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Residential Electricity Consumption in South Africa

Virtual Stakeholder Workshop

22 June 2021

2-4 PM

Presenters

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Researcher

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Agenda

Session 1: Overview & key findings

- Introduction
- Project overview
- Key findings
- The future

Session 2: Research methodology

- REC 2020 Household survey
- Household calibration
- National calibration
- LEAP model development

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Introduction

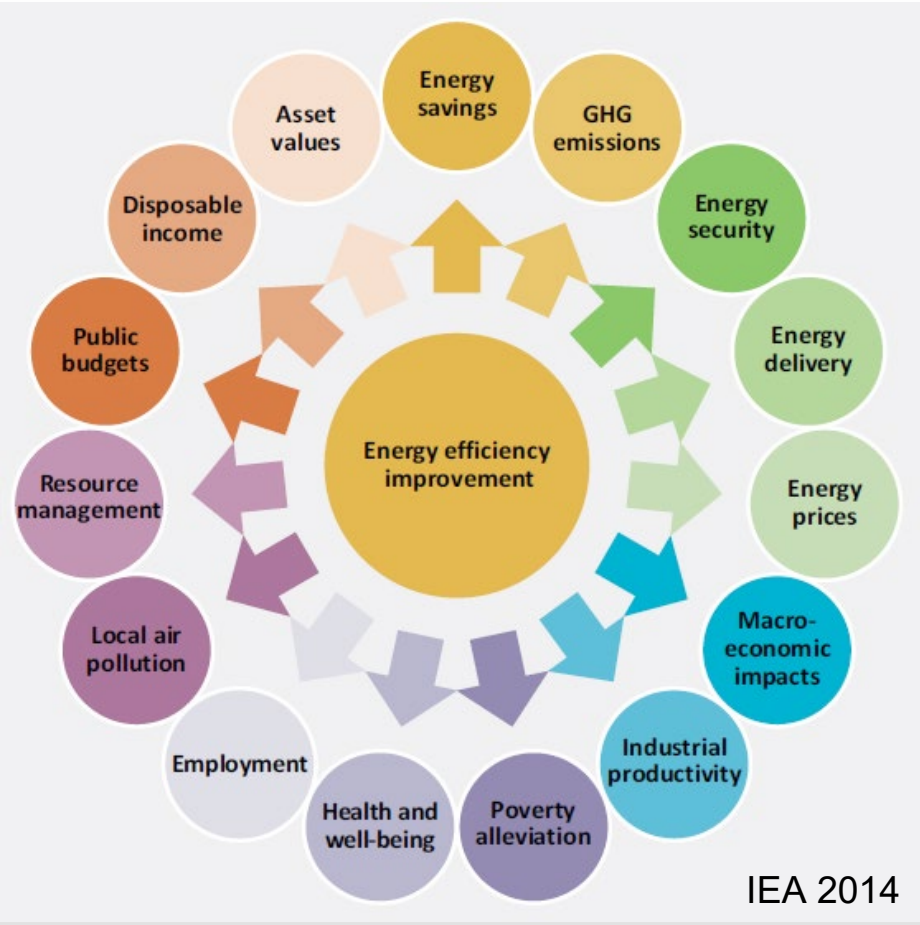
Introduction: Residential energy consumption

Globally

- 20% of global energy is consumed in the sector
- Energy efficiency potential largely untapped
- Benefits of EE well published by IEA

South Africa

- Sector comprised of 16.9 million households (2016)
- About 86% electrified
- Consumes about 17% of grid electricity (HW)
- Represents about 35% of peak demand
- Household electricity spend varies greatly with income
- Up to 50% of households may be in energy poverty
- The sector very heterogeneous & dynamic
- The sector remains understudied
- Better understanding of the sector required to meet policy objectives



IEA 2014

Acronyms

S&L – Standards & Labelling

MEPS – Minimum Energy Performance Standards

NRCS – National Regulator for Compulsory Specifications.

Regulatory process

NRCS gazetted VC9008 Regulations (2014)

- e.g. : Refrigerators
- Shall comply with SANS 941,
- Minimum energy efficiency rating of Class B

SANS 941

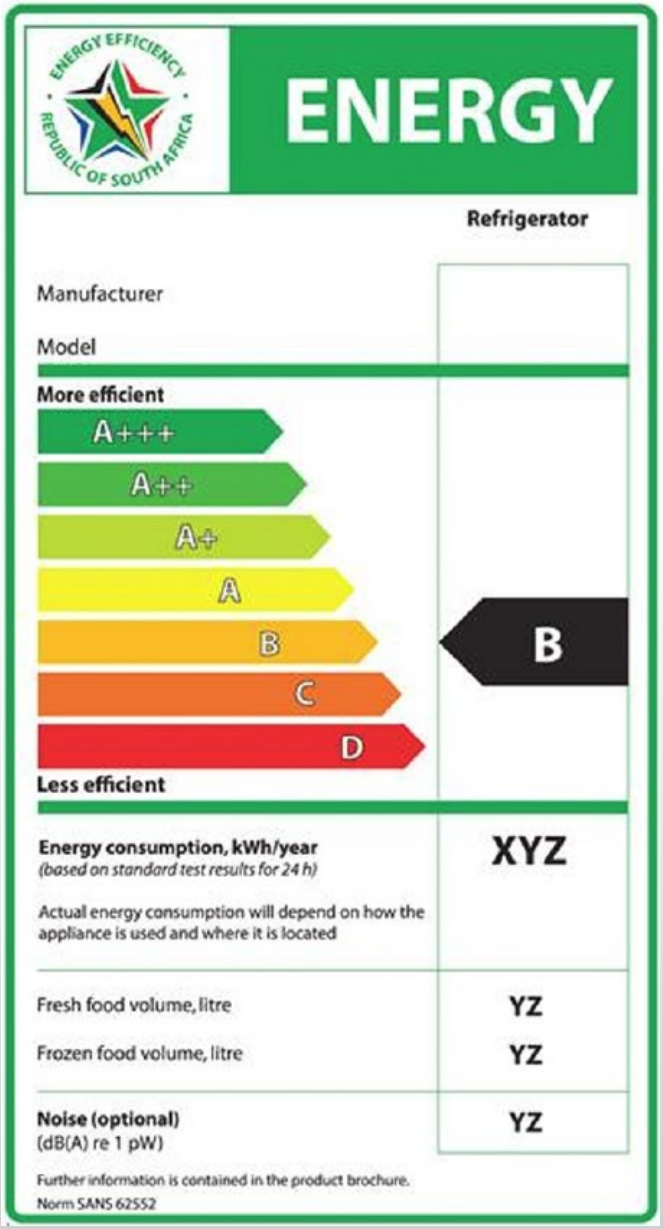
General & specific requirements

- All appliances shall have an energy label, etc
- Fridges shall comply with SANS 62552

SANS 62552

Specific stipulations For fridges

- the kWh for the various fridge performance classes
- the testing method to be used



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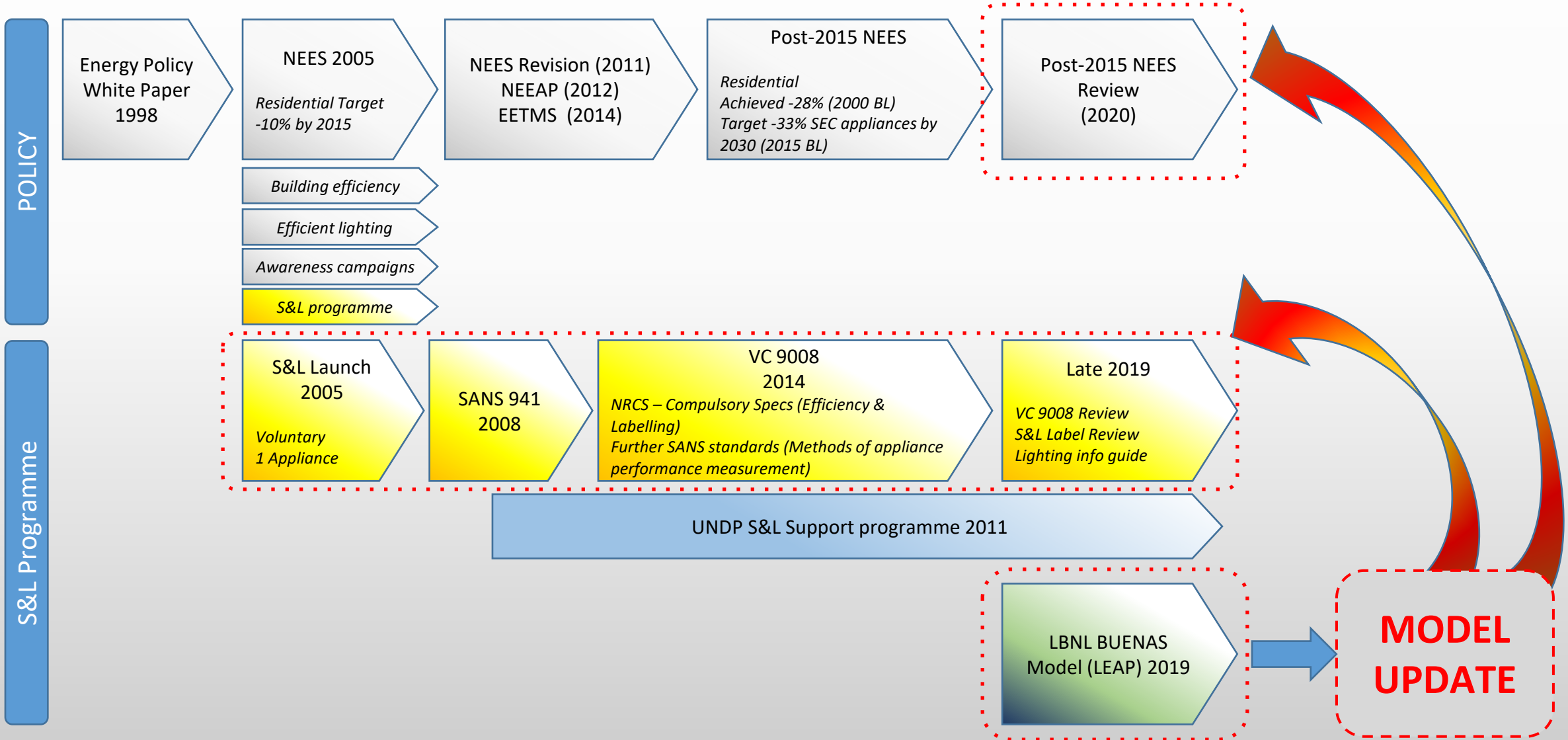
Residential Energy Efficiency in South Africa



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Project objectives

- **Determine impacts of S&L programme 2015 – 2020**
- **Estimate potential savings to 2040 under various scenarios**
- **Review Post-2015 NEES residential targets**

LEAP model refinements

- Disaggregate households by income group
- Refine appliance kWh estimates based on real utilisation patterns
- Determine the stock vintage profile
- Refine appliance survival profiles
- Calibrate the model to residential consumption at the national level (required broadening of end use categories)

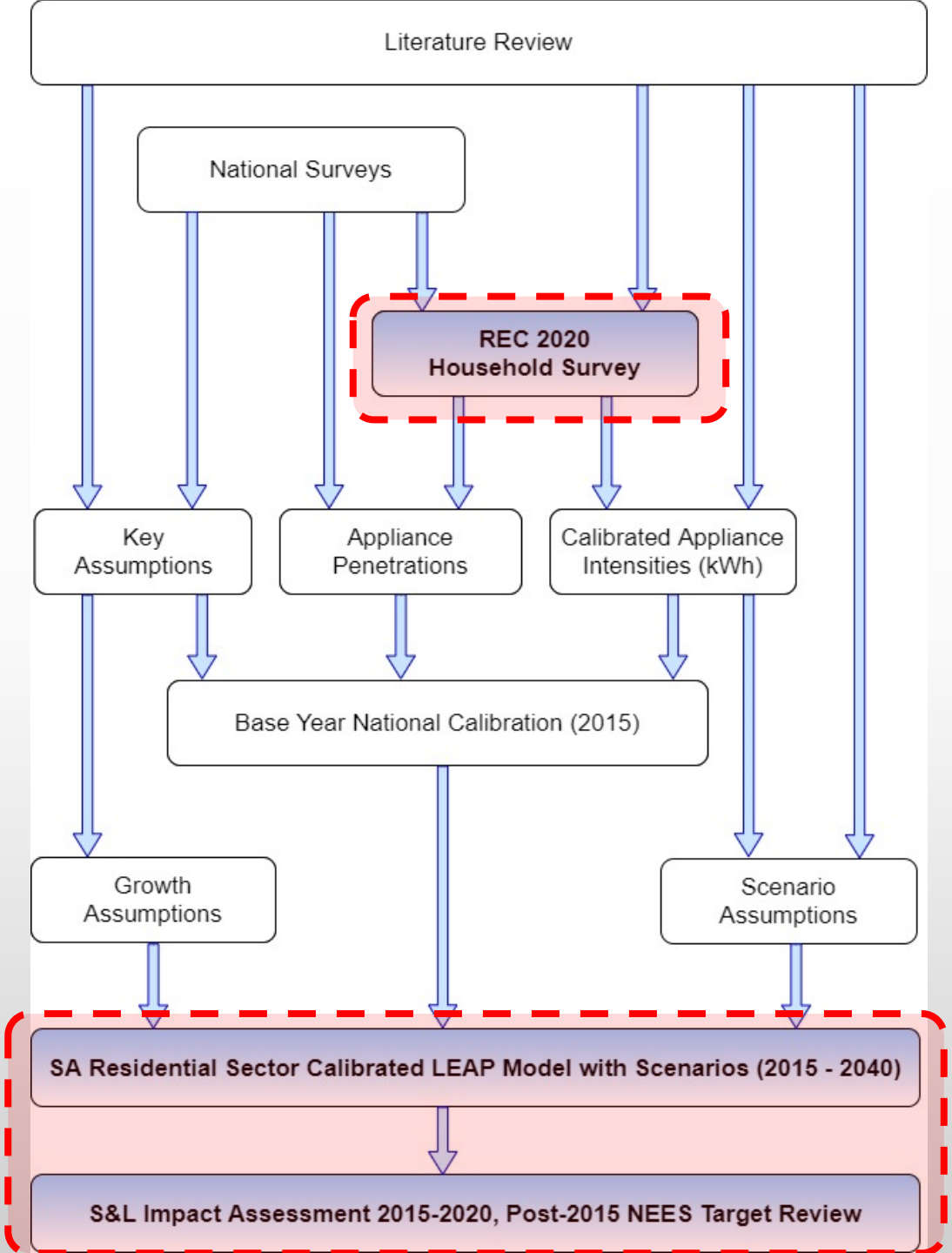
Income group definition

Gross Household Monthly Income (2020 Rands)

Low	Middle	High
< R5,000	R5,001 - R20,000	> R20,001

Project overview

Key data sources & process steps



Scenario development

Reference case
- **EXCLUDING S&L**
- Replaced stock @ 2015 intensities

Actual case
- **INCLUDING S&L**
- Replaced stock @ improved intensities

Moderate MEPS
- **1-step nudge to market in 2025**
- **Prevent regress / backslide | Equal best of the market**

Extensive MEPS
- **2-step changes in 2025 and 2030 (Ambitious)**
- **Beat the market | Increase the basket of appliances**

Behavioural
- **Pot lids | Geyser switching | Kettle overfilling**
- **Additive with MEPS impacts**

Reference case

2015 — 2020 — 2021 — 2040

Scenario development: kWh intensity example (Extensive MEPS, High Income)

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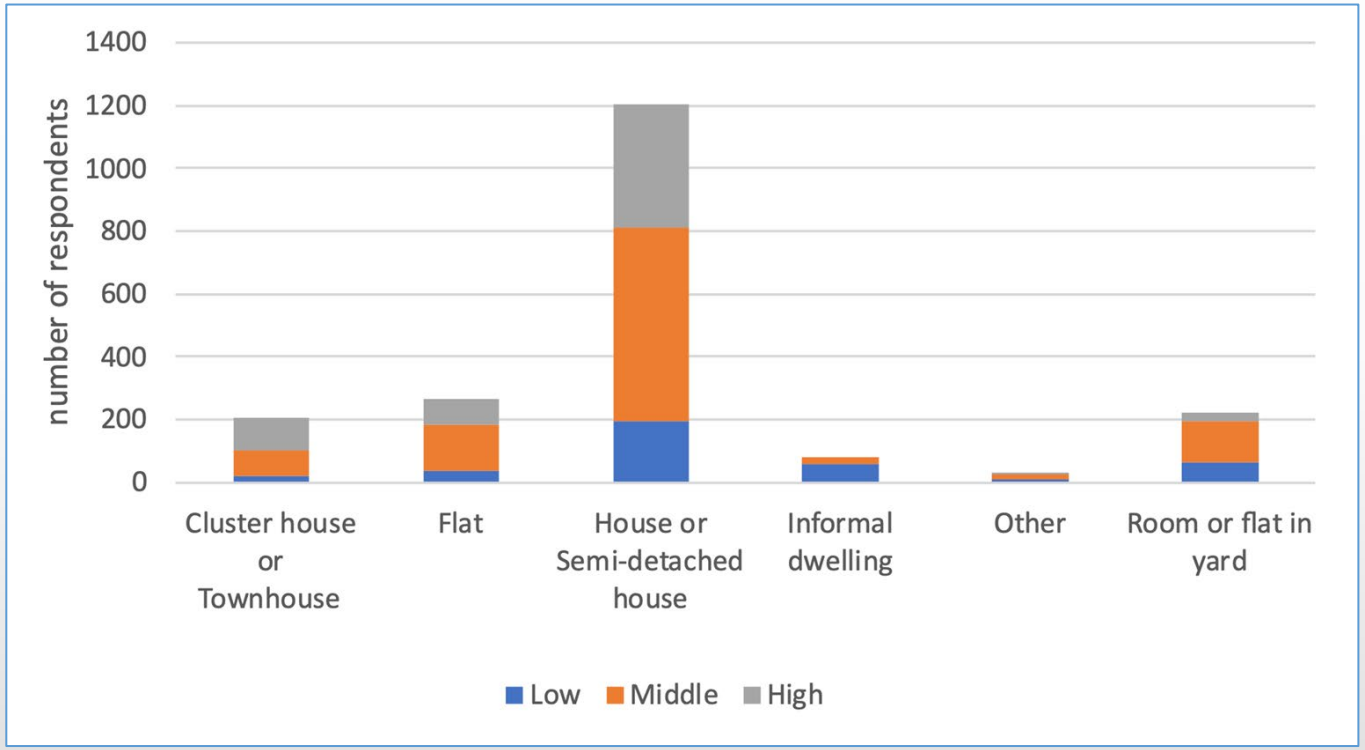
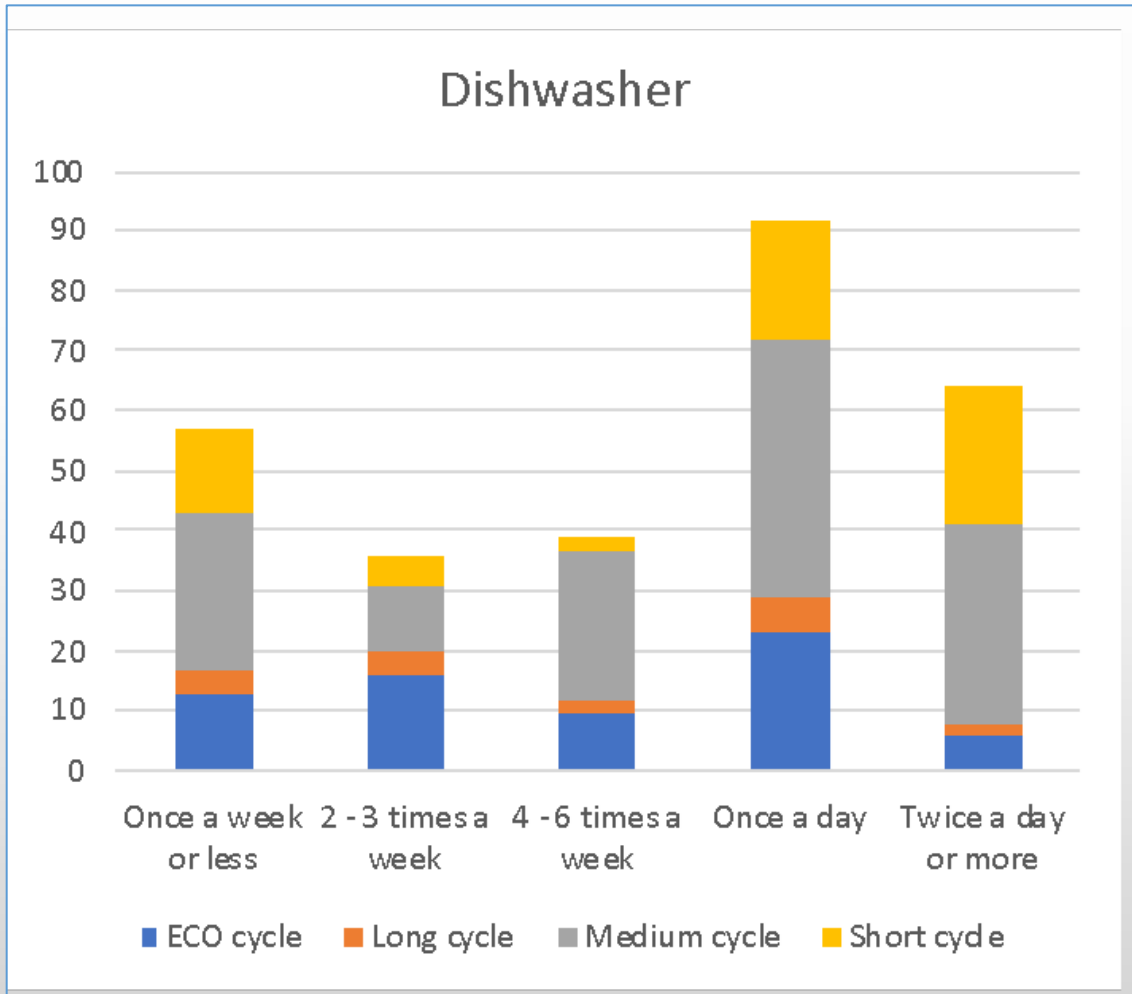
Survey insights

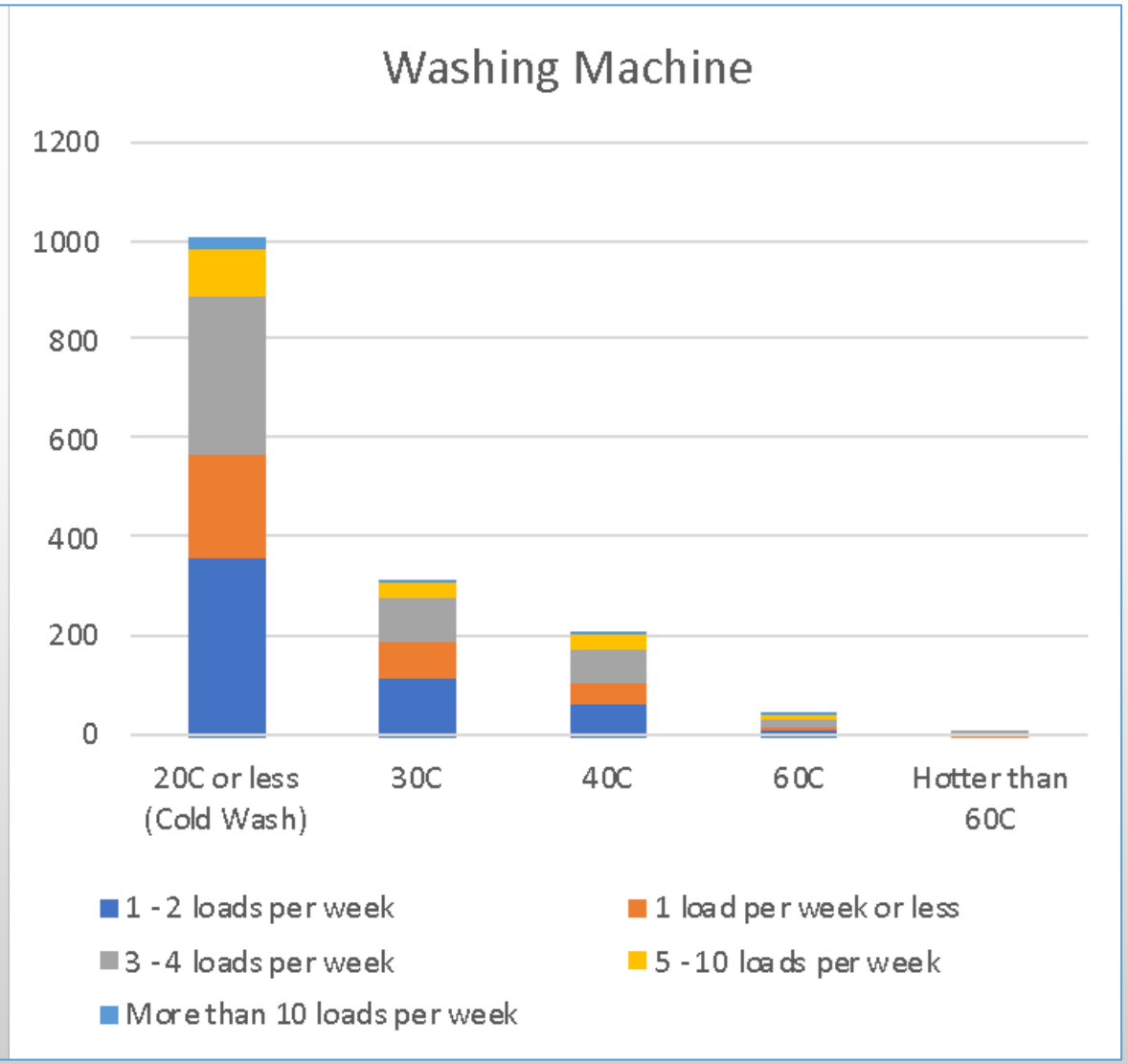
Survey insights 1: Demographics

Major metro	Number of completed questionnaires
City of Cape Town Metropolitan Municipality	142
City of Ekurhuleni Metropolitan Municipality	85
City of Johannesburg Metropolitan Municipality	147
City of Tshwane Metropolitan Municipality	135
eThekwini Metropolitan Municipality	120
Nelson Mandela Bay Metropolitan Municipality	43

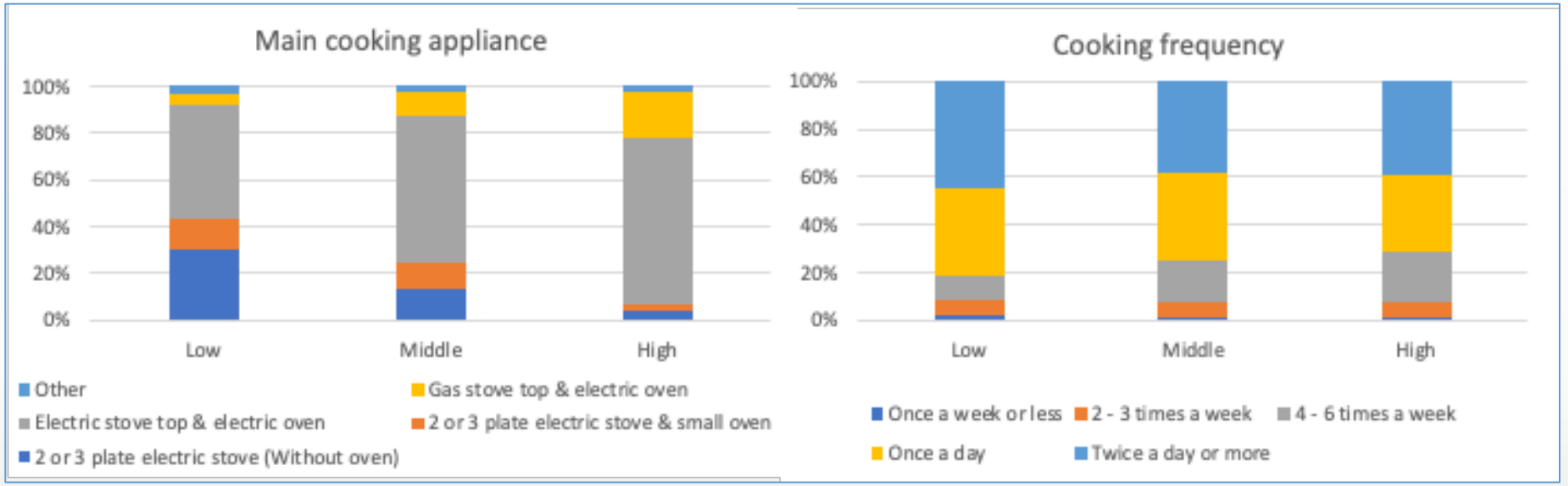


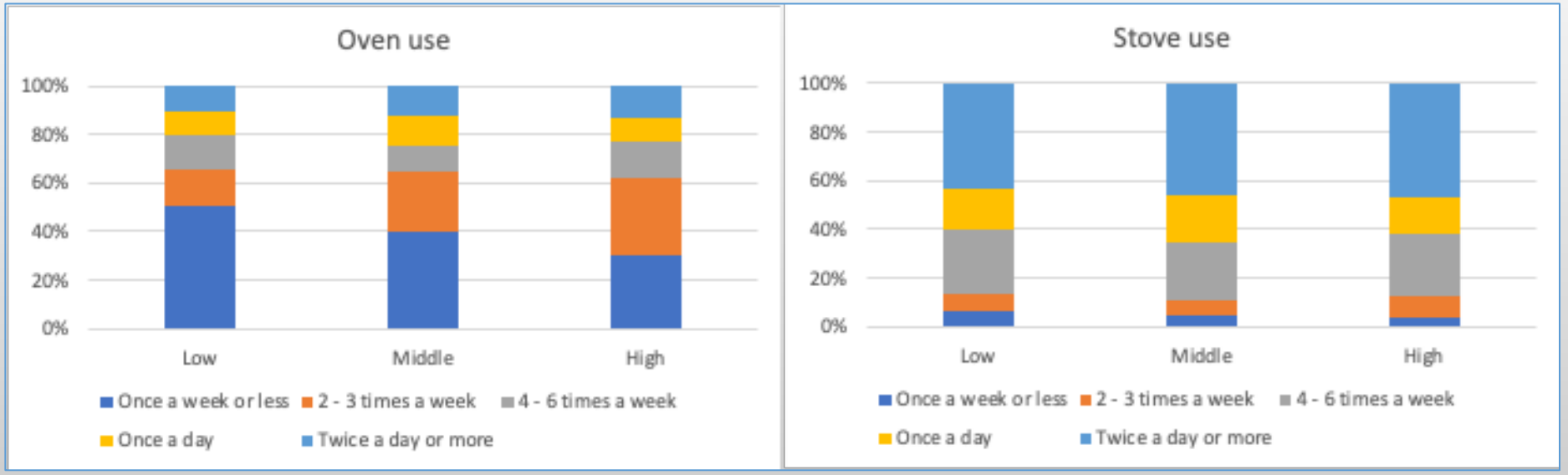
Survey insights 2: Washing machine and dishwasher utilisation



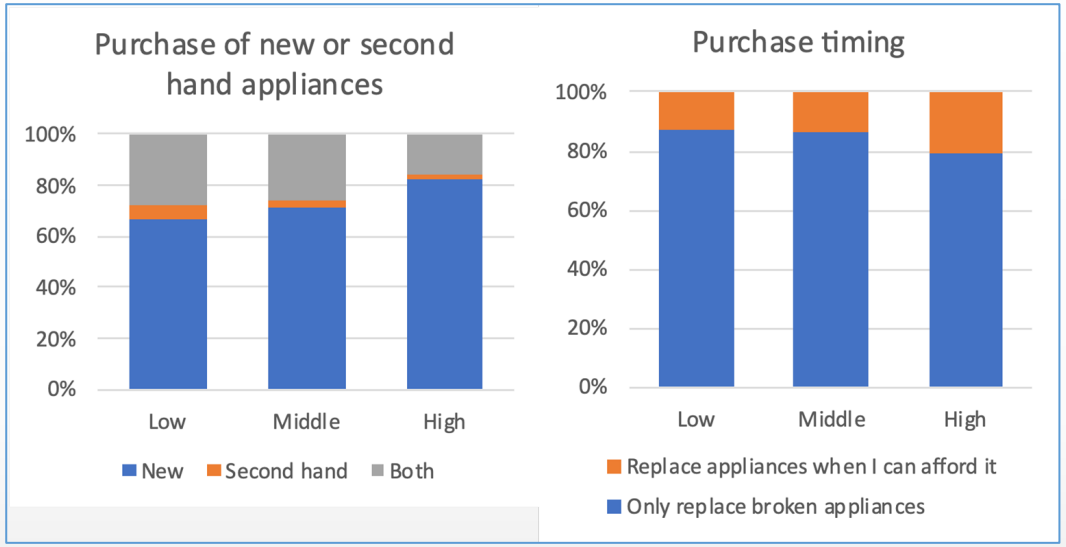


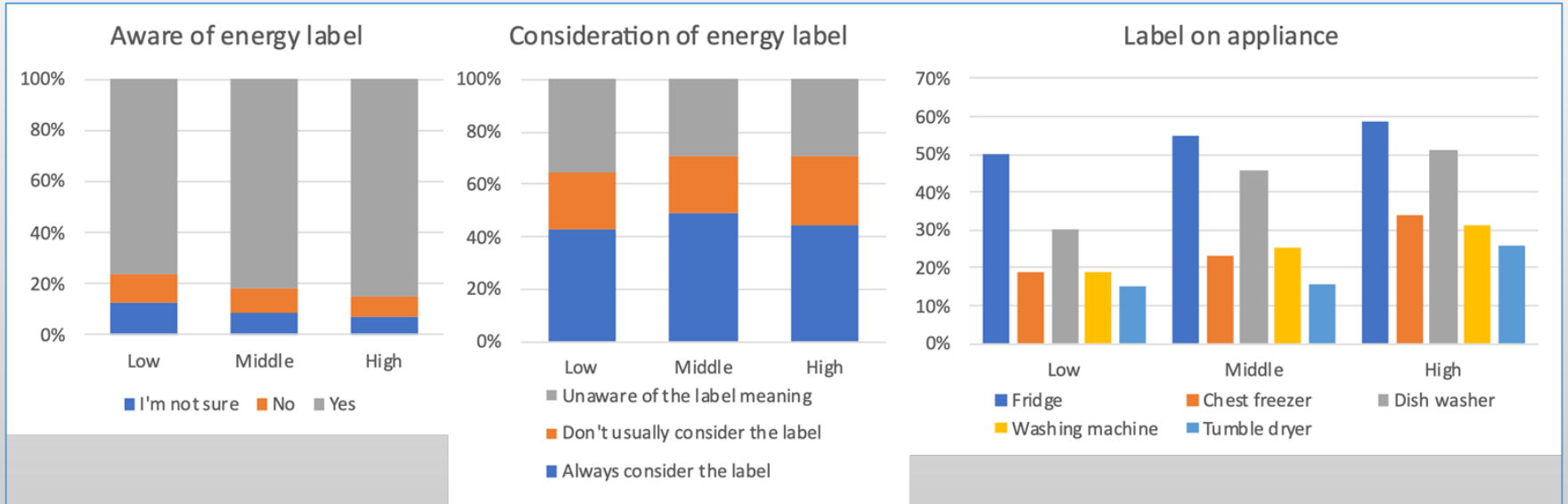
Survey insights 3: Cooking appliances & frequency of use





Survey insights 4: Appliance purchasing habits awareness of S&L





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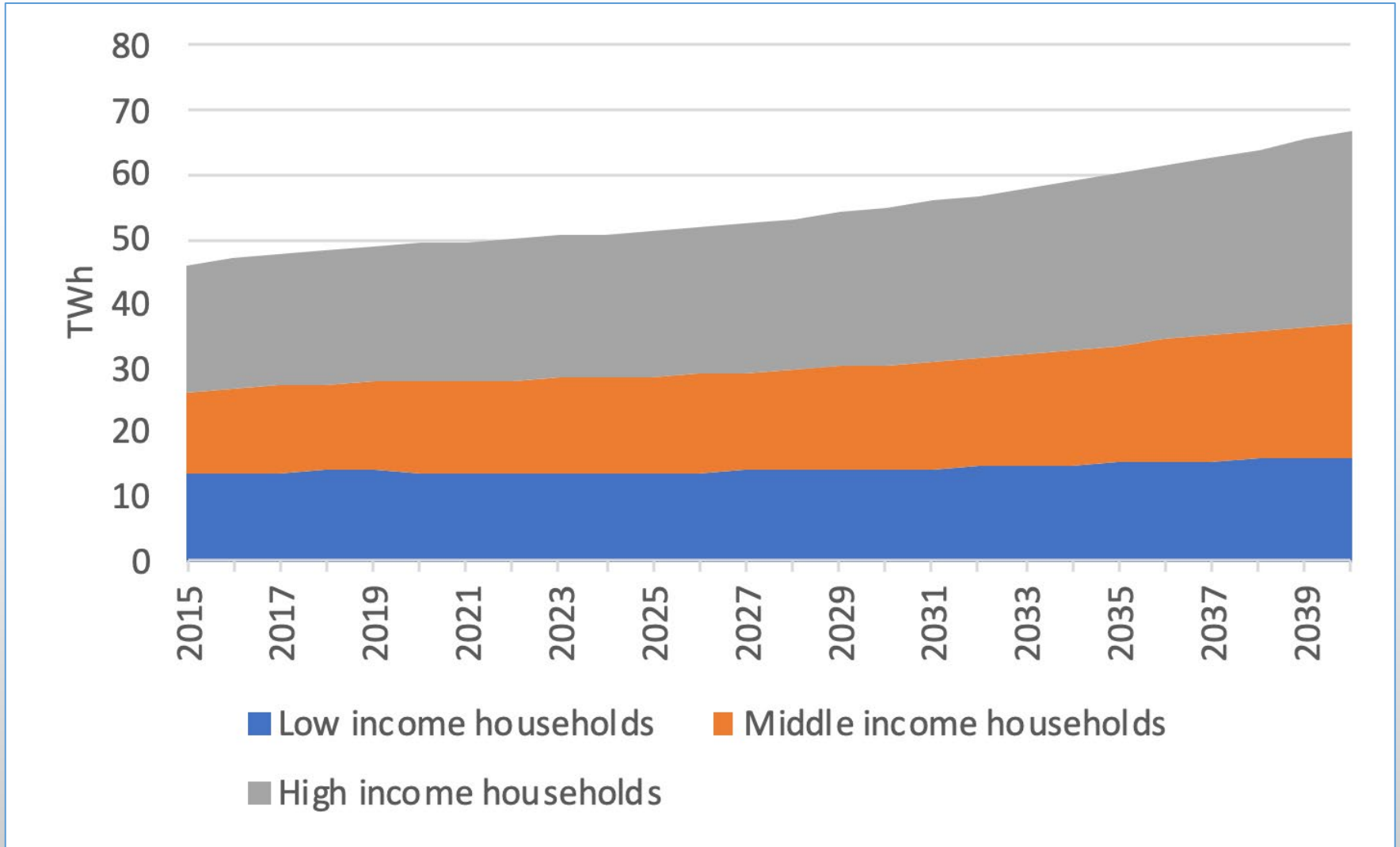
Key findings

Key findings: Electricity consumption per income group (2015-2040)



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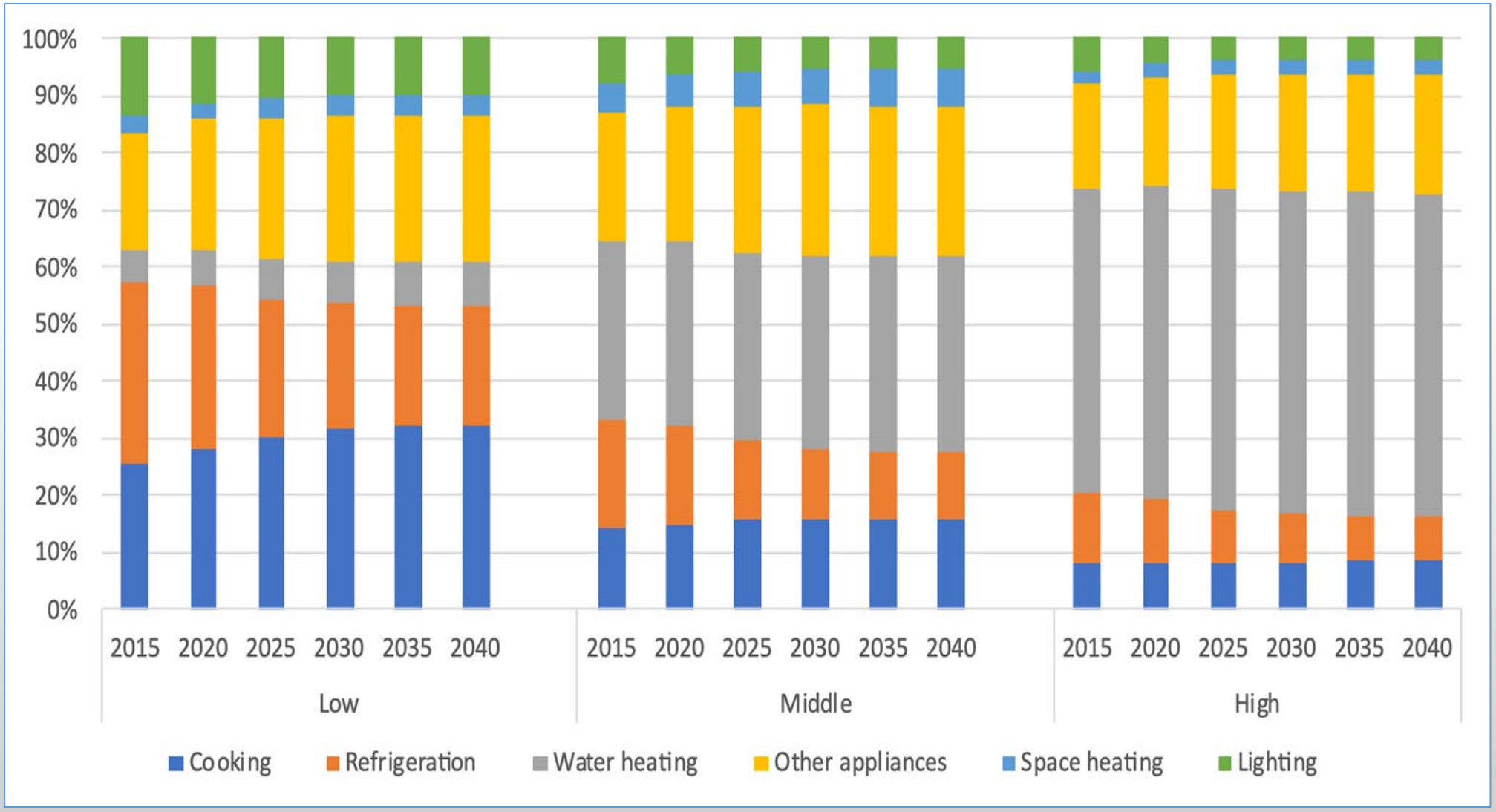
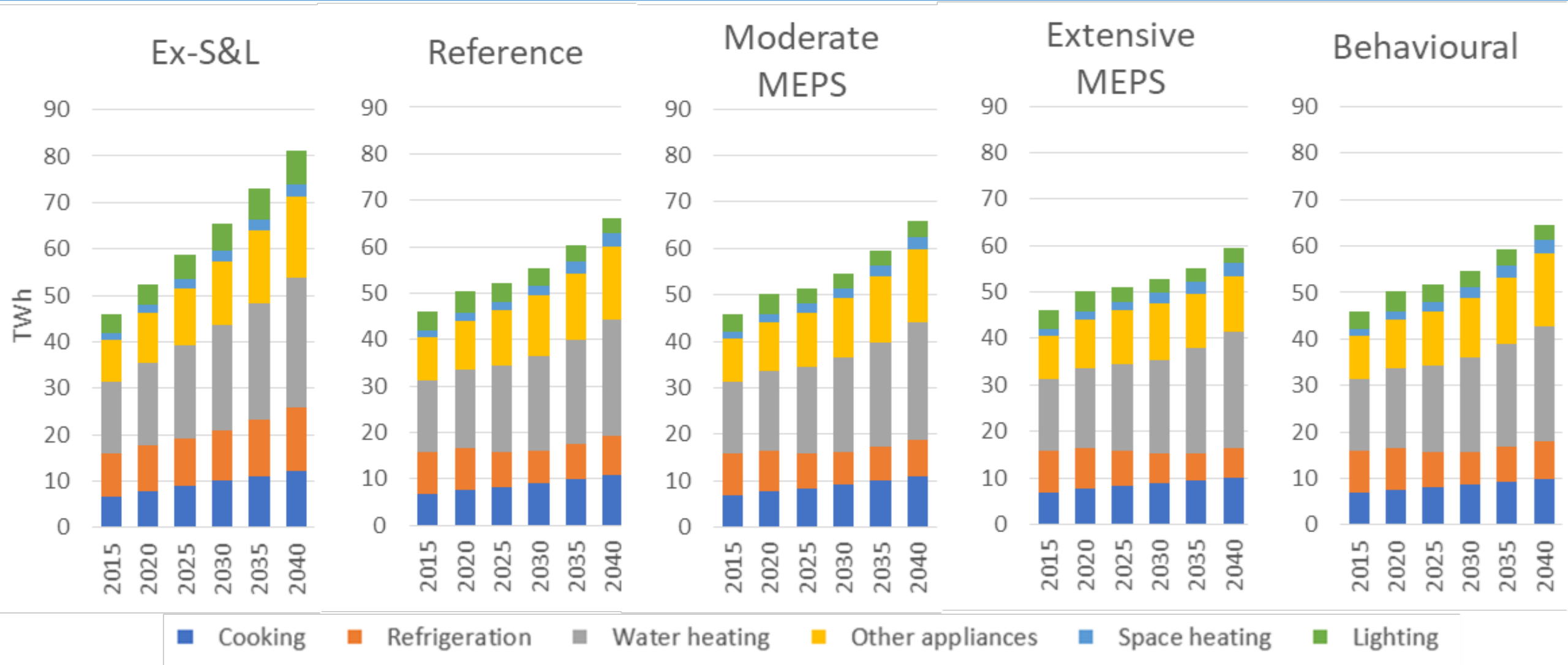
End use share of consumption: Reference case (2015-2040)



S&L programme scenarios (2015-2040)



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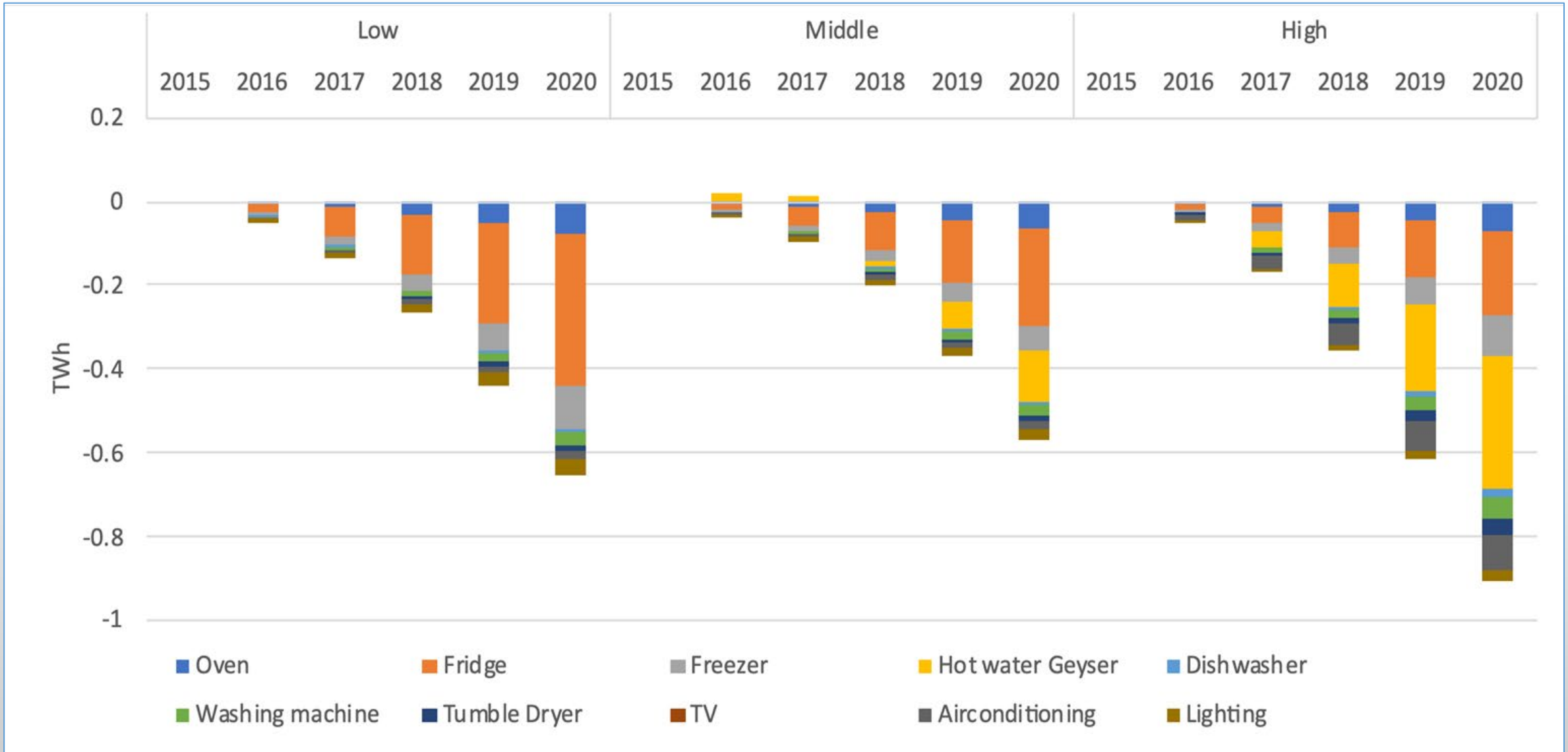
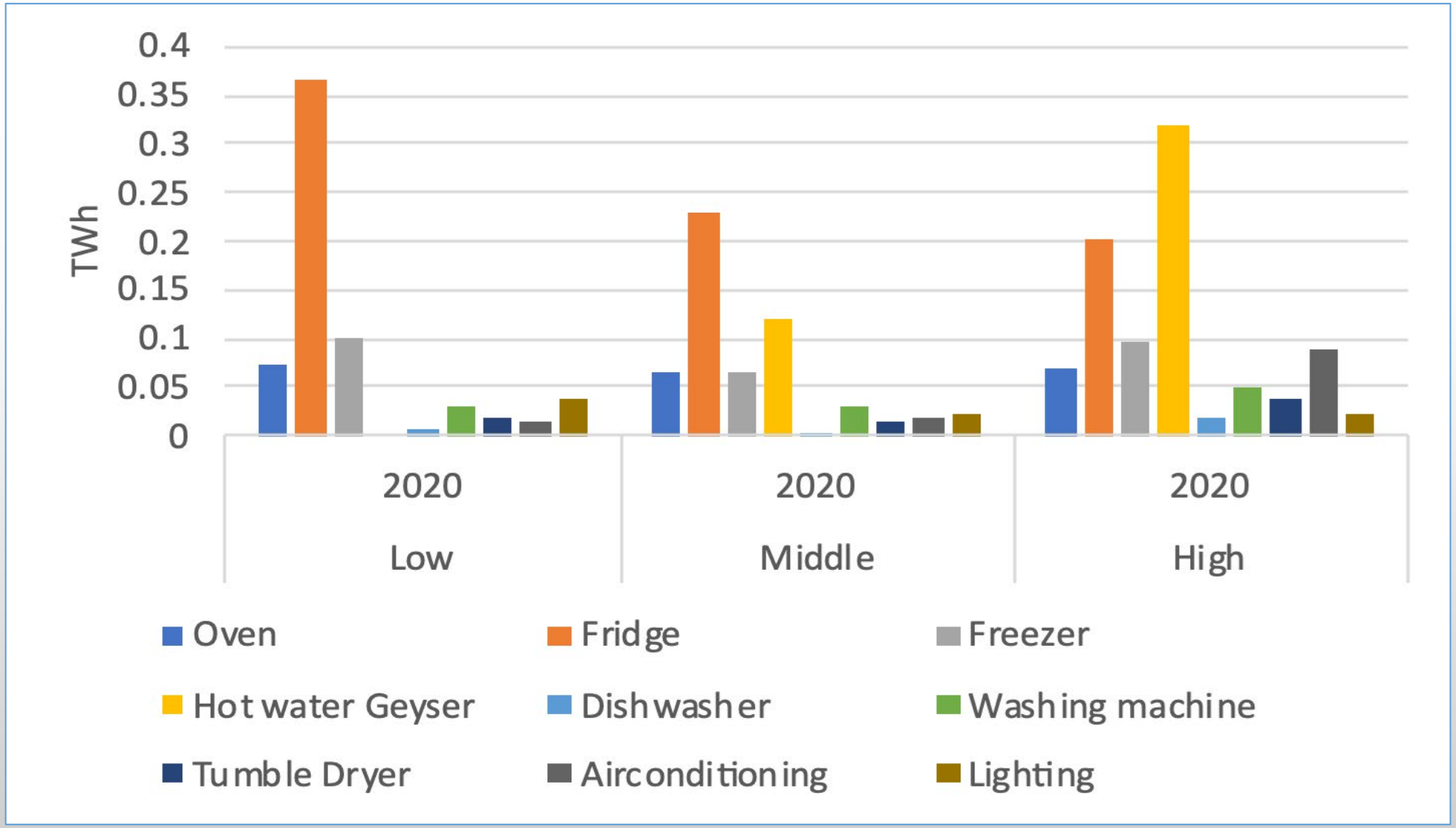
S&L programme impacts (2015-2020)

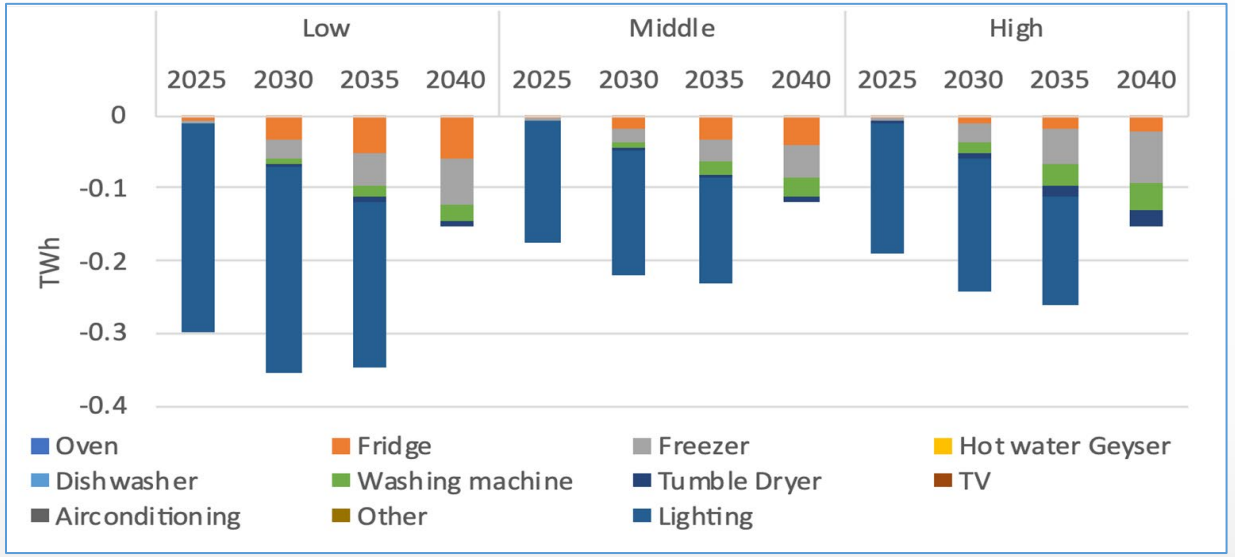


S&L programme impacts (2020)

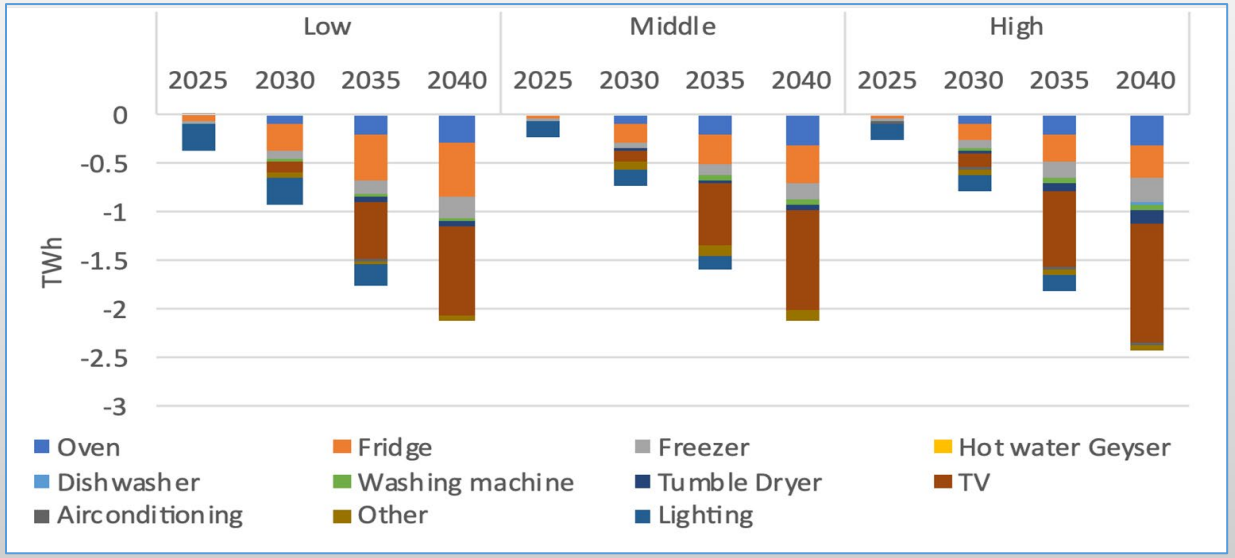


Projected S&L impacts: Moderate & Extensive MEPS Scenarios (2021-2040)

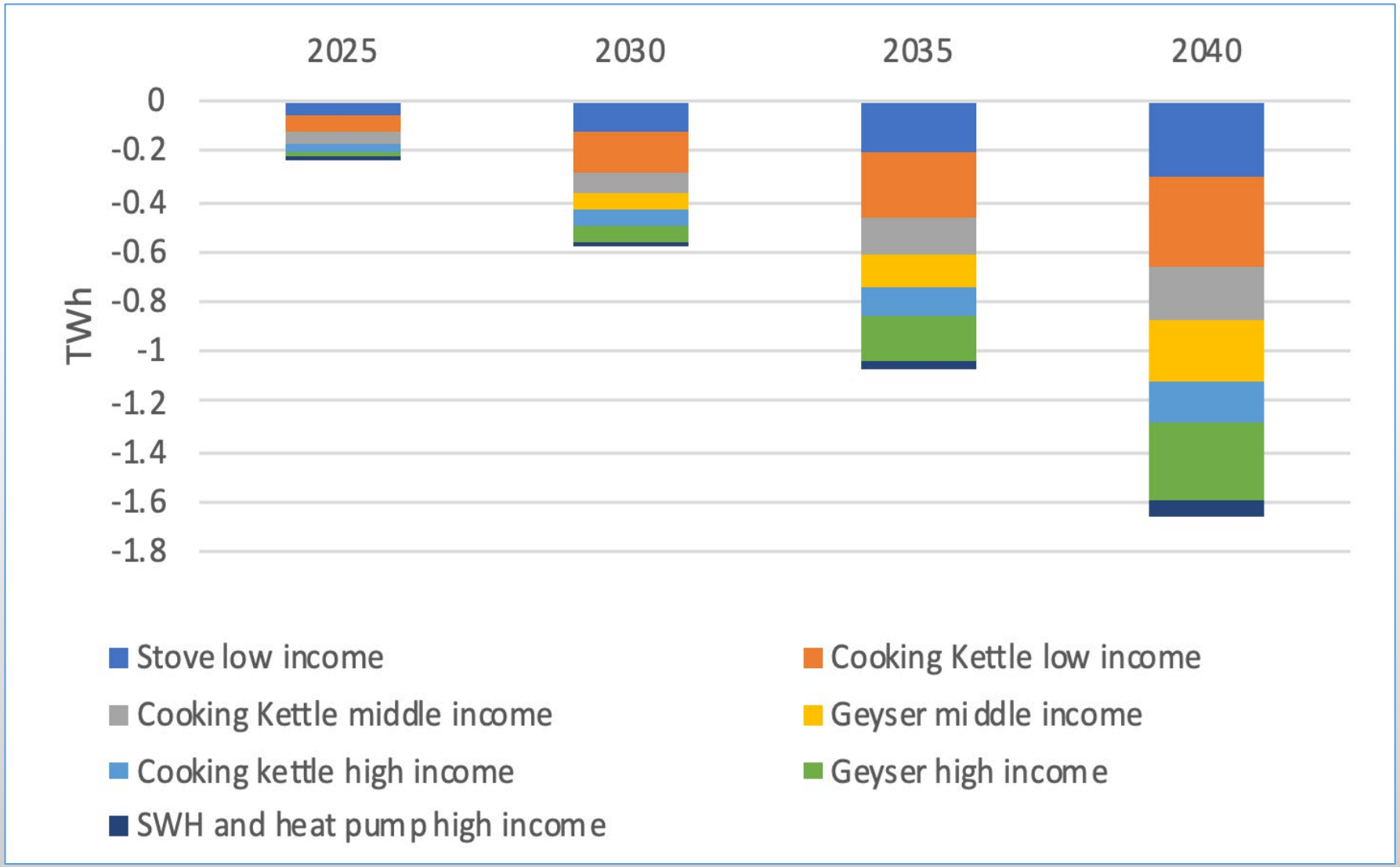
Moderate MEPS



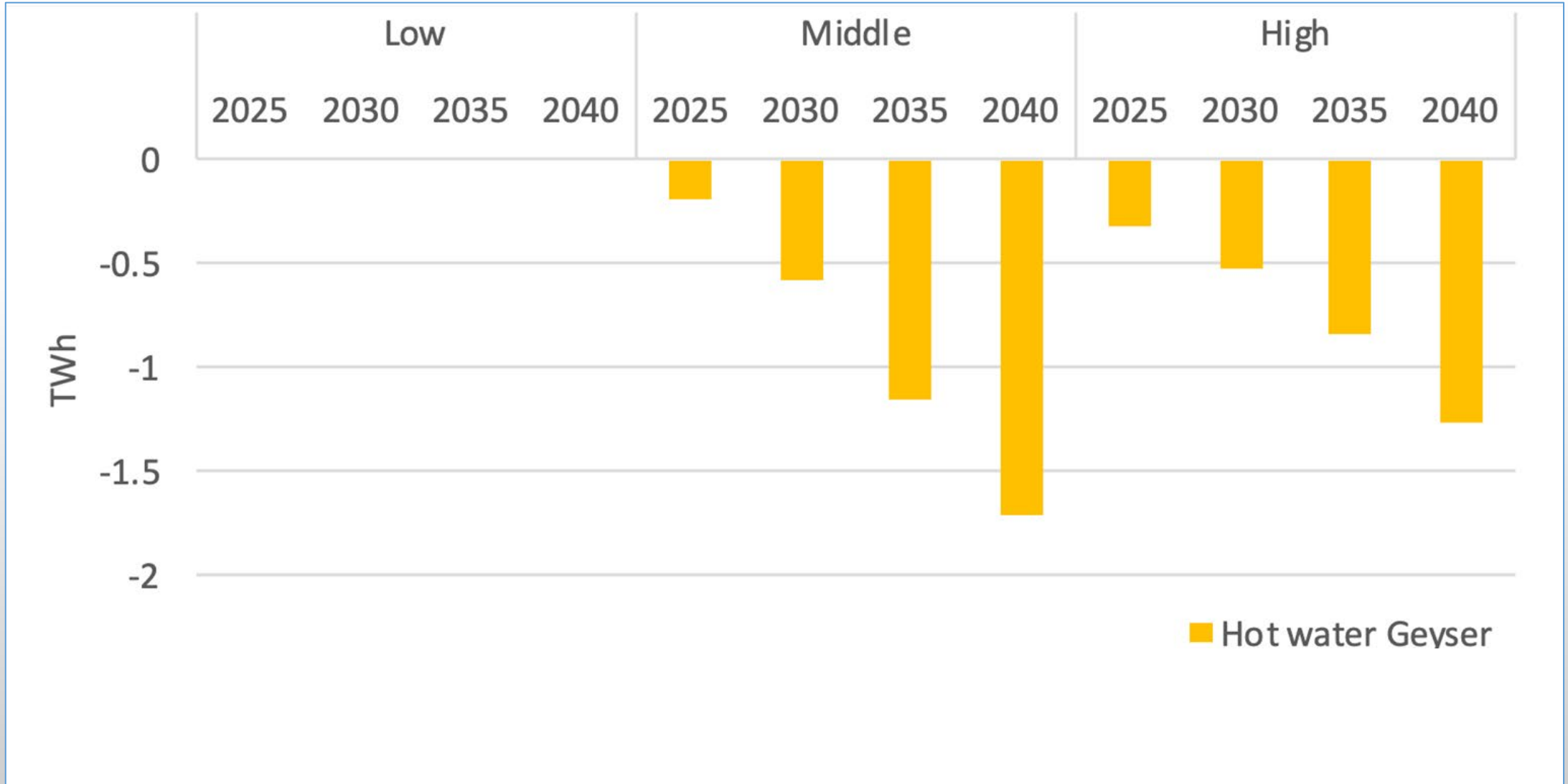
Extensive MEPS



Behavioural imapcts (2025-2040)



Impacts of increased SWH & Heat Pump adoption



Key findings: General

- LEAP and stock based analysis provide a good, easy to use, platform for analysing impacts of demand side policy

- Model disaggregation into income groups allows
  - Analysis of policy impact on energy poverty
  - Better representation of the impact of changes to household income on electricity demand forecasts
  - However - the data for this disaggregation requires attention

Key findings: S&L programme assessment

- Meaningful savings achieved from 2015 - 2020
- Programme will continue to realise savings
- Refrigeration - achieves the highest savings in the low income group
- Water heating - achieves the highest savings in the high income group
- The S&L programme results in a drop in energy intensity of 4.3% in the low income group in the 2020 Reference case compared to the Ex-S&L scenario
- Similar reductions in energy intensity are seen in the middle and high income groups.
  - Energy intensity of supplying energy services in middle income households drops by 3.8% and in high income households it drops by 4.2%.
  - This amounts to an overall reduction in energy intensity of 4.1% in 2020 in the Reference case compared to the Ex-S&L scenario.

Key findings: Assessment of Post-2015 NEES targets

- Assessment relates only to targeted of 33% reduction in average specific energy consumption of new household appliances compared to the 2015 baseline

- In both the Moderate and Extensive MEPS scenarios the appliances most likely to meet or exceed a 33% efficiency improvement are those that were targeted by the S&L programme.

Review of appliance targets	Intensity improvement (%) 2015 - 2030	
Appliance	Moderate MEPS	Extensive MEPS
Lighting	3%	**44%**
Cooking - Oven	**36%**	**63%**
Fridge/Freezer	**52%**	**61%**
Deep Freeze	**59%**	**76%**
Hot Water Geyser	9%	9%
Hot Water (SWH/Heat Pump)	27%	27%
Dishwasher	31%	**35%**
Washing machine	**39%**	**43%**
Tumble drier	**39%**	**59%**
TV	0%	**68%**
Aircon	19%	21%

Key findings: Assessment of Post-2015 NEES targets

- The model results indicate that if the S&L and MEPS programmes continued in their current form, with appliance standards at the current level, they would achieve a saving of 10% in 2030 compared to the case where only moderate savings occur in the absence of these programmes. If the 2015 household baseline consumption is simply extended to 2030, the model shows a saving of 19%.

- The results indicate that without an expansion of the programme the 33% target will not be achieved.

Model Results			
Moderate MEPS			
	2020	2030	2040
Low	6.3%	25.4%	28.2%
Middle	6.1%	20.2%	21.3%
High	5.7%	18.9%	22.8%
Total	5.2%	19.3%	19.8%
Extensive MEPS			
	2020	2030	2040
Low	6.3%	28.4%	37.1%
Middle	6.1%	22.7%	28.9%
High	5.7%	20.7%	28.8%
Total	5.2%	21.7%	27.4%

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Key recommendations

Key recommendation 1: Hot water (Resistive)

- Significant user of electricity in SA households
- Modelled consumption is extremely sensitive to assumptions: water use, thermostat temperature, incoming water temperature, etc
- Yet literature available is very sparse (only a handful of SA studies)
- A bottom-up calculation requires
  - Daily volume HW per person (all income groups)
  - Geyser thermostat temperature (middle & high income)
- Broad range of estimates for actual geyser stock in the literature
- Penetration of >1 geyser per household is not known
- VC 9006 is a major step towards reducing standing losses (D >> B)
  - Consumer education still required (Class B is broad)
- Inline water heaters require further research

For a "Class D" geyser at around 65°C, each 1°C increase in setpoint temperature causes standing losses to increase by roughly 50 Wh/day

Key recommendation 2: Hot water (Solar Water Heaters)

- Real (in-situ) SWH performance studies for SA almost non-existent
  - Previous M&V studies all modelled
- Accurate installation numbers are very sparse (mostly since 2015)
- This may be alleviated through close research partnerships with
  - Municipalities
  - RE Industry Associations

- Accelerated rollout of HP & LP SWHs (& Heat Pumps) could have substantial benefits

Key recommendation 3: VC 9008 Amendments

- Proposed VC9008 amendments roughly comparable to the Moderate MEPS Scenario
  - Given the modest savings a revision towards the Extensive MEPS should be considered
- Proposed amendments include other things
  - Refrigerant types for cold appliances
  - Water performance for washing machines & dishwashers.
  - Integrating these new aspects into S&L label will require careful label revision to avoid risk of information overload

Key recommendation 4: Lighting

- Inherently difficult technology to characterise through a questionnaire
- REC 2020 survey findings
  - Few households were using LEDs - still much potential for savings
  - Revealed overwhelming agreement (79%) that the information provided on lamp packaging helps customers choose (supports move towards improved labelling to allow comparisons between type, cost and luminous efficacy)
- Longitudinal measurement study suggested across income groups
- Existing fitting designs can limit the savings that can be achieved
  - Dimmers should be investigated for energy savings

Key recommendation 5: Behavioural interventions

- Poorly implemented behavioural interventions can be worse than none at all
- Rebound effects are difficult to anticipate or quantify
- Long term national EE strategy should consider technical & behavioural interventions
- Thermal cooking interventions could meaningfully impact on low income households
- The potential for low-cost, high-impact, sustainable behavioural interventions should be further investigated (as a complement to technical interventions)

Other recommendations: Municipal data

- Only George Municipality took part
  - Promoted the survey
  - Provided kWh data
- Accurate bottom up calibration of households require real kWh
- Future surveys rolled out in close partnership with municipalities & ESKOM?

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Other recommendations: Solar PV data

- PV penetration is high (and increasing)
- kWh production is unknown (user side of the meter)
- Industry associations such as AREP may assist with yield estimates

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The future

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Questions?

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Session 2: Research methodology

- REC 2020 Household survey
- Household calibration
- National calibration
- LEAP model development

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Household survey

REC 2020 Household survey: Overview

Aim

- gather appliance ownership and utilisation data
- to improve estimates of end use electricity consumption

Three survey methods were considered

- online panels
- e-surveys conducted in partnership with municipal metros
- a small door to door survey
- final choice: online panel (2075 Responses)

Design process

- Literature review, testing, ethics approval

Survey timeline 30 July to 10 October

REC 2020 Household survey: Target information per appliance / end use

Electrical loads

End use category	Appliance	Quantity/ Ownership	Size	Type	Usage	Age
Lighting	Lamps	X		X	X	
Cooking	Stove & Oven	X	X	X	X	
	Microwave	X			X	
	Kettle	X			X	
	Other	X		X	X	
Food cooling	Fridges & Fridge/Freezers	X	X		X	X
	Chest freezers	X	X	X	X	X
Cleaning	Dishwasher	X			X	X
	Washing machine	X		X	X	X
	Tumble dryer	X			X	X
Hot water (Bathing, showering, washing)	Water heater	X	X	X	X	X
	Kettle	X			X	
Heating	Space heating	X	X	X	X	
Other appliances	Entertainment	X	X	X	X	
	Other	X	X	X	X	
Comfort	Air conditioning	X		X	X	X
	Fans	X	X	X	X	

REC 2020 Household survey: Sample questions & assumptions

How often do you normally cook hot food in your household?

- Twice a day or more
- Once a day
- 4 – 6 times a week
- 2 – 3 times a week
- Once a week or less

Which of these best describes your MAIN cooking appliance?

- Electric stove top & electric oven (Combined unit or separate oven & hob)
- Gas stove top & electric oven (Combined unit or separate oven & hob)
- 2 or 3 plate electric stove & small oven
- 2 or 3 plate electric stove (Without oven)
- Other

REC 2020 Household survey: Sample questions & assumptions

In a normal week how many times is the OVEN used?

- Twice a day or more
- Once a day
- 4 - 6 times a week
- 2 - 3 times a week
- Once a week or less

In a normal week, how many times is the STOVE used?

- Twice a day or more
- Once a day
- 4 - 6 times a week
- 2 - 3 times a week
- Once a week or less

REC 2020 Household survey: Sample questions & assumptions

Do you have a microwave oven in your household?

- Yes
- No

What do you mainly use your microwave for?

- Heating up food and re-heating food
- Defrosting food
- Cooking meals from raw
- Heating up drinks like tea & coffee
- A bit of everything

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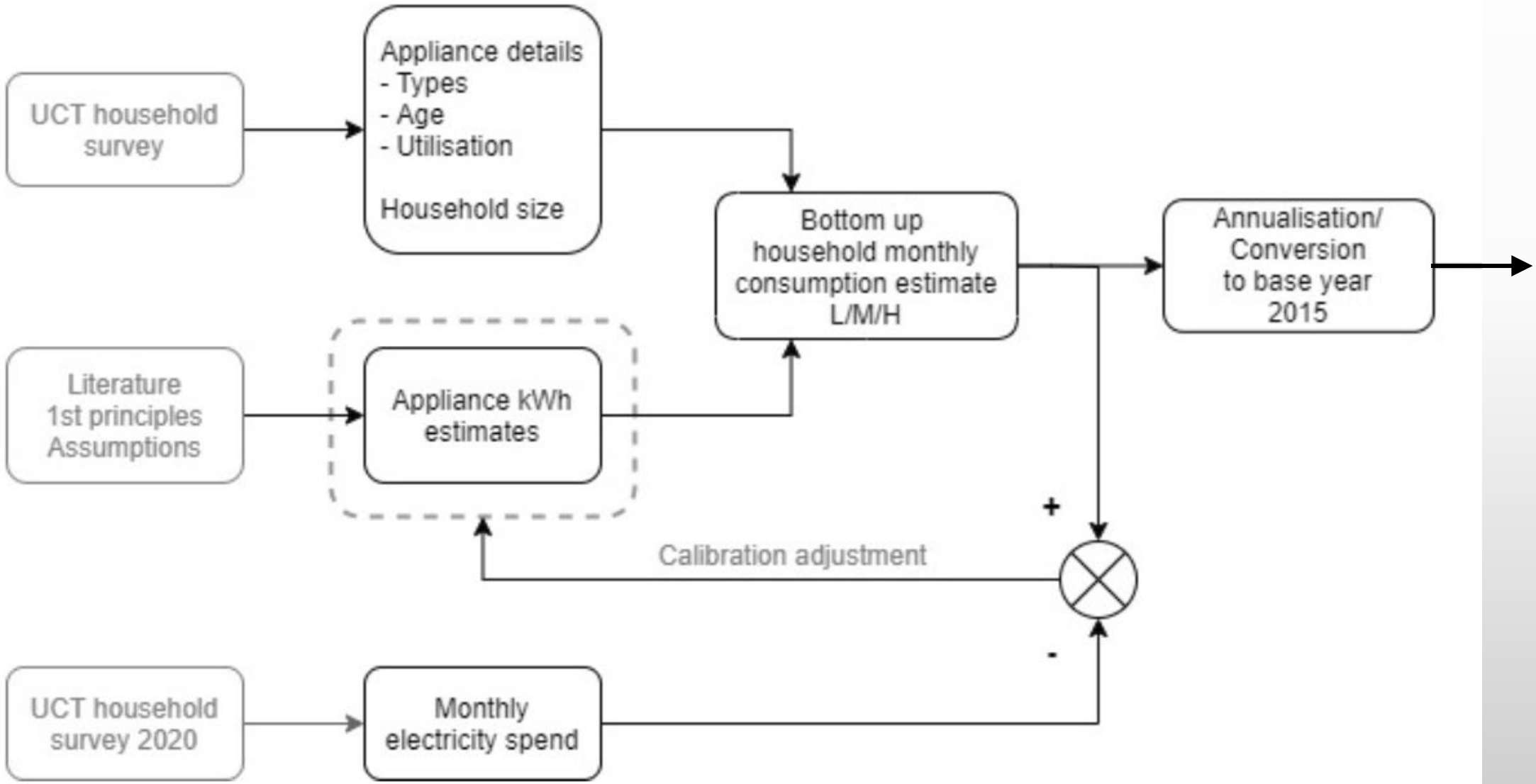
Household calibration

Household calibration



REC 2020 Household survey: Independent variables (Lighting)

HOUSEHOLD SIZE

APPLIANCE TYPE

APPLIANCE AGE

APPLIANCE QTY

HOUSEHOLD INCOME

APPLIANCE USAGE PATTERNS

REC 2020 Household survey: Independent variables (Laundry)

HOUSEHOLD SIZE

APPLIANCE TYPE

APPLIANCE AGE

APPLIANCE QTY

HOUSEHOLD INCOME

APPLIANCE USAGE PATTERNS

kWh tables: Input data to household calibration

Annual kWh consumption estimates for refrigerators (age & size dependent)

Refrigerators (Annual kWh in 2020)	Appliance age				
Size	1 - 2 years	3 - 5 years	6 - 10 years	More than 10 years old	Not sure
Bar Fridge (Small)	105	143	163	300	300
Single Door (Medium)	183	249	286	525	525
Double door (Top Freezer)	229	313	359	681	681
Double door (Bottom Freezer)	229	313	359	681	681
Large (Multi-door)	381	519	596	1131	1131

Annual kWh consumption estimates for dishwashers (age & usage dependent)

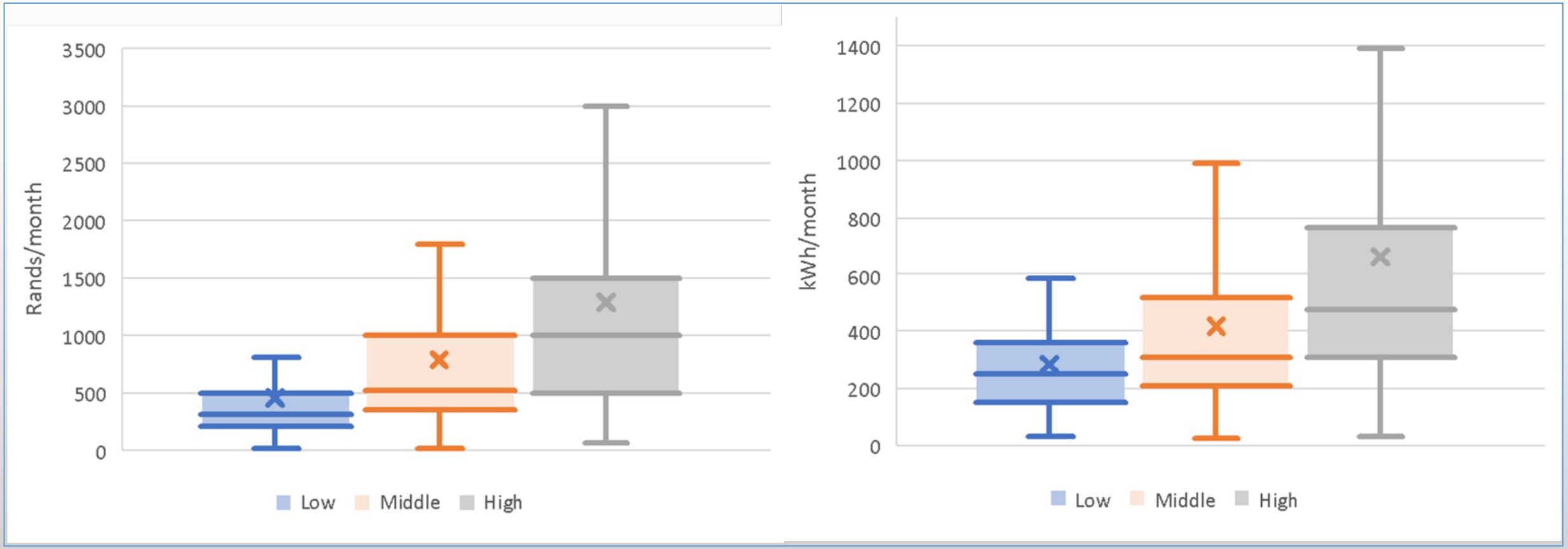
Dishwashers (Annual kWh in 2020)	Appliance age				
Usage	1 - 2 years	3 - 5 years	6 - 10 years	More than 10 years old	Not sure
Twice a day or more	594	717	784	1174	1109
Once a day	297	359	392	587	555
4 - 6 times a week	212	256	280	419	396
2 - 3 times a week	106	128	140	210	198
Once a week or less	42	51	56	84	79

kWh tables: Input data to household calibration

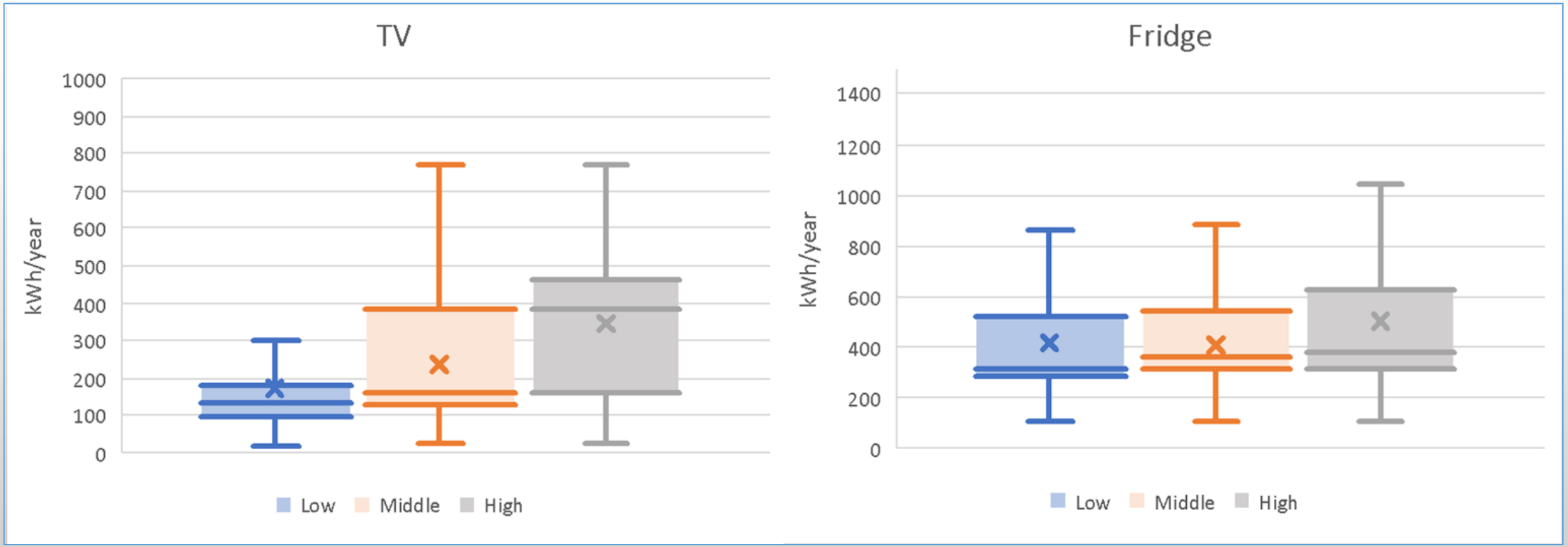
Annual kWh consumption estimates for stoves (usage, occupancy & income dependent)

Stove: Middle income (Annual kWh in 2020)	Household size					
Usage	1	2	3	4	5	6…
Twice a day or more	225	249	274	298	322	347
Once a day	113	125	137	149	161	173
4 - 6 times a week	80	89	98	106	115	124
2 - 3 times a week	40	45	49	53	58	62
Once a week or less	16	18	20	21	23	25

Sample data from household calibration calculations



Sample data from household calibration calculations



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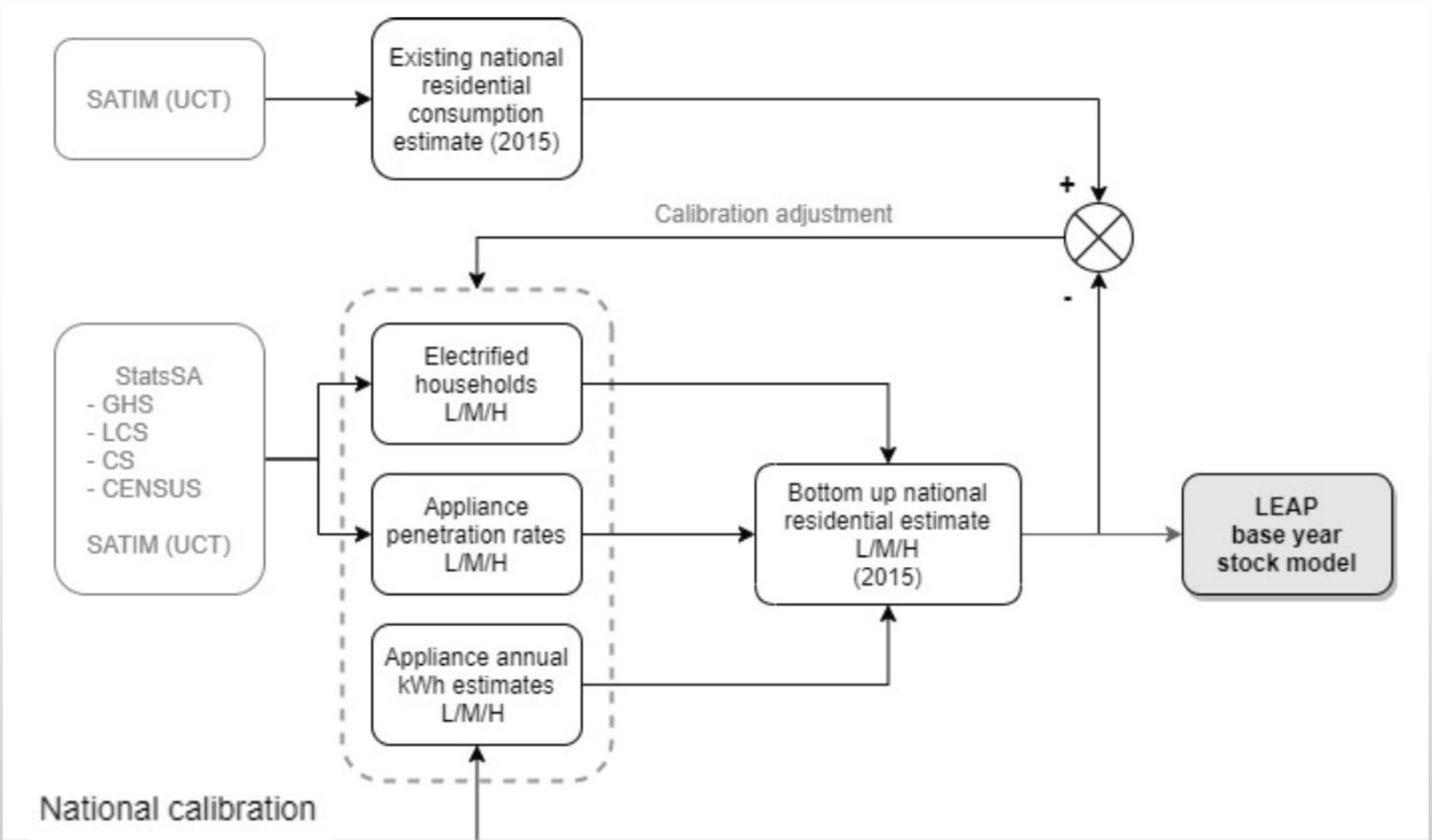
National calibration


SATIM (UCT)
Existing national residential consumption estimate (2015)
+
Calibration adjustment
-
StatsSA
- GHS
- LCS
- CS
- CENSUS
SATIM (UCT)
Electrified households L/M/H
Appliance penetration rates L/M/H
Appliance annual kWh estimates L/M/H
Bottom up national residential estimate L/M/H (2015)
LEAP base year stock model
National calibration

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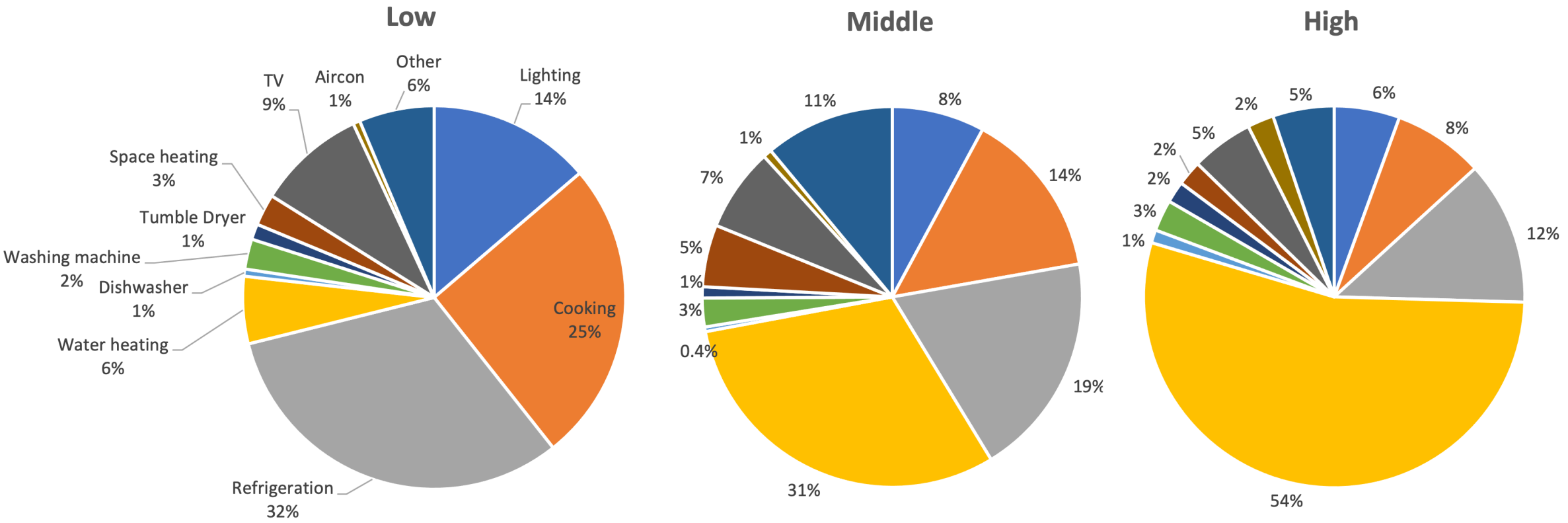
National calibration comments

- National residential electricity consumption estimate (2015 TWh)
- National consumption matched bottom up estimates very closely
- National appliance penetration estimates obtained from other sources
  - AMPS, LCS, Census, Community Survey & GHS.

National calibration results



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SA LEAP Model

The SA LEAP model

- LEAP developed, maintained and distributed by the Stockholm Environmental Institute (SEI)
- Widely used internationally (over 190 countries)
- Scenario based modelling tool
- User friendly modelling platform
  - Flexible scale (sectors, technologies, time)
  - Alternative methods of demand analysis
  - Emissions accounting
  - Optimisation on the supply side
- https://leap.sei.org

LEAP: SA LEAP 0408

Area Edit View Analysis Tags General Tree Chart Advanced Help

New Open Save Email Backup Find Settings Tags Scenarios Fuels Effects Units What's This?

Analysis Results Energy Balance Summaries Overviews Technology Database Notes

SA LEAP
- Key Assumptions
- Demand
  - Low income households
  - Middle income households
  - High income households
    - Cooking
    - Refrigeration
      - Fridge
      - Freezer
    - Water heating
    - Other appliances
    - Space heating
    - Lighting

Tags: Settings

Branch: Demand\High income households\Refrigeration\Fridge\...

Branch: All Branches | Variable: Sales | Scenario: EXC: Excluding SandL to 2020

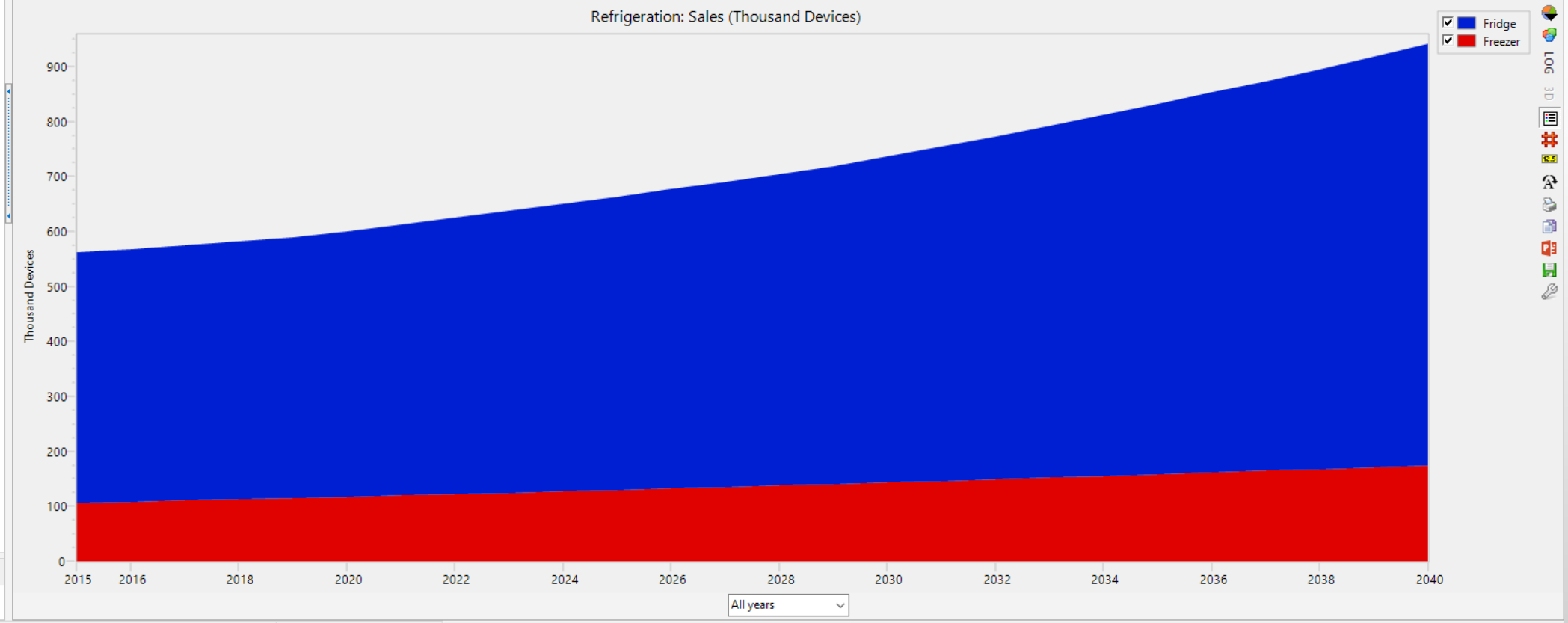
Sales | Marginal Final Energy Intensity | Max Scrappage Fraction | Usage Factor | Scrappage | Device Share | Fraction of Scrapped Replaced | All Variables

Sales: Annual sales of devices. Values ignored in years before the First Sales Year entered for each device. [Default="0"]

Branch	2015 Value	Expression	Scale
Fridge	455 332.00	Growth(1%, 2020,2%,2030,2.6%)	
Freezer	106 554.00	Growth(2%)	
Total:	.991627187	2040,940 826.51	

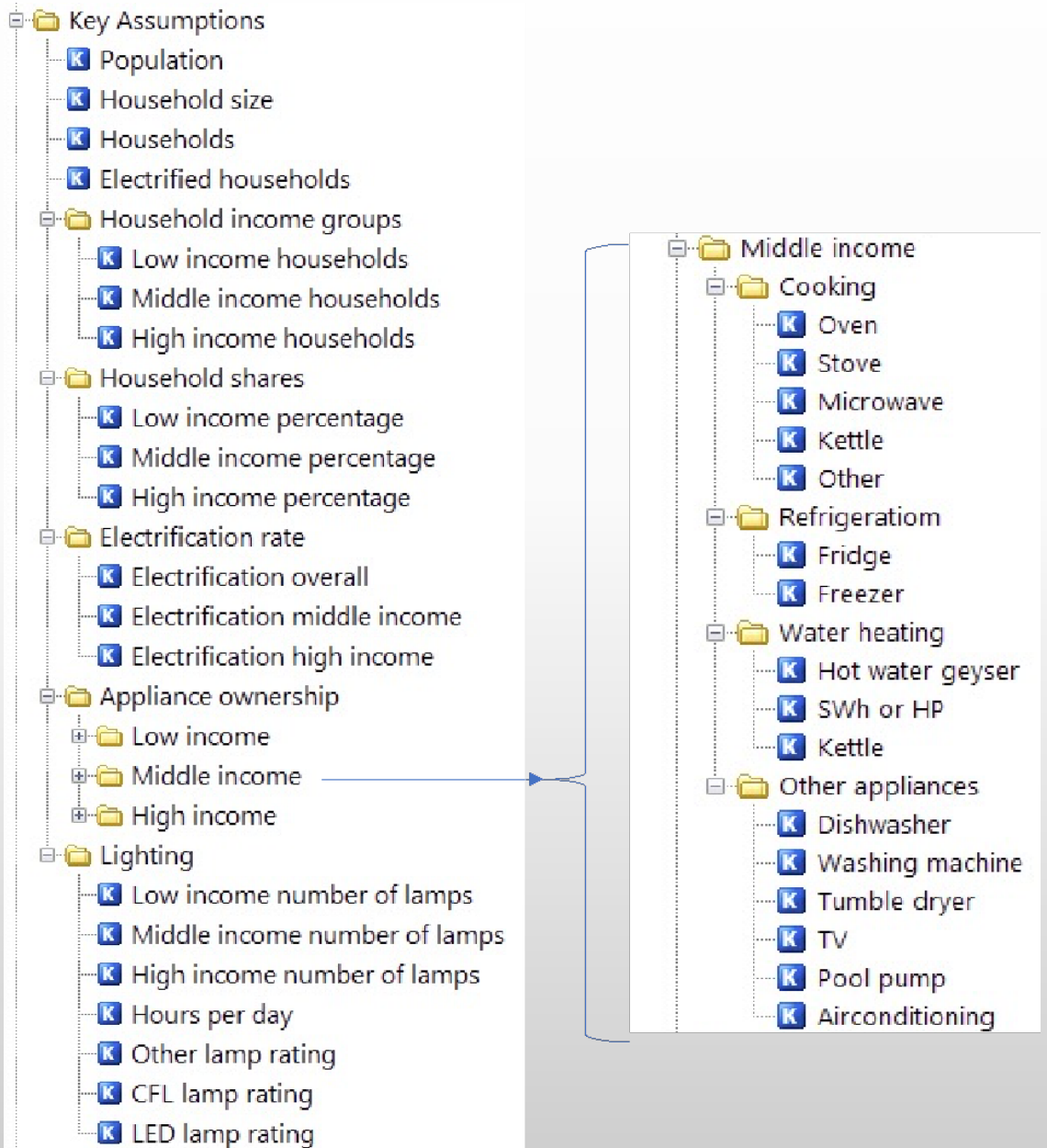
Chart | Table | Builder | Notes | Elaboration | Help

Show: Sales

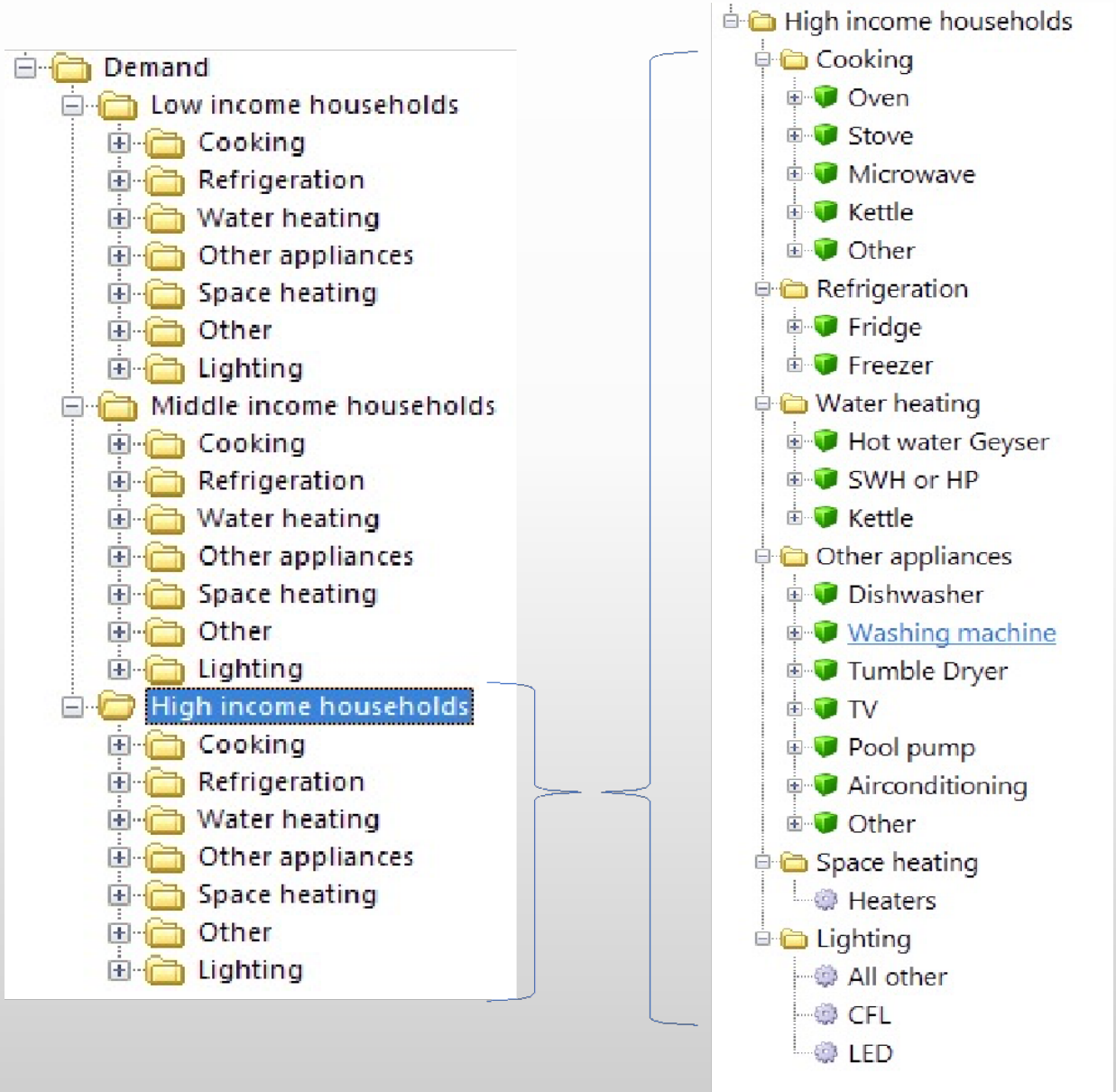


2020.1.0.24 (64-Bit) | Area: SA LEAP 0408 | Analysis | Registered to: "richard.larmour@uct.ac.za" until July 7, 2022

LEAP SA model structure: Key Assumptions



LEAP SA model structure: Demand



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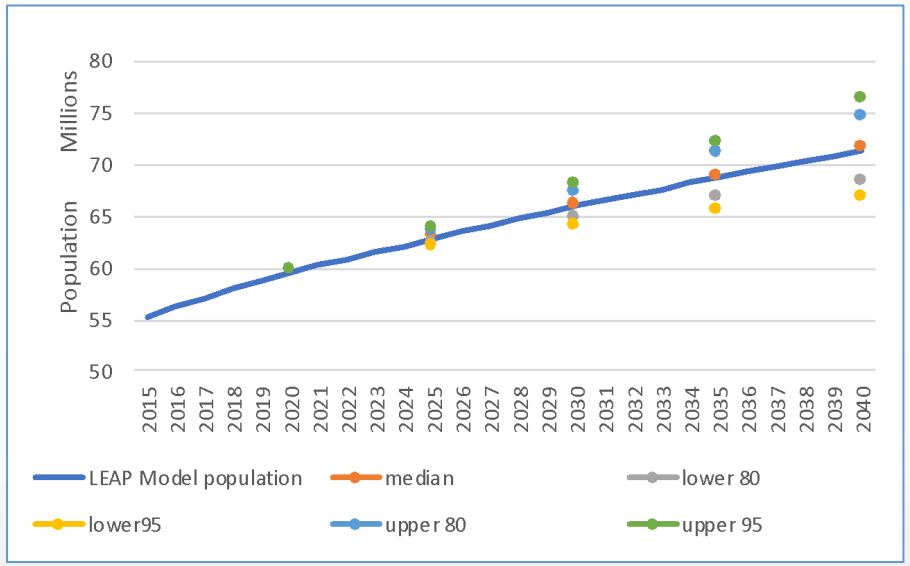
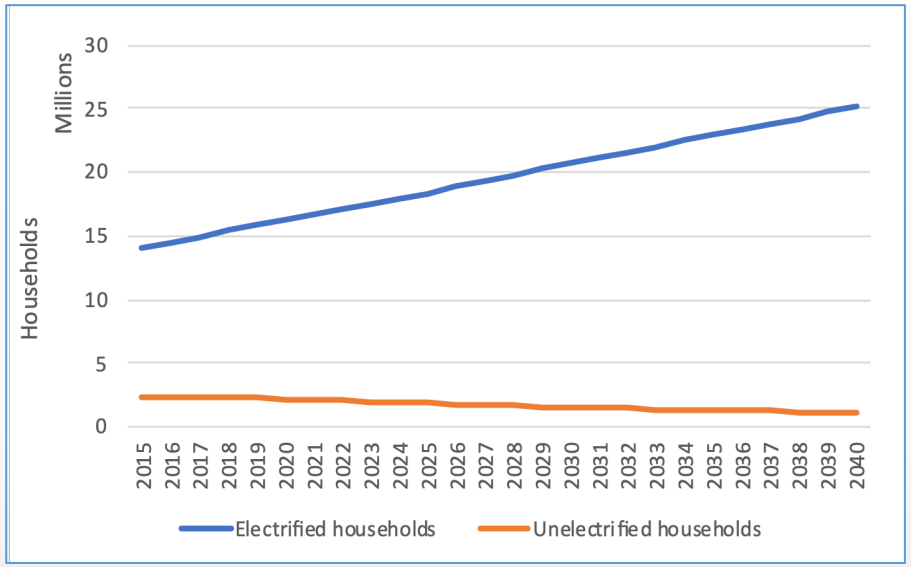
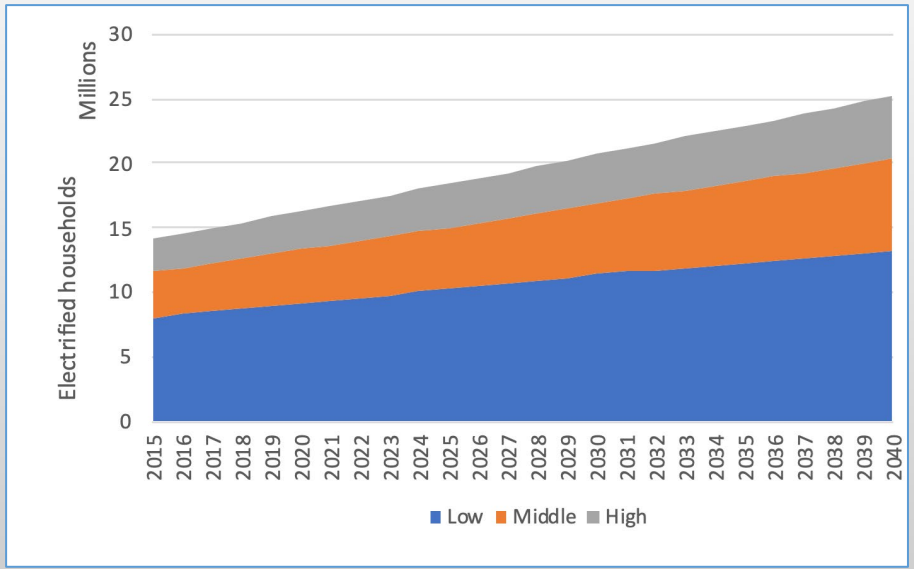
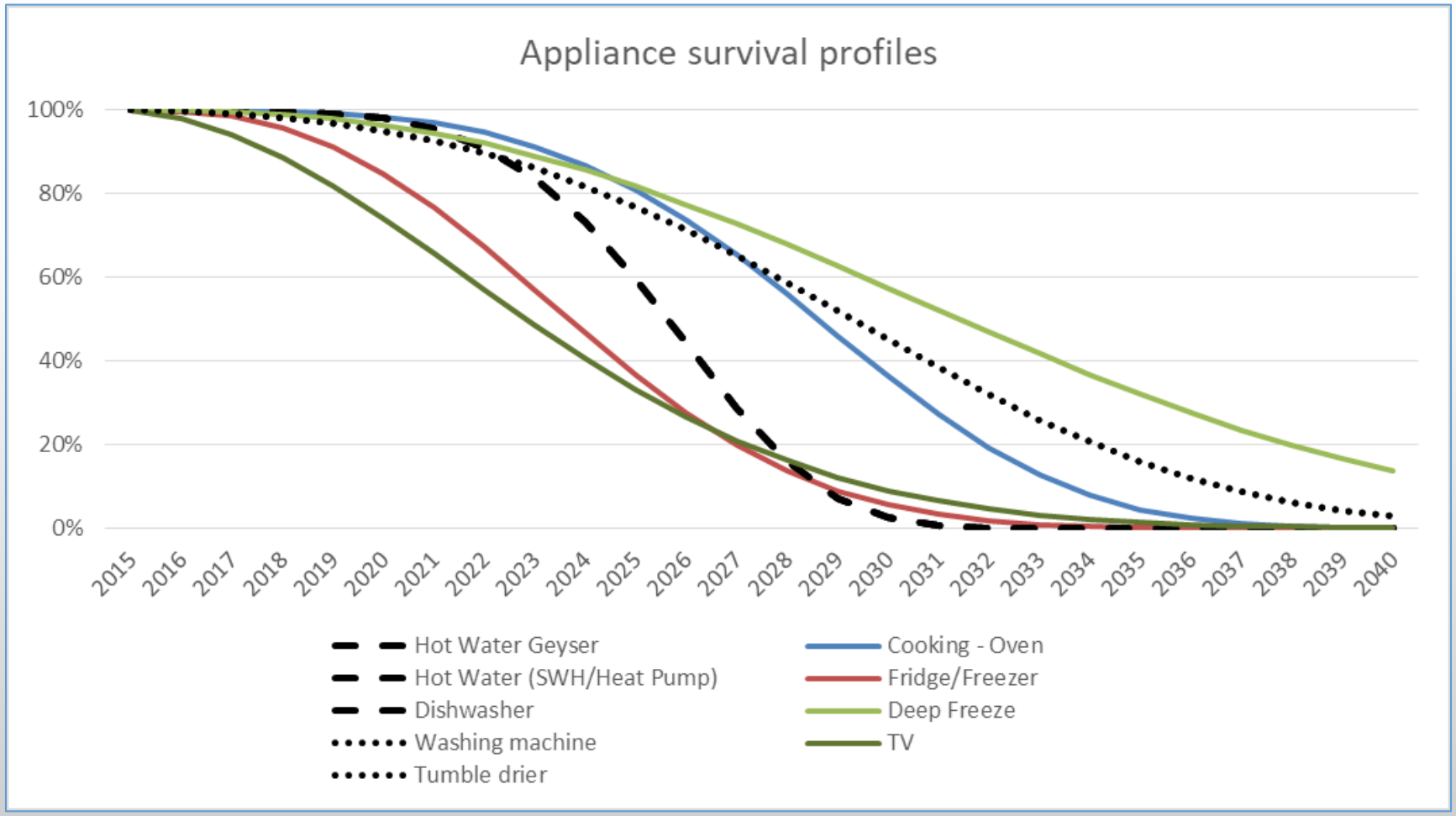
Key assumptions (population, electrification & household income shares)



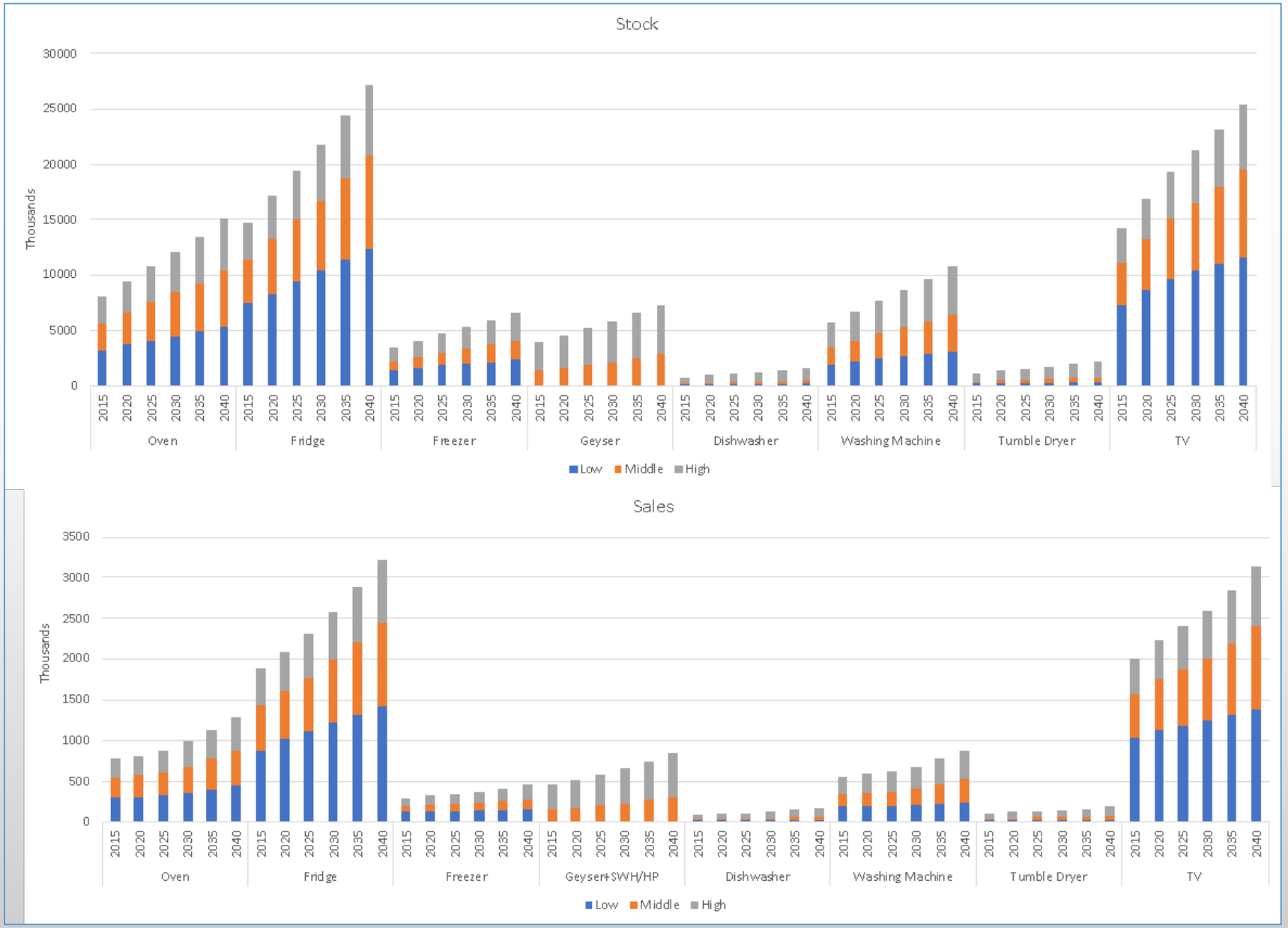




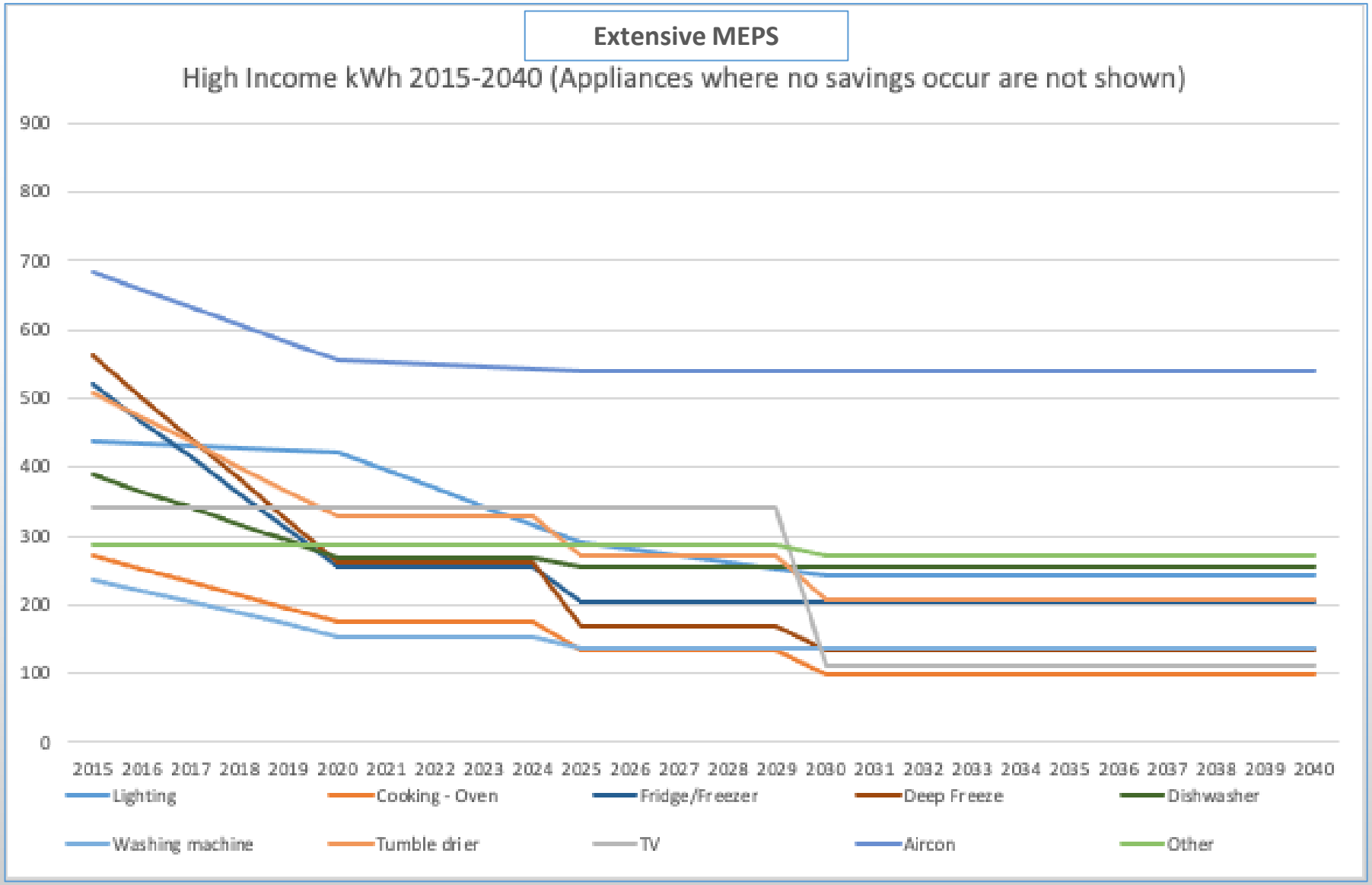
LEAP SA model structure: Stock model appliance ages & survival profiles



LEAP SA model: Stock of targeted appliances & sales (2015-2040)



Scenario development: kWh intensity example (Extensive MEPS, H/Inc)



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Thanks & Acknowledgements