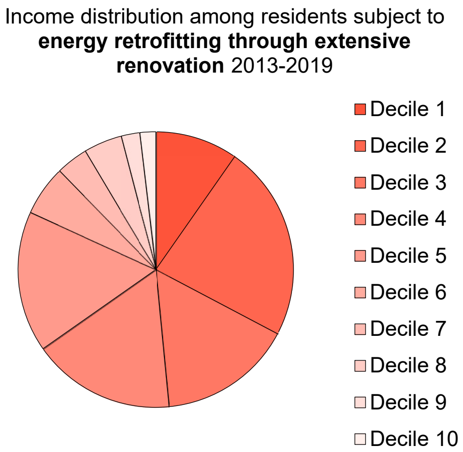

Figure 5.4. Representation of the income distribution among buildings that have undergone energy retrofitting through extensive renovation between 2013 and 2019. This entails a total of 253 buildings that could be identified among buildings with a renewed EPC prior to 2022-01-01 in Paper IV. Note that results for rent increases in Figure 5.3 only refer to rental housing, while the distribution in this figure include rental as well as tenant-owned housing.

5.2.2 Energy Poverty Vulnerability and Flexibility (RQ III)

To investigate how the energy transition of housing is affecting future vulnerabilities to energy poverty in Sweden, two studies were carried out that focused on vulnerabilities to energy poverty in the multifamily housing stock (Paper V) and in the single-family housing stock (Paper VI), respectively.

Multifamily Housing

Having conceptualised the risk for energy poverty in Swedish multifamily housing as elevated when tenants pay cold rent, Paper V analysed how a new energy transition policy demanding individual metering and billing of energy for heating (cold rent) in the worst-performing buildings would be distributed across income groups. Details of energy performance limits and policy requirements can be found in Paper V, but the regulation was nonetheless enforced in 2021. Exempts from the requirement are possible if energy performance is improved sufficiently to fall below the specified energy performance limit.

Figure 5.5 shows the number of residents, in each income decile, living in buildings targeted by the new requirement for cold rent. It can be seen that lower income residents are severely overrepresented, with close to three times as many residents affected in the lowest income decile as in the highest income decile. Moreover, the diameter of the circles in Figure 5.5 is proportional to the median per capita yearly energy use for housing in each income decile. Evidently, the lowest per capita energy use coincides with the highest exposure to cold rent requirement in income decile 1, whereas the highest per capita energy use coincides with the lowest exposure to cold rent requirement in income decile 10. Thus, this implies that a policy aiming to give tenants economic incentives to reduce their energy use is disproportionately skewed towards lower income households with high price elasticity, yet low per capita energy use.

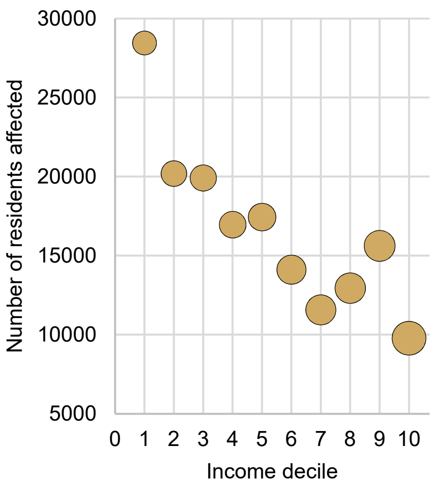

Figure 5.5. The number of residents in each income decile affected by the new regulation for individual metering and billing of energy for heating (Paper V). The diameter of the circles reflects the median yearly per capita energy use in each income decile, ranging from low to high (1-10). The figure is based on data retrieved 2020-01-01 covering approximately 80% of the Swedish multifamily housing stock, corresponding to 96 004 EPCs out of which 7 420 were affected by the new regulation. Note that this figure differs slightly from the figure in Paper V as it has been updated with newer data.

Moreover, while the removal of warm rent in itself entails an elevated risk for energy poverty, the results in Figure 5.5 show that this risk will be introduced in a part of the multifamily housing stock where several vulnerabilities collide; cold rent will be required in buildings with low energy performance, and that are predominately occupied by low-income tenants. These coinciding risk factors cause this new energy transition policy to generate a significant vulnerability to energy poverty among the affected low-income tenants.

Single-Family Housing

In the Swedish single-family housing stock, vulnerability to energy poverty was conceptualised by combining the energy vulnerability framework with the concept of flexibility capital. In Paper VI, logistic regression analyses were performed to explore what sociodemographic variables affected households' vulnerability to energy poverty along the two axes of the framework in Figure 4.1. The results of these regression analyses are shown in Figure 5.6, where arrows indicate the direction in which different variables were shown to have statistically significant correlations with the ability to pay for heating and flexibility capital, respectively.

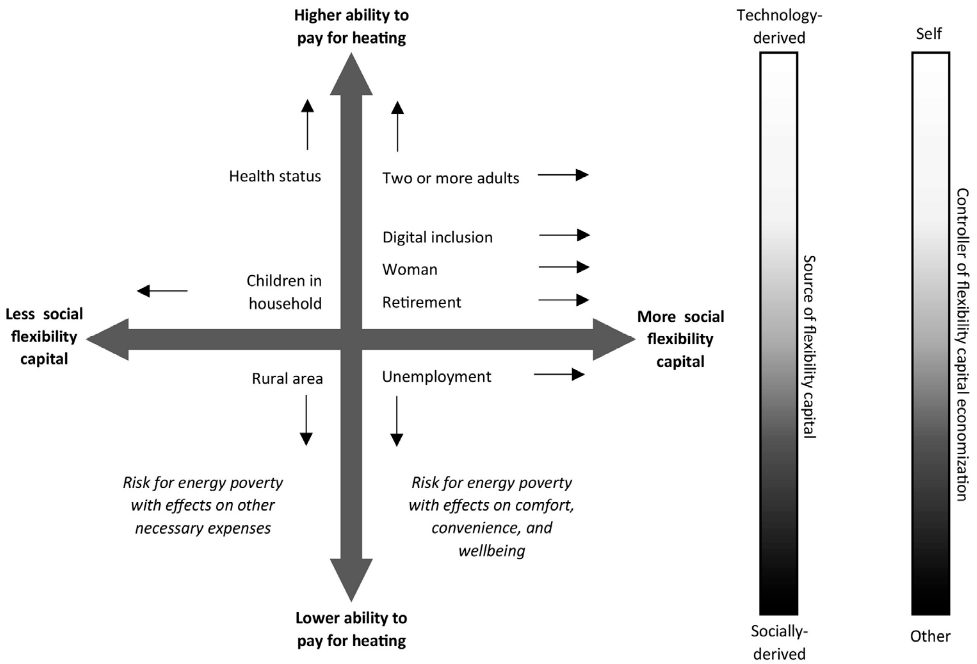

Figure 5.6. Variables affecting households' vulnerability along the lines of ability to pay for heating (a reversed interpretation of energy vulnerability) and flexibility capital without controlling for household income. The results are based on two multivariate linear regression analyses conducted on single-family housing in Paper VI using national survey data from the SOM Institute. All variables in the figure had statistically significant correlations in the direction(s) of their associated arrow(s).

Vulnerability to energy poverty is primarily present in the framework's two lower quadrants, and the results in Figure 5.6 confirm what has been suggested by the energy vulnerability literature, namely that there are factors beyond financial resources that affect households' ability to pay for heating. For example, it can be seen that a better health status increases the ability to pay for heating, even when controlling for household income (Paper VI), indicating that a lower health status might increase the energy demand for heating. Similarly, living in a rural area was shown to negatively correlate with the ability to pay for heating regardless of household income, confirming that energy poverty vulnerability can be geographically bound, as proposed in the energy vulnerability framework. Finally, purely financial factors, such as unemployment and being only one adult in the household, were also shown to push households towards the two lower quadrants in the framework. These correlations however disappeared when controlling for household income, meaning that they merely act as proxies for households' financial resources.

Having detailed some of the variables that can contribute to a higher energy poverty vulnerability in households, the results along the horizontal axis further nuance the understanding by exploring variables contributing to different *types* of energy poverty vulnerability. It was found that having children in the household had a negative correlation with flexibility capital, meaning that the risk of suffering from energy poverty primarily in terms of financial distress is elevated in these households.

On the contrary, factors such as unemployment, retirement, and being two or more adults, i.e., factors that facilitate shifting energy demanding activities in time and space, were shown to have a positive correlation with flexibility capital. For energy vulnerable households, these traits thus contribute to an elevated risk for energy poverty affecting comfort, convenience and wellbeing, i.e., hidden energy poverty. The positive impact of digital inclusion on flexibility capital has not been previously emphasised in the literature, and could potentially be explained by general information access, or awareness of how energy markets and the timing of energy use interplay. However, the finding of how gender affects flexibility capital confirms previous research pointing to gender playing a central role in flexibility work. The generally higher flexibility capital among women has, in part, been explained by the fact that women traditionally are responsible for daily energy-demanding household chores such as cooking, dishes, and laundry.

Going one step further by combining the different results in Figure 5.6 suggests, e.g., that single parents are relatively likely to be placed in the bottom left quadrant, with an elevated risk for financial effects of energy poverty. On the other hand, single pensioners are more likely to be placed in the bottom right quadrant, with an elevated risk for energy poverty affecting their general comfort, convenience and wellbeing. This highlights the varying abilities among households to dodge energy price peaks in times of unstable energy markets, and point to the fact that there indeed will be asymmetric risks and burdens in future energy systems if they become reliant on dynamic pricing to promote demand-side flexibility.

Thus, in combination, the results from Paper V and Paper VI show that there are considerable risks for increased vulnerability to energy poverty in both multifamily housing and single-family housing as the energy transition proceeds. The general increase in policy aiming to move from more static energy pricing to more dynamic price models, as is the case of both cold rent and demand-side flexibility, risk aggravating inequalities unless unequal starting points, in terms of affluence and flexibility capital, are recognised in energy policymaking.

6. Discussion

In this chapter, the presented findings will be unpacked and contextualised, with the aim to put the different pieces of the thesis together, and to connect them to the broader societal context. This is done by outlining the main contributions, as well as the limitations, of the results; discussing the implications of the findings for policy and society; revisiting the impact of underlying normative assumptions in energy transition policy; and by exploring the interpretation of the results under the current, and rapidly changing, circumstances.

6.1 Main Contributions

The aim of this thesis has been to advance the knowledge of how the energy transition of Swedish housing is affecting social justice and vulnerability to energy poverty. To answer to this aim, the normative and the empirical work must be put together.

In answering RQ I, the developed normative framework emphasised the need to prioritise the worst-off. Yet the results in relation to RQ II and RQ III show little consideration of such priorities. In answering RQ II, it was found that low-income households have carried a disproportionate cost burden of energy retrofitting over the past decade. Not only is this in direct conflict with the normative framework, but it was also shown to violate the polluter-pays and the ability-to-pay principle. At the same time, the answers to RQ III showed that low-income households are disproportionately affected by new risks to energy poverty in the multifamily housing stock, and that increased development towards dynamic pricing risks aggravating inequalities, due to households' varying flexibility capital, in the single-family housing stock. It can thus be concluded that the energy transition of Swedish housing has not, and is unlikely to continue to, fulfil the established criteria for a just energy transition.

Yet a just energy transition of housing remains vital in order to shape a more equal society as well as to build legitimacy, and thus long-term support, in the transition towards sustainability. By unpacking this brief summary of the results, the following sections outline how the presented thesis makes contributions of conceptual as well as of empirical nature for the understanding of, and the support for, justice in the energy transition of Swedish housing.

6.1.1 The Conceptual Contributions

The introductory chapter of this thesis described a general lack of recognition of justice and energy poverty in the energy transition of Swedish housing, and specifically problematised this in the light of increasing economic inequality alongside an accelerating energy transition. Two significant contributions of the presented thesis have thus been the novel conceptualisations of (i) a just energy transition of housing, and (ii) energy poverty; both developed through a combination of theoretical perspectives combined with particular consideration for relevant contextual factors.

First, the developed normative framework for a just energy transition of Swedish housing differs from other normative frameworks primarily in the way that it has deemed increasing economic inequalities, and a prioritisation of the worst-off, to be core considerations of a just transition. As such, the framework effectively and directly counteracts the structural neglect of the most vulnerable in transition planning [142], and creates an arena, as well as an agenda, to integrate principles of justice in policymaking. Moreover, although equality underpins most existing frameworks in the realm of energy justice and just transitions [143], it has been argued that the connection between just energy transitions and increasing economic inequalities remains underrated and in need of enhanced recognition [144, 145]. The approach in Paper I thus makes a significant contribution to this cause by putting the societal context of increasing economic inequality at the centre of analysis. As such, the developed framework in Paper I contributes to a more integrated understanding of how societal structures inevitably affect the conditions for, and the outcomes of, energy transitions. By directly applying the framework in Paper I, the paper further contributes with concrete exemplifications of how the four ordered principles can be utilised to evaluate justice implications in reasoning and discussions of different approaches in the energy transition.

Second, the conceptualisation of energy poverty in a Swedish context marks a first academic effort in describing this problem in Sweden, and thus makes an important contribution in putting energy poverty on the Swedish academic as well as political agenda. Similar to the normative framework, the energy poverty conceptualisation considers current contextual factors in its methodological approach; this is done through the inclusion of flexibility capital to describe households' ability to dodge the current energy price peaks. This approach holds value as a means to determine varying energy poverty vulnerability among Swedish households in the ongoing energy crisis, but the integration of the theoretical concepts of flexibility capital and the energy vulnerability framework also constitutes an academic novelty in itself. In combination, these concepts manage to describe two various forms of energy poverty: the one where high energy expenditures limit other necessary expenses (low flexibility capital), e.g. causing the 'heat or eat' dilemma, and the one where energy use is restricted to limit energy costs (high flexibility capital), thus causing hidden energy poverty, which is not recognised by common expenditure-based energy poverty indicators. Designing a conceptual understanding that accounts for both of these expressions of energy poverty allows for an inclusive awareness of the problem that does not exclude households in hidden energy poverty from being recognised as such. This awareness will be necessary in order to create useful energy poverty indicators to correctly identify, and support, energy poor households.

Moreover, although the conceptualisation in Paper VI is particularly designed for the current exceptional circumstances, it also holds explanatory power in future energy systems increasingly reliant on dynamic pricing to incentivise demand-side flexibility. By viewing flexibility capital as the ability to dodge both short-term and long-term energy price peaks, the conceptual framework developed in Paper VI becomes a useful tool to understand how new vulnerabilities can emerge in a country previously largely spared from energy poverty.

The conceptualisations in Paper I and Paper VI are not meant to represent unchallenged perspectives of what a just transition of housing entails, or of how energy poverty in Sweden should be understood, analysed, and described. Although these results fill a gap in the Swedish discourse at policy, societal, and academic level, their main contribution lie in initiating a dialogue that is long overdue. In so doing, more people can be involved in the shaping of pathways towards sustainability, and energy transition policy can be re-politicised to account for current socioeconomic and geopolitical developments.

6.1.2 The Empirical Contributions

The database developed from the previous work by Mangold [132] and Johansson [133] within the research project NBI constitutes a significant novelty in itself. Through the national coverage of conjoined building-specific information on buildings' energy use, and sociodemographic information about residents, unprecedented analyses and findings have been enabled. In general, the possibility to study how policy targeting *buildings* of specific energy ratings end up targeting *residents* of different socioeconomic status has enabled a bridging of gaps; between academic fields, policy spheres, and societal challenges. These analyses manage to show how energy efficiency policy in multifamily housing is tightly connected to residential segregation, and how residential areas usually depicted as wasteful and in need of sustainable transformations [146, 147] are, in fact, among the most energy efficient per capita. Perhaps most importantly, using the NBI database to provide policy support has contributed to an increased awareness and recognition of social equality and justice in Swedish energy policy in housing.

More specifically, the methods developed in Paper II enable the database to be utilised to study building-specific energy performance improvement over time to an extent, and detail, that has previously not been possible. Such application of EPCs was unprecedented within academia at the time of publication, with one exception, which however was geographically limited [148]. In combination with the access to auxiliary data on residents, ownership, rent levels, and renovation investments, novel analyses of social implications of the development of the energy transition of Swedish multifamily housing could be conducted with unmatched empirical rigour.

With this setup of the NBI database, the first major empirical contribution is the comparison of energy use per square meter and energy use per capita in Paper III. Several scholars have argued that there is a lack of, and a need for, occupant-centric building performance metrics [149, 150]; such metrics have been found to better reflect the effect of energy efficiency measures [151], and have been suggested as useful instruments to better represent energy use equity [152]. Yet, most likely owing to a lack of data access, few studies have mapped and compared per capita energy use to traditional energy performance metrics, and Paper III thus provides unparalleled insight into how per capita energy use varies across the multifamily housing stock.

Above all, the contribution of this study lies in generating a more nuanced understanding of energy use in housing. Not only were current correlations between energy use in housing and income strikingly different when comparing energy use per square meter to energy use per capita, but the development over the past decade was even shown to be in opposite directions; whereas inequalities between income groups in energy use per square meter had decreased, inequalities in per capita energy use had increased. These results highlight how deeply dependent our understanding of societal development is on the metrics we use for evaluation, but also how the metrics we use easily can come to unintentionally dictate the objectives we work towards, and thus the policy measures we choose to implement. In this case, it is evident that merely sticking to traditional energy performance metrics creates blind-spots in our understanding of the development, and of the actions needed to reduce overall energy use.

The second major empirical contribution enabled by the NBI database is the study of general and systematic correlations between energy retrofitting and rent increases. How energy retrofitting affects rent increases has been a highly debated topic in society and academia alike, with ongoing problematisations of 'renovictions' [153, 154] and 'green gentrification' [32, 33, 155], i.e., landlords utilising renovation projects as a means to increase rent levels [156]; sometimes with ulterior motives to change the social composition of neighbourhoods [154]. Previous studies have however suffered methodological limitations, such as a lack of disaggregated data, or merely relying on modelled results [31, 157]. Followingly, the study of national correlations between energy retrofitting and rent increases in Paper IV constitutes a novelty with significant contributions to the understanding of general patterns and systematic practices among landlords, and their implications for rent increases in energy retrofitting. The finding that tenants carry a cost burden for energy retrofitting in extensive renovation projects is in line with results from a similar study in Germany [31], and confirms observed conflicts between tenants and landlords [158]. Demonstrating this pattern at a national scale enables a wider discussion of cost distribution in energy retrofitting that looks beyond individual renovation projects. As such, a dialogue can be initiated on whether this cost burden should, in fact, fall on tenants or not, and whether there are sufficient compensatory measures in place within or outside of energy policy.

A third major empirical contribution can be found in Paper VI, utilising data from the national SOM survey, that beyond conceptualisation also makes valuable empirical contributions to the understanding of how flexibility capital varies with sociodemographic factors in the single-family housing stock. Several of the quantitative findings could confirm correlations that previously have only been studied qualitatively in smaller scopes. This includes the findings that children in the household limits flexibility [37], that women tend to do more flexibility work than men [159, 160], and that more time spent at home – e.g. due to retirement or unemployment – increases flexibility [161]. Other correlations that had previously only been suggested, such as the positive effect of digital inclusion on flexibility capital [128], could also be quantitatively confirmed. Beyond flexibility, the empirical results in Paper VI could also confirm sociodemographic factors that had been suggested as relevant for energy vulnerability, namely the benefit of good health, as well as the disadvantage of living in a rural area [122]. Adding this empirical rigour to the conceptual framework thus elevates the understanding of energy poverty in Sweden; not only is does Paper VI conceptualise what affects energy poverty vulnerability, and which shapes energy poverty can take, but it also reveals what household characteristics are more likely to lead to the different types of energy poverty vulnerability.

Finally, the empirical results are best interpreted as providing overarching portraits of general trends in Sweden. The research findings should not be interpreted as describing local phenomena and correlations, nor should they be seen as representing the experience of individual residents, as this would require other, more qualitative, research methods. But in an unparalleled way, the results of the presented thesis reveal, at a national scale, which societal groups benefit, and which lose, from the current approach to the energy transition.

6.1.3 Limitations of Empirical Findings

Ultimately, the findings are limited by the quality and granularity of the utilised data. Apart from the random and systematic measurement errors in the data, that were discussed and addressed in Chapter 4, there are a few other characteristics of the data that limit the analyses and interpretations of the results.

In the NBI database, data on renovation investments, rent increases, residents' income, and number of residents are aggregated at property level. This means that intra-property variation is lost, and extremes are thus reduced. The implications of this are that the results in e.g. Paper III, albeit showing significant differences between income deciles in terms of per capita energy use, show the differences in *average* values between *properties*; thus, extremes of high and low per capita energy use in individual apartments, in individual buildings, within properties, are overlooked. Similarly, average rent increases at property level studied in Paper IV fail to observe the variation between apartments, which are likely to be significant as rent levels ultimately are determined at apartment level. As such, the empirical results can be assumed to underestimate the income-related differences in terms of residential density, per capita energy use, and cost-burdens from energy retrofitting.

In Paper IV, there are methodological limitations owing both to the granularity of data as well as to a general lack of data. Several assumptions are made regarding how energy retrofitting affects rent increases since there is no available information about what measures that have been conducted in specific renovation projects. Instead, the combination of a renovation investment and an observation of improved energy performance is assumed to be the testimony of energy retrofitting. Given that energy efficiency measures in general do not enable rent increases, it is further assumed that the observed rent increase from energy retrofitting has been achieved through the inclusion of other types of quality-upgrading measures. Consequently, little is known about what is actually driving the rent increases, and whether they in actuality are associated with energy retrofitting or not; this flaw inevitably impairs the understanding, interpretation, and validation of the findings. However, as previously argued, they point to general and systematic patterns regarding renovation, energy retrofitting, and rent increases, which reveals, in a novel manner, how the cost burden of energy retrofitting has been distributed between income groups at a national level.

Finally, Paper VI utilises data from the national SOM survey to predict self-perceived energy vulnerability and self-perceived flexibility capital. While these results are used to describe varying household vulnerability to energy poverty, it must be kept in mind that the results merely describe self-perceived vulnerabilities. If observations of flexible energy use practices in households had been made, the prediction of flexibility capital would be more reliable. Similarly, the financial ability to pay for heating would have to be more closely studied through analyses of incomes, heating costs, and potential arrears on energy bills in order to get more representative and reliable results on energy vulnerability. As such, the results in Paper VI should mainly be viewed as preliminary findings of how vulnerability varies along the lines of the energy vulnerability framework and flexibility capital. More research, utilising different methodological approaches, are needed to fully confirm the findings in Paper VI, and there is also a need to include more variables that can help explain energy vulnerability, such as source of heating and dwelling size.

6.2 Implications for Policy and Society

A core element, and a main value, of this thesis lies in the combination of evaluating new empirical findings against existing as well as newly developed justice frameworks. Adding a normative lens and vocabulary to the quantitative results elevates them from merely being descriptive to becoming strong statements about the observed development, thus opening for a discussion on the attributes of a just transition. Here, the implications of the empirical findings will be further unpacked to outline some main considerations that need to be addressed in order to prevent the transition from causing injustices, inequalities, and vulnerabilities to energy poverty.

6.2.1 Burden-Sharing

In the context of distributive justice, or burden-sharing, it was found that both the polluter-pays and the ability-to-pay principles have been violated in the Swedish energy transition of housing; this as low-income households, with a relatively low per capita energy use for housing, have carried a disproportionate cost of energy retrofitting between 2013 and 2019. This finding raises question of (i) whether compensatory measures are needed for these households, and (ii) if the current approach in the energy transition is effective in terms of social, but also environmental, sustainability. These questions demand urgent attention as the Renovation Wave, minimum requirements for energy performance, and the ongoing energy crisis are likely to impose an upcoming avalanche of energy retrofits.

First, remedying the cost burden carried by low-income residents is a matter of both achieving a just transition in general, and a transition that does not aggravate inequalities in particular. To this cause, there are several measures that could be considered that either regulate rent increases in advance, i.e., ex-ante, or that compensate for rent increases afterwards, i.e., ex-post. One ex-ante measure that is being increasingly used is the possibility for tenants to choose between different renovation options for the interior of their apartment when the landlord carries out a renovation project or energy retrofitting. Usually, such options come in a form of mini, midi, and maxi scale, with increasingly extensive interior measures and associated rent increases [162, 163]. A critique of this approach has however been that the mini option still entails palpable rent increases for many residents; a previous study showed that over a third of tenants cannot accept any rent increase from renovation, whereas nearly half of tenants can accept a rent increase of up to 10% [164]. Thus, as a response, alternatives where the mini option is in fact a "zero", or close to costless, option have started to emerge [165, 166]. To ensure that tenants are not forced to endure rent increases above their affordability, such "zero" options could be demanded from landlords in order for them to e.g. be eligible for renovation subsidies or other benefits of the sort. In so doing, this could be a way to ensure procedural justice in decision-making in relation to energy retrofitting.

In terms of ex-post measures, it becomes a matter of economically compensating for rent increases through a system that specifically targets the worst-off; this could, e.g., be by increasing subsidies already reaching these groups, or implementing a particular "just transition" subsidy with the aim to include all groups in society in the benefits of transitions. There is, of course, also the possibility that sufficient compensatory measures already exist outside of the energy policy sphere; such examples could be housing allowances, or other social welfare subsidies that potentially covers the cost burden experienced by low-income households in energy retrofitting. However, such subsidies most likely only benefit the very worst-off, and there will inevitably be households on the border of receiving welfare subsidies that will experience a significant burden of rent increases without the access to social compensation.

Second, the results on the implications of metrics from Paper III raise questions of the direction in which traditional energy performance metrics are steering the energy transition; in regards to social justice and sustainability, but also in relation to environmental progress. Ultimately, metrics used to evaluate progress in the energy transition act as markers for sustainability. But although such markers should point in the direction of sustainable practices, they are in fact mere markers, not at all objective [167], sometimes even symbolic, and often in neglect of deeper unsustainable societal structures [168]. Metrics for energy efficiency have previously been found to include value judgements that can cause societal trade-offs and unjust cost burdens for certain societal groups [167]. Moreover, sustainability markers have been argued to generally cater to middle-class norms [168], as the results in Paper III evidently confirm.

In terms of buildings' energy use, it is evident that traditional energy performance metrics in similar ways constitute biased indicators for sustainability; for example, these metrics cancel out area, i.e., a main factor in driving total energy use. Aiming to improve buildings' technical energy performance *alongside* assessing and working towards reduced energy use per capita would add more instruments to the policy portfolio. Such instruments could be, e.g., employing policies to reduce, or even limit, living space per capita, or re-introducing the property taxation in Sweden. As such, a more *efficient* use of living space in the housing stock could enable a more *equal* distribution of living space. More efficient use of the existing housing stock has been argued to be an overlooked necessity to reduce energy use and emissions from the housing sector [169], as technical efficiency alone will not be enough [170]. This perspective has also been raised in the academic context of energy *efficiency* versus energy *sufficiency*, where reduced per capita living space in its role as a sufficiency approach is seen as an important, yet politically unorthodox [171], instrument to limit energy use in housing [172, 173].

This dialogue can also be viewed in light of sufficientarianism and the notion of prioritising basic needs among the worst-off, as suggested by the normative framework developed in Paper I. As such, the debate surrounding efficiency versus sufficiency can be rephrased as a matter of excessive energy use versus energy use to meet basic needs. Ultimately, it is not a problem that energy is used for housing, as this is inevitable and necessary, but rather it becomes a problem when it is being used excessively. Excessive energy use in housing can either be viewed as (i) when energy performance is too low, i.e., when energy use per square meter is too high, or as (ii) when housing in itself is used excessively, i.e., when living space and energy use per capita is too high. As concluded in Paper I, increased focus on the latter would push wealthier households towards the frontline of the energy transition, and would relieve some of the pressure of measures and potential costs on low-income households already in a pressed situation fighting to meet basic needs.

This is not only relevant in the context of energy retrofitting, but also in relation to demand-side flexibility; in systems increasingly reliant on dynamic pricing of electricity, households with the ability to provide flexibility will benefit more than those with limited abilities to do so. As mentioned, flexibility capital depends on several factors related to households' affluence and social composition, but flexibility is also strictly tied to the dualism between excessive energy use and energy used to meet basic needs. In more affluent households, where energy is likely to be used more excessively to, e.g., heat a jacuzzi, sauna, or secondary residences, flexibility is easier to provide as there are many low-hanging fruits to harvest before severely compromising with comfort and convenience. However, in more economically restricted households, energy use is likely to be more tightly connected to basic needs, meaning that providing flexibility at certain times is more likely to (i) be more difficult, and thus lead to either an exclusion of economic benefits or an addition of costs from dynamic pricing, depending on the pricing structure, and (ii) directly compromise with comfort and convenience due to cumbersome flexibility efforts. Energy austerity through self-restriction in these households is thus likely to lead to an underconsumption of energy, i.e., hidden energy poverty, which is problematic given that hidden energy poverty is particularly difficult to identify, and thus remedy.

However, political expediency and trust in green growth systematically puts reduced consumption (of e.g. building area and total energy use) subordinate to improved energy efficiency. A contradicting example is however given in the current European energy crisis, aggravated by the war in Ukraine, as countries are starting to implement rationing measures to reduce energy use and curb the peaking energy prices. Interestingly, these measures in general, or at least initially, target excessive energy use, such as not illuminating advertisement signs at night-time; forbidding open doors in shops with air-conditioning; and banning heating of private swimming pools from September [174]. This showcases how there in a time of urgent crisis is a political understanding, as well as a will, to protect energy use for basic needs by primarily targeting excessive energy use for energy-saving.

The societal and policy-related implications discussed here are by no means limited to the Swedish context, as scrutiny is primarily brought upon narratives in energy transition policy that permeate not only Swedish policymaking, but EU directives and regulations as well. Although the research findings are nationally situated, many of the results could also be confirmed in similar studies from other countries, and the implications discussed here are thus equally relevant in a broader European context. Nationally as well as internationally, it remains vital to see the energy transition in a greater perspective, and truly question in what areas of society energy use currently can be justly reduced. Given the deep inequalities in energy use, overall living conditions, and in abilities to participate in transition policy and its measures, questions emerge of (i) where society should prioritise reduced energy use, and (ii) who is currently in a rightful position to contribute to, and prioritise, energy efficiency and flexibility in their daily life. Backed by the normative contributions and findings of this thesis, there are numerous reasons to question a transition approach that imposes energy retrofitting in densely occupied, and thus resource efficient, low-income multifamily housing, while little political action is being taken to reduce the excessive use of space, and thus energy, in the villas and secondary residences of the more affluent part of the population. Drawing on arguments of distributive justice, sufficiency, and meeting basic needs, a just transition will demand energy transition policy in housing that increasingly targets excessive energy use, and limits the imposition of disproportionate burdens to households primarily using energy to meet their basic needs; of living space, warmth, and other necessities at the home front.

6.2.2 Energy Poverty and Flexibility

Currently, the soaring energy prices are affecting households all across Europe. While the ongoing energy crisis is an issue beyond what is usually studied in the realm of energy poverty, existing knowledge on energy poverty is nonetheless well suited to identify the most vulnerable households; ultimately, although everyone is affected by the energy crisis, not everyone is exposed. Given that energy prices are likely to remain high and volatile for the foreseeable future, this thesis' exploration of energy poverty vulnerability can thus contribute to the understanding of where vulnerabilities are likely to be the most severe. Such knowledge will be needed in order to (i) implement more effective and accurate subsidies of reactive nature, (ii) implement more proactive measures, and (iii) to avoid locking in inequalities in future energy systems.

When the Swedish government provided reactive subsidies to households during the winter of 2021, household electricity use was utilised as base of allocation, where increased electricity use led to higher compensation [175]. In the coming winter, energy prices are expected to be even higher, and various political measures to relieve households' cost burdens have already been suggested [176]. Regardless of the chosen approach, it becomes an issue of distributing tax-funded subsidies in an efficient manner that maximises benefits, arguably, for those most in need; i.e., in accordance with prioritarianism. Here, the results from the presented thesis could play an important role in achieving a distribution of reactive subsidies that is not based on households' energy use, but rather on their need for financial support to pay energy bills. Already in the early autumn of 2022, there are reports of households severely struggling to pay for their heating expenditures and to keep their homes adequately warm. Primarily, attention is being brought to families with children in general [177], and single parents, mainly mothers [178], in particular, where the 'heat or eat' dilemma is even explicitly mentioned. Attention is also brought to pensioners living alone [179, 180]. These reports are fully in line with the findings in Paper VI and suggests, or perhaps confirms, that it is primarily households in an already economically disadvantageous situation that suffer from the high energy prices. This indicates that energy subsidies, at least in part, could be distributed more accurately and effectively by being added to existing social welfare subsidies already reaching these groups.

In addition, media attention is also being brought to the relatively small, yet exposed, group of tenants paying cold rent, often in buildings with direct electric heating [181]. As such, the research findings in Paper V are effectively confirmed as well, and the accurate predictive capability of both Paper V and Paper VI suggests that this thesis can provide valuable support for policymakers in designing more fairly targeted subsidies. Drawing on other contributions from the presented thesis, such as ideas of sufficiency and prioritising energy use to meet basic needs, could in addition suggest a type of reversed energy subsidy that, after a certain breaking point, *decreases* with increasing energy use rather than increases.

Moreover, knowledge on energy poverty vulnerability will be needed for measures of more proactive nature as well, such as enabling energy efficiency measures in low-energy performance dwellings; in houses with inefficient heating systems; or among households where income or geographical location are limiting investment opportunities. With accounts of an increasing number of households having their electricity supply disconnected due to arrears on electricity bills [182], another one of the previous arguments as to why energy poverty is not an issue in Sweden is being challenged. As such, the Swedish self-image of being immune to energy poverty is being dismantled, and policymakers are facing the difficult task to rapidly develop the field of energy policy to include perspectives of social justice and equality. A contribution of this thesis could thus be to inform the development of this new field within energy policy to ensure that the distribution and nature of energy poverty vulnerability in Sweden is being adequately recognised and accounted for.

Looking further ahead, there are important implications from the novel linking of energy poverty and flexibility. This link is present in Paper V as well as in Paper VI, where economic incentives for more efficient and flexible energy use were considered in the form of cold rent and dynamic pricing, respectively. These measures rely on price elasticity, i.e., the responsiveness to fluctuating prices and costs, among households. Herein lies structural inequalities. First, household income inevitably affects the economic incentives for households to respond to dynamic prices, where lower income households to a greater extent will be economically imposed to reduce or shift their energy use. Second, the empirical results from Paper VI clearly point to the unequal distribution of flexibility capital among households, and thus the practical ability to economise on dynamic pricing models. These structural inequalities can be viewed in the context of *flexibility justice*, as discussed by Powells and Fell [128], in how the imposed or uncomfortable flexibility of some might come to directly enable the convenient energy use of others.

Considering that dynamic pricing can lead to energy poverty-related issues both in households that lack and that have access to flexibility capital, questions emerge regarding how to avoid energy poverty from becoming the price paid by some for future flexible energy systems utilised by many. For example, Paper VI confirmed that flexibility is gender-conditioned, which suggests that more dynamic electricity pricing could aggravate existing gender inequalities of domestic work; this is only one example of why it has been suggested to apply more feminist perspectives that, beyond gender, analyse how different power relations are affected by new systems and practices [77]. Moreover, the lower flexibility capital among households with children highlight the need to consider the child perspective also within energy policy, and, ultimately, to fundamentally scrutinise to what extent flexibility is truly possible within the rhythms of everyday life [183, 184]; here, there is still a need to further consider how and why energy is being used within a social context, rather than seeing energy users as fixed parts of the energy system [185]. The fact that current policy documents on dynamic pricing and demand-side flexibility do not recognise any asymmetries in the preconditions for, and implications of, flexibility [29] is thus problematic, and entails a considerable risk of social inequality being built into future energy systems.

To some extent, the implications of the research findings discussed here are specific to the Swedish context, primarily owing to the previous lack of attention to energy poverty. As such, conceptualising and providing initial descriptions of energy poverty in Sweden will have limited implications in an international context beyond, naturally, adding to a wider understanding of how energy poverty varies between geographical contexts. Moreover, as cold rent tends to be the standard in many other European countries, the implications of such requirements are very particular to the Swedish case. In terms of flexibility, however, there is much pointing to similar development towards demand-side flexibility and dynamic pricing in other countries as well, given the general increase towards more renewable and intermittent electricity generation. Thus, the discussed justice implications from demand-side flexibility are, in large, transferrable to an international context, and suggest that flexibility could be an important aspect to include in the understanding of energy poverty outside of Sweden as well.

6.3 From Political Assumptions to Social Injustice

The lack of consideration for social perspectives in Swedish energy policy was documented already in the introduction of this thesis. The research results not only confirmed this, but could also show how it has directly translated into injustices, and risks for social inequalities being reproduced, in the energy transition of Swedish housing. Returning to the ideas in Chapter 2, it is unlikely to be a coincidence that Swedish energy policy lacks social perspectives, and that injustices therefore are occurring. Arguably, these injustices stretch beyond an arbitrary lack of social perspectives in Swedish energy policy in particular; they are structural effects of the underlying normative standpoints and assumptions in energy transitions in general, and of the post-political and post-social ontologies of transition narratives in particular.

The policies that have been analysed in this thesis all follow a green growth agenda; energy retrofitting as well as economic incentives for reduced energy use (through individual metering and billing of energy and demand-side flexibility) are all underpinned by assumptions of techno-economic management and a trust in decoupling [186, 187]. By default, these policies all target or burden areas of the housing stock where *energy efficiency* is the lowest; in general, this coincides with low household incomes as energy performance of housing, as well as the technical performance of other commodities, tend to improve with increasing income [188]. Worst-performing buildings are targeted in energy retrofitting policy, e.g., through minimum requirements for energy performance, as well as in requirements for individual metering and billing of energy for heating, which was shown to cause risks for rent increases and energy poverty, respectively. Similarly, low-income residents face elevated risks for increased energy costs from dynamic pricing, as investments in automated technology and improved energy efficiency as means to dodge daily energy price peaks might be unattainable.

Although it is well known that energy policy prioritises energy efficiency over energy sufficiency [189], this thesis has, in a novel manner, revealed how a systematic favouring of policy for efficiency can lead to injustices in the energy transition of housing. This points to how a de-politicisation in favour of technical and economic feasibility has enabled a systematic exposure of low-income households in the energy transition of Swedish housing; even though these residents are currently living with high residential density, a low per capita energy use for housing, and primarily consuming energy to meet basic needs.

Deserting the post-social ontology of transition narratives would enable a recognition of these socially embedded inequalities, re-politicise transition planning, and support the notion of differentiated responsibilities in the energy transition. It would also help highlight the connection between inequality and unsustainability, where studies consistently show how an accumulation of wealth among the top 10%, a common inequality indicator beside the Gini-coefficient, is positively correlated with increased greenhouse gas emissions [190-192].

Ultimately, adopting a socially anchored ontology would increase the emphasis on social change in addition to technological development, and as such put more focus on sufficiency alongside efficiency in the policy portfolio. In the end, one approach should not be chosen over the other, but it is the utter dominance of a single approach, systematically putting vulnerable groups at risk, that is problematic.

Recognising that economic inequality is a central part of the problem gives it a natural, and central, part in the design of solutions; as is the main theme, and endeavour, of the presented thesis. With the energy transition of Swedish housing as a telling example, the research findings effectively demonstrate that technological advancement will not lead to a just transition by default; left unaddressed, social inequalities are thus likely to be aggravated and reproduced, and, ultimately, to counteract efforts for environmental sustainability.

6.4 Findings in the Light of Changing Circumstances

Although energy prices started peaking in Sweden already in December of 2021, the Russian war in Ukraine marks a historical turning point with severe implications for the EUs energy market, energy prices, and European households. While the rising energy prices were considered in Paper VI in how they affect energy poverty vulnerability in Sweden, they also have a number of considerable implications for the interpretation and implications of the findings of other papers in this thesis, either written before or at the very start of the war.

First, the rising energy prices generally improve the assessed profitability of energy retrofitting; and if profitability is higher, landlords may be less inclined to include other quality-upgrading measures to enable rent increases in energy retrofitting projects. Followingly, the patterns observed in Paper IV, particularly the identified cost burden for tenants in extensive energy retrofitting projects, might not be as visible in the coming years as they were between 2013 and 2019. It is thus important to bear in mind that the observed patterns between energy retrofitting and rent increases in Paper IV primarily are a testimony and a reflection of circumstances prevailing between 2013 and 2019, and that they under the changing circumstances have limited predictive capability. However, it remains likely that established and systematic practices continue to be adopted despite the increasing energy prices; inevitably, profit-seeking landlords will be able to make bigger profits if old practices are utilised in more profitable projects, and socially responsible landlords were perhaps not utilising such practices in the first place.

Second, the rising energy prices also put tenants' cost burden for energy retrofitting in a new light. Rent levels are negotiated annually in relation to, among other things, average interest rates and energy prices over the recent years; looking ahead, it is thus anticipated that rent increases will be high, with landlords currently demanding increases of around 10% [193], partly owing to the energy prices [194].

Consequently, it is possible that the rent increases from energy retrofitting are offset by a lower annual rent increase if the landlord's energy expenditures are limited by improved energy efficiency [195]. With the rapidly increasing energy prices, energy retrofitting can thus be viewed as a protection against higher yearly rent increases in multifamily buildings with warm rent, and a protection against energy poverty in multifamily buildings with cold rent. In sum, with rising energy prices, tenants' benefits from energy retrofitting increase and potentially outweigh the rent increases, i.e., cost burden, of energy retrofitting.

Third, the increasing energy prices are likely to affect the implications of the new requirement to implement cold rent in the worst-performing multifamily buildings. Since the regulation states that this requirement can be circumvented if energy performance is improved to above the limit for worst-performing buildings, it is possible that increased energy prices, and improved profitability of energy efficiency measures, will make the opt-out option increasingly popular in comparison to implementing cold rent. This implies that the negative consequences of the regulation, i.e., imposing an increased risk for energy poverty in an already vulnerable part of the multifamily housing stock, might not actually to a great extent be realised. Instead, this could imply that energy retrofits and energy efficiency measures will be imposed in this part of the housing stock; referring back to the previous paragraph, this could entail a cost burden for tenants in line with the results of Paper IV, but could also act as a protector against high rent increases and energy poverty. Ultimately, it is beneficial for residents to have the energy performance of their dwelling improved, as it keeps energy costs down and improves indoor environment in general, and in relation to extreme heatwaves and cold spells in particular [196]. This becomes especially important in low-income areas where residential density tends to be higher, causing high moisture loads, poor indoor quality, and excess indoor temperatures [15]. However, although the outcome of the new cold rent regulation might not be as anticipated in Paper V, this regulation still constitutes a telling example of how energy policy lacks consideration of social perspectives in general, and how risks for energy poverty have been strikingly overlooked in Sweden in particular.

It is evident that implications from policies, measures, and existing practices can, and are likely to, change along with changing circumstances. But regardless of if a rent increase is eventually offset by reduced energy costs, or if a requirement for cold rent ends up being averted, it remains crucial to consider, track, and evaluate how costs and risks are being distributed in the energy transition of housing. Inevitably, the ongoing energy crisis is likely to spur energy retrofits and increase renovation rates in general, implying that the distributive implications of the benefits as well as burdens of energy retrofitting will be amplified in their scope.

Finally, the war in Ukraine and the energy crisis are causing an avalanche of reactive measures. Apart from the electricity price subsidy already mentioned, that arguably turned out to primarily benefit middle and higher income households [197], fuel taxes were also reduced in an effort to curb households' economic effects of the war [198]. In a recent policy brief, researchers found that these tax reductions also mainly benefitted high income households [199]. There are thus significant risks of unjust burden-sharing occurring between socioeconomic groups in these reactive political responses. Although energy transition policy and reactive energy crisis policy might be different in nature, their distributive considerations are similar. Given that the normative framework for a just energy transition of Swedish housing was developed with regard to the Swedish context of increasing economic inequality, with a particular consideration of the worst-off, the framework can undeniably be applied to policy responses in the current energy crisis as well.

Thus, in addition to considering the ongoing crisis when conceptualising and empirically analysing energy poverty in Sweden, the work in the presented thesis can also help inform how reactive energy policy measures should be designed to ensure a just distribution of benefits and burdens. Aligning with both the ability-to-pay principle and the normative framework suggests that priority should be given to the worst-off in terms of minimising their burdens, and maximising their benefits, of current policy measures. As such, the normative contributions of the presented thesis can fill a larger purpose within energy policy, with the ultimate objective being that neither a transition nor a crisis should exacerbate the already increasing economic inequalities in Sweden.

7. Conclusions

At last, this concluding chapter returns to the core inquiries of the presented thesis; interlinks the findings with a broader narrative to create a coherent story; and utilises this story to pose questions and offer recommendations of research needed to build on this thesis, and to continue the promotion of a just energy transition of housing.

7.2 Answering the Research Questions

To answer to the aim of advancing the knowledge and conceptual understanding of how the energy transition of Swedish housing is affecting social justice and vulnerability to energy poverty, three research questions were posed, addressed, and answered as follows.

RQ I: *What criteria need to be met for the energy transition of Swedish housing to be just?*

Paper I explored what criteria need to be met in order for the energy transition of Swedish housing to be just. Different fundamental normative theories, that were considered particularly relevant to the Swedish context of increasing economic and housing-related inequalities, were selected and combined; this resulted in the following normative framework, consisting of four ordered principles, for a just energy transition of Swedish housing:

(1) Not discriminate against people on morally irrelevant grounds, such as their ethnic, religious, sexual (etc.) orientation (**the equal treatment principle**).

(2) Prioritise the needs of the worst-off, with an increase in priority the worse off they are (**the priority principle**).

(3) Produce the maximum benefit (in terms of well-being, capabilities, and resources) per resource unit (**the efficiency principle**).

(4) Use a transparent procedure where decisions are made by reasonable, fair-minded, well-informed, and cooperative people, among which are those who are (potentially) negatively affected, under equal terms, and where the decisions being made can be appealed (**the principle of procedural fairness**).

The principles depart from fundamental rights of equal treatment (*the equal treatment principle*), to a particular, yet not absolute, prioritisation of the worst-off in the energy transition (*the priority principle*), to a distribution of the transition's benefits and burdens in a way that produces the maximum good (*the efficiency principle*), to finally ensuring procedural fairness in transition decision-making (*the principle of procedural fairness*). When applying the framework to three identified approaches for reduced energy use in the housing stock in Paper I, it was found that commonly applied and recognised approaches have rather low compliance with the normative framework, whereas the less endorsed approach, of utilising living space in the housing stock more efficiently, has high compliance with the framework. This is showed in Table 7.1 alongside indications of how the different appended papers empirically support the findings of the normative evaluation.

Table 7.1. Characteristics of approaches to reduce energy use in the housing stock and their evaluated compliance with the developed normative framework (Paper I). An indication is also given regarding how different appended papers empirically support the findings of the normative analysis.

Approach for energy transition of housing	Energy savings potential	Recognition	Compliance with normative framework
Improved technical performance (Renovation Wave)	High potential	Highly recognised and endorsed	Low compliance (**Paper IV**)
Economic incentives for more energy-efficient behaviour (or increased demand-side flexibility)	Relatively low potential	Recognised but not highly endorsed	Relatively low compliance (**Paper V**) (**Paper VI**)
More efficient use of living space	Can reduce energy use for construction and operation of new buildings	Unrecognised	High compliance (**Paper III**)

***RQ II**: What distributive implications has the energy transition of Swedish multifamily housing had thus far?*

Distributive implications from the energy transition of Swedish multifamily housing could be determined by combining the results from Paper III and Paper IV. In Paper III, it was found that per capita energy use for housing increases with rising income due to larger living space per capita. Thus, low-income residents have a low per capita energy use for housing due to relatively high residential density, despite generally living in buildings with relatively low energy performance.

In Paper IV, cost burdens from energy retrofitting between 2013 and 2019 were analysed by comparing rent increases in renovation projects with and without energy performance improvements. It was found that while energy retrofitting had entailed a cost *relief* for tenants in smaller renovation projects, it had entailed a cost *burden* for tenants in more extensive renovation projects. While smaller energy retrofitting projects had been rather evenly distributed across the multifamily housing stock between 2013 and 2019, more extensive energy retrofitting projects had been predominately carried out by public housing companies, meaning that low-income residents had disproportionately carried the cost burden for energy retrofitting.

In combination, these results point to a violation of the *polluter-pays principle* (low-income residents have low per capita energy use for housing) as well as the *ability-to-pay principle* (low-income residents have lower ability to pay). Combining these burden-sharing principles with the developed normative framework for a just energy transition, which emphasises the need to prioritise the worst-off, shows that the energy transition hitherto has caused unjust burden-sharing between income groups. This can be viewed in light of the dualism between energy *efficiency* and energy *sufficiency*, where the former promotes improved technical energy performance of housing, whereas the latter primarily promotes reduced living space per capita in the housing stock. While the dominating focus on energy efficiency has caused unjust burden-sharing in the energy transition, increased focus on energy sufficiency would rather put more affluent households at the frontline of the transition – in large contributing to a more just distribution of costs and burdens.

RQ III: *How is the energy transition affecting future vulnerabilities to energy poverty in Swedish housing?*

Energy poverty vulnerability was studied for multifamily housing in Paper V, and for single-family housing in Paper VI. In Paper V, it was found that new energy transition policy, imposing cold rent in the worst-performing multifamily buildings, would primarily target low-income households. Removing warm rent, a strong protector against energy poverty, in parts of the multifamily housing stock where energy performance and household incomes are low entails a significantly increased risk for energy poverty among the affected households.

In Paper VI, energy poverty vulnerability in single-family housing was first conceptualised through a combination of the theoretical frameworks *energy vulnerability* and *flexibility capital*. As such, energy poverty vulnerability is understood through circumstantial factors, such as geography, health, and needs (energy vulnerability), as well as through the ability to dodge price peaks (flexibility capital); the latter being particularly relevant given that (i) energy poverty initially became an issue in Sweden along with the energy price peaks in the winter of 2021, and that (ii) dynamic pricing to incentivise demand-side flexibility is increasingly relied upon to balance intermittent electricity generation in future energy systems.

How various sociodemographic characteristics affected vulnerability along the lines of energy vulnerability and flexibility capital was then statistically analysed. It was found that factors such as being only one adult, or having children in the household, increased the risks of financially suffering from energy poverty, by, e.g., having to compromise with other necessary expenses; as an example, this indicates that single parents have a particular predisposition to experiencing the 'heat or eat' dilemma. On the other hand, being only one adult while unemployed or retired were factors that increased the risks of *hidden* energy poverty, primarily causing compromises with comfort, convenience, and well-being; this indicates, e.g., that single pensioners have a particular susceptibility to hidden energy poverty. Most importantly, the results showed that flexibility capital is unequally distributed between households, and that there are several factors beyond purely financial ones that affect households' vulnerability to energy poverty.

In sum, the results from Paper V and Paper VI show that energy transition policy, in its increasing reliance upon economic incentives for more efficient energy use (cold rent as well as dynamic pricing), pose increased risks for energy poverty as low-income households are disproportionately targeted and burdened by, as well as responsive to, such measures.

7.2 Concluding Remarks: From Snapshot to Story

It could be argued that the findings in the presented thesis reflect a snapshot of the state of things at the time of analysis. This snapshot shows how rapid action, driven by a sense of urgency, evidently compromises with social justice and equality in the energy transition of Swedish housing.

It is but a snapshot as it describes the distributive outcomes of individual policy measures at a given time, and as discussed in the previous chapter, many of the outcomes are likely to change along with swift changes in energy prices and other circumstances. Yet, this does not diminish the value of the findings; snapshots are ultimately the pieces that in sum, and in time, make up our understanding of the world.

But the presented thesis does not only attend to the unpredictable, albeit here found to be coherent, outcomes. Perhaps more importantly, it attends to the structures and mechanisms that brought them about. Here, the workings of underlying, normative political assumptions emerge; there is the assumption of green growth, prompting a stronger focus on efficiency than on sufficiency, as well as the assumption of economic incentives automatically generating desirable outcomes, in blunt neglect of the unequal abilities to respond to, and economise on, such price signals.

With changing circumstances, outcomes are likely to change faster than their underlying mechanisms that are usually both structurally and politically anchored. Thus, domination of techno-economic reasoning and natural sciences in energy transitions is likely to continue for the foreseeable future, as is the observed lack of integration of social justice and equality in Swedish energy policy. This is where the implications from this thesis go from providing a mere snapshot of the status quo to telling a meaningful story; and perhaps a different side to the story that is usually being told.

In broad terms, it is the story of a how inequality is both the means that brought us to the climate crisis and the end in our efforts to avert it. It is the story of how established structures tend to benefit the ones who put them in place. Ultimately, it is the story of how technological development as an enabler for energy transitions has come to be viewed in fragments, snapshots even, without sufficient recognition of the societal structures and inequalities it is supported by, and simultaneously aggravates. As such, it is the story of the de-politicisation of energy transitions, and of how perspectives from the social sciences are strikingly missing in the lion's share of contemporary energy transition policy and research.

In a counterbalancing act, the presented thesis makes a critical effort in applying perspectives from the social sciences in analyses of energy transition development. It does so in integrating structural and contextual factors, such as increasing economic inequality and soaring energy prices, to promote a meaningful inclusion of energy justice and energy poverty in Swedish energy policy; in showing how low-income households are structurally burdened by transition policy; and in describing how structural inequalities in flexibility and energy vulnerability are distributed and can be accounted for when designing future energy systems. In short, by putting inequality at the centre of analysis, this thesis challenges the grand narrative of transition as pure salvation.

In empirically showing how inequalities currently are being reproduced in the energy transition of Swedish housing, the research findings highlight the need to protect affordable and adequate housing, to rightfully share costs and burdens of the transition, and to alleviate risks for energy poverty; all while simultaneously working towards reduced energy use in the housing stock. Although this is a difficult task, it is one that demands urgent attention; especially with Sweden being considered a forerunning country in terms of energy transitions to which other countries are likely to glance and follow suit. Ultimately, the energy transition entails an opportunity to reduce inequalities in housing in general, and in relation to heating in particular. By disclosing the asymmetric consequences of past decisions, the presented thesis provides credible accounts of the need for increased integration of social perspectives in energy transition planning, and offers practical support for more just pathways ahead.

7.3 Future Avenues of Research

This thesis makes a significant contribution in highlighting, defining, and describing a problem in how Swedish energy policy is navigating concerns of social justice and equality. But now that (i) the problem has been recognised, and (ii) the energy transition, alongside the energy crisis, is triggering several political responses in housing energy policy, what is urgently needed is effective solutions.

For the anticipated minimum requirements of energy performance, a pressing issue to address is how to ensure that the imposed energy retrofits are conditional in terms of rent increases (distributive justice) and tenant influence (procedural justice). Implementing such extensive policy requirements without paying careful attention to matters of social justice and equality would entail substantial risks for increased inequality, but also for social unrest and resistance. By focusing research efforts in the direction of design, and integration, of commands that promote a just implementation of minimum requirements, benefits could be directly harvested by vulnerable groups.

It also remains to be explored how future energy systems, assumingly dependent on demand-side flexibility, can be designed in a way that does not pose significant risks for energy poverty or increased energy-related inequalities. Studies should thus try to identify where true potential for flexibility exists, and where this potential can be utilised in a way that does not increase inequality or impose pressure in already strained households. How can we design systems that enable flexibility among excessive energy users, yet limits the imposition of flexibility among households primarily using energy to meet basic needs? Here, finding ways to achieve "excessive-peak shaving", i.e., cutting peak demand of excessive energy use, could diversify the composition of households fronting the energy transition.

Finally, although energy poverty has here been introduced to the Swedish academic and political agenda, energy poverty research in Sweden is still at a preliminary stage. The results presented in this thesis add to a conceptualisation of the problem and identify a few of the risk factors that shape energy poverty vulnerability in different ways. Yet, little is known about the total number of households suffering from energy poverty, and the specifics of their hardship is yet to be understood. While there are some expenditure-based indicators focusing on the share of disposable income spent on heating, the amount and characteristics of households suffering from *hidden* energy poverty, which cannot be identified through expenditure-based indicators, remains unknown. To gain a better understanding of where, why, and how hidden energy poverty is manifested in Sweden, research approaches beyond quantitative indicators are needed. Qualitative research methods could make an important contribution to document the lived experiences among households that previously have struggled, or currently are struggling, to keep their homes adequately warm; considering how these experiences have been overlooked in Swedish academia, policy, and society alike, such research could provide an important nuancing, or even re-telling, of our common history.

Still, given the urgency of the current energy crisis, there is in parallel a need to skip ahead of deepened understanding of the problem and quickly focus research on finding the most effective means to alleviate risks for energy poverty. This entails researching where different types of measures have the most impact, as well as what constitutes the most financially effective approaches; these questions are in urgent need of answers to ensure that tax-funded subsidies are distributed in a manner that maximises societal benefits, and effectively protects the most vulnerable from the harsh winter ahead.

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A different side to the common story

Climate change is imposing rapid action to improve energy efficiency in the housing stock. This action is needed and ultimately inevitable; but housing is more than a commodity in need of performance optimisation. Housing is a human right that is currently being distributed across societies with historically high levels of economic inequality, a development to which Sweden is no exception. Although the transition towards more sustainable housing stocks will bring about many benefits, there will also be burdens that in some way must be justly shared across these societies. In addition, there is a risk that new energy policy and changes in the energy system will cause new vulnerabilities to energy poverty – an issue from which Swedish households, in large, previously have been spared. To ensure a just energy transition, it is thus crucial to promote, and scrutinise, the inclusion of social perspectives in transition policymaking. In a targeted contribution to this cause, this thesis has explored how the energy transition of Swedish housing is affecting social justice and energy poverty; and followingly, how socioeconomic inequality is being affected in the name of energy efficiency.

This doctoral thesis is a product of research conducted by Jenny von Platten in a collaboration between Lund University and RISE Research Institutes of Sweden. Starting from a master's degree in energy systems engineering, Jenny now dedicates her research to social justice and energy poverty in the energy transition of Swedish housing. As such, she identifies as an 'undisciplined' researcher.

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