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Heating and cooling demand forecast in Cyprus

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Abstract
Heating and Cooling Demand (Forecast) in Cyprus
This report describes the rationale and the equations used to project the demand of energy services in Cyprus for the period 2013-2015, according to the methodology used by the JRC-EU-TIMES model. It describes the sets used in the model, the inputs and variables used in the equations, the general approach used in all sectors and the variants specific to the residential sector. Finally, the last section describes the projections resulting from these calculations.

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1. Introduction

This note describes the rationale and the equations used to project the demand of energy services in Cyprus for the period 2013-2015, according to the methodology used by the JRC-EU-TIMES model.

The document is structured as follows. Section 2 describes the sets used in the model. Section 3 describes the inputs and variables used in the equations. Section 4 describes the general approach used in all sectors (4.1) and the variants specific to the residential sector (4.2). Finally, section 5 describes the projections resulting from these calculations.

2. Sets

Set name (abbreviation)	Elements
Countries TIMES (ct)	CY
Countries TIMES EU28	CY
Dwelling ages (da)	EXISTING, NEW
Dwelling types (dt)	RURAL, URBAN, MULTIPLE
Sector	Industry,Residential Cooling,Residential Heating,Residential Water,Residential Other,Commercial Cooling,Commercial Heating,Commercial Water,Commercial Other (for final reporting)
Sector CY	NonNetallicMinerals,FoodDrinkTobacco,OtherIndustries,Cooling,Heating,Electric (email KK 18/09/2015)
Sector PRIMES (sp)	Sector PRIMES Industry, Sector PRIMES Construction, Sector PRIMES Tertiary, Sector PRIMES Transport
Sector PRIMES Construction (spc)	Construction
Sector PRIMES Industry (spi)	Iron and steel, Non-ferrous metals, Chemicals, Non-metallic minerals, Paper pulp, Food drink and tobacco, Engineering, Textiles, Other industries
Sector PRIMES Tertiary (sp3)	Market services, Non market services, Trade, Agriculture
Sector PRIMES Transport (spt)	Public road transport, Private cars, Motorcycles, Rail, Aviation, Inland navigation, Trucks, Rail freight, Inland navigation freight
Sector TIMES (st)	Sector TIMES Industry, Sector TIMES Residential, Sector TIMES Commercial, Sector TIMES Agriculture, Sector TIMES Transport
Sector TIMES Agriculture (sta)	AGR
Sector TIMES Commercial (stc)	CHSE, CHLE, CCSE, CCLE, CWSE, CWLE, CLIG, CCOK, CREF, CPLI, COEL, COEN, ONE
Sector TIMES Industry (sti)	IIS, IAL, ICU, INF, ICH, IAM, ICL, ICM, ILM, IGH, IGF, INM, IPH, IPL, IOI, NEC, NEO
Sector TIMES Residential (str)	RHRE, RHUE, RHME, RCRE, RCUE, RCME, RWRE, RWUE, RWME, RHRN, RHUN, RHMN, RCRN, RCUN, RCMN, RWRN, RWUN, RWMN, RLIG, RCOK, RREF, RCWA, RCDR, RDWA, ROEL, ROEN
Sector TIMES Residential Cooling (strc)	RCRE, RCUE, RCME, RCRN, RCUN, RCMN
Sector TIMES Residential Heat (strh)	RHRE, RHUE, RHME, RHRN, RHUN, RHMN
Sector TIMES Residential Insulation (stri)	Sector TIMES Residential Insulation Existing, Sector TIMES Residential Insulation New
Sector TIMES Residential Insulation Existing (strie)	RHRE, RHUE, RHME

Set name (abbreviation)	Elements
Sector TIMES Residential Insulation New (strin)	RHRN, RHUN, RHMN
Sector TIMES Residential Water (strw)	RWRE, RWUE, RWME, RWRN, RWUN, RWMN
Sector TIMES Transport (stt)	TCS, TCL, TBU, TBI, TFH, TFL, TMO, TTP, TTF, TTL, TAV, TAI, TNA, TNB

3. Parameters

3.1 Constant values (input file "Constants AEEI eq 0 PE eq 0 DR new.csv")

Name	Unit	Description	Policy parameter	Source
$AEEI_{st}$	Dmnl	Autonomous energy efficiency improvement rate	Yes	Existing data in JRC-EU-TIMES
CORRECTION	Dmnl	Calibration factor for alignment to 2013 energy balance	No	Calculated
$DIFHEAT_{ct,dt}$	Dmnl	Heat new dwellings compared to existing per category in the base year	No	Existing data in JRC-EU-TIMES
$DWSTOCKBASE_{ct,dt}$	d	Stock of dwellings in base year	No	Existing data in JRC-EU-TIMES
$EFFEXI_{ct}$	Dmnl	Annual heat efficiency improvement on existing dwellings because demolishing	Yes	Existing data in JRC-EU-TIMES
Mapping RD AGE $DW_{str,da,dt}$	Dmnl	Mapping residential sectors-dwelling ages-dwelling types	No	Existing data in JRC-EU-TIMES
Mapping $sectors_{sp,st}$	Dmnl	Mapping PRIMES-TIMES sectors	No	Defined
PRCOOL $BY_{ct,da,dt}$	Dmnl	Penetration of cooling in dwellings, base year value	No	Existing data in JRC-EU-TIMES
PRHEAT $BY_{ct,da,dt}$	Dmnl	Penetration of heating in dwellings, base year value	No	Existing data in JRC-EU-TIMES
Price $elasticity_{st}$	Dmnl	Elasticity for the cost term	No	Existing data in JRC-EU-TIMES
SAVEPER	Yea	The frequency with which output is stored (yearly).	No	Defined
$SHAREDEMOLEX_{ct,dt}$	Dmnl	Share of existing building categories in demolition	No	Existing data in JRC-EU-TIMES
$SHARENEW_{ct,dt}$	Dmnl	Share of building categories in new construction	Yes	Existing data in JRC-EU-TIMES
$TARGCOOL_{ct}$	Dmnl	Target penetration rate for cooling	Yes	Existing data in JRC-EU-TIMES
$TARGHEAT_{ct}$	Dmnl	Target penetration rate for heating	Yes	Existing data in JRC-EU-TIMES
$TARGYEARCOOL_{ct}$	Dmnl	Number of years for target penetration (cooling)	Yes	Existing data in JRC-EU-TIMES
$TARGYEARHEAT_{ct}$	Dmnl	Number of years for target penetration (heating)	Yes	Existing data in JRC-EU-TIMES
$TEMPCOR_{ct}$	Dmnl	Temperature correction for 2005 to multiply the heat demand per dwelling	No	Existing data in JRC-EU-TIMES (Eurostat)
$TOTDEMOL_{ct}$	Dmnl	Share of dwellings demolished per year	Yes	Existing data in JRC-EU-TIMES
UNIT B	B	Billions (10e9)	No	Defined
UNIT POP	p	People	No	Defined
UNIT SAVINGS	X/d	Energy savings	No	Defined
UNIT TRANSPORT	Gxkm	Transport activity (Gpkm or Gtkm)	No	Defined

Name	Unit	Description	Policy parameter	Source
UNIT YEAR	Year	Time	No	Defined
UNIT €	€2010	€2010	No	Defined

3.2 Time series (input file "Data CY – Annual 20150921.xlsx")[1]

Name	Unit	Description	Policy data	Source
DEMAND $DAT_{ct,st}$	X[2]	Base year demand values	No	Existing data in JRC-EU-TIMES
DEMAND EU28 DAT_{st}	X	Existing demand projection for EU28	No	Existing data in JRC-EU-TIMES
Driver $elasticity_{st}$	Dmnl	Elasticity for the driver term	No	Existing data in JRC-EU-TIMES
$DWPERS_{ct}$	p/d	Number of persons per dwellings	Yes	EU Reference Scenario (PRIMES)
ENERGY COST $INDUSTRY_{ct}$	€2010/toe	Unit cost of fuel purchasing as in PRIMES	Yes	EU Reference Scenario (PRIMES)
ENERGY COST $RESIDENTIAL_{ct}$	€2010/toe	Unit cost of fuel purchasing as in PRIMES	Yes	EU Reference Scenario (PRIMES)
ENERGY COST $TERTIARY_{ct}$	€2010/toe	Unit cost of fuel purchasing as in PRIMES	Yes	EU Reference Scenario (PRIMES)
ENERGY COST $TRANSPORT_{ct}$	€2010/toe	Unit cost of fuel purchasing as in PRIMES	Yes	EU Reference Scenario (PRIMES)
FINAL ENERGY $DEMAND_{ct,sp}$	PJ	Final energy demand from PRIMES/EU Reference Scenario	Yes	EU Reference Scenario (PRIMES)
GDP_{ct}	B*€2010	GDP as in PRIMES/EU Reference Scenario	Yes	IRENA study

[1] Some time series are calculations from figures stored in "CY_GDP_forecast_IRENA_study.xlsx", "Energy balance 2013_v4.xlsx", and "JRC-IDEES_En_CY.xlsx".

[2] X=Gpkm for TCS, TCL, TBU, TMO, TTP, TTL. X=Gtkm for TFH, TFL, TTF. X=Mt for IIS, IAL, ICU, IAM, ICL, ICM, ILM, IGH, IGF, IPH, IPL. X=PJ for the rest.

Name	Unit	Description	Policy data	Source
GDP SECTOR$_{ct,sp}$	B*€2010	Sectoral GDP as in PRIMES/EU Reference Scenario	Yes	IRENA study)
HOUSEHOLD EXPENDITURE POP$_{ct}$	€2010/p	Household expenditures per capita	Yes	EU Reference Scenario (PRIMES)
POP$_{ct}$	p	Population	Yes	IRENA study
RATIO U2F DAT	Dmnl	Ratio useful-to-final energy from JRC-IDEES database	Yes (2011 onwards)	JRC-IDEES
SPECIFIC ENERGY CONSUMPTION	PJ/X	Energy consumption per unit of physical output/activity	Yes (2011 onwards)	JRC-IDEES
TRANSPORT ACTIVITY$_{ct,spt}$	Gxkm	Transport activity as in PRIMES/EU Reference Scenario	No	EU Reference Scenario (PRIMES)

3.3 Variables

Name	Unit	Description	Source equation
COOLDW$_{ct,da,dt}$	X/d	Cooling demand per dwelling category from base year	19
COST TERM$_{ct,st}$	Dmnl	Energy cost driver	8
DEMAND$_{ct,st}$	X	Projected demand,	1
DEMAND EQU$_{ct,st}$	X	Projected demand	2
DEMAND EU28$_{st}$	X	Projected demand	Not included in the document
DEMAND F	PJ	Projected final demand	Not included in the document
DEMAND F REP	PJ	Projected final demand, aggregation for reporting	Not included in the document
DEMAND F REP CY	PJ	Projected final demand, aggregation for reporting	Not included in the document
DEMAND RATIO	Dmnl	Difference wrt projections for JET report 2013	Not included in the document
DEMAND U	PJ	Projected useful demand	Not included in the document
DEMAND U REP	PJ	Projected useful demand, aggregation for reporting	Not included in the document
DEMAND U REP CY	PJ	Projected useful demand, aggregation for reporting	Not included in the document
DEMDW$_{ct,str}$	X/d	Projected demand per dwelling	20
DEMOLEXI$_{ct,dt}$	d	Number of dwellings demolished per year by category	15
DEMSAVE$_{ct,ime,strie}$	Dmnl	Saving of demand in existing dwellings in percentage	**Error! Reference source not found.**

Name	Unit	Description	Source equation
$DEMSAVN_{ct,imn,strin}$	Dmnl	Saving of demand in new dwellings at construction in percentage	**Error! Reference source not found.**
$DIFFERENCE\ DEMAND\ EU28_{st}$	Dmnl	Percentage difference between existing and projected demand	Not included in the document
$DRIVER_{ct,st}$	Dmnl	Drivers from PRIMES/EU Reference Scenario	7
$DRIVER\ GR_{ct,st}$	Dmnl	Driver growth rate as in PRIMES/EU Reference Scenario	6
$DRIVER\ TERM_{ct,st}$	Dmnl	Demand driver	5
$DWSTOCK_{ct,da,dt}$	d	Stock of dwelling by category and by construction period	13
$DWSTOCKTOT_{ct}$	d	Total stock of dwellings	12
$EFFICIENCY\ TERM_{st}$	Dmnl	Autonomous energy efficiency improvement term	11
$ENERGY\ COST_{ct,sp}$	€/toe	Unit cost of fuel purchasing as in PRIMES	10
$ENERGY\ COST\ GR_{ct,sp}$	Dmnl	Growth rate of unit cost of fuel purchasing as in PRIMES	9
$FINAL\ ENERGY\ DEMAND\ EU28_{sp}$	PJ	Final energy demand from PRIMES/EU Reference Scenario	Not included in the document
$GDP\ GR_{ct}$	Dmnl	GDP growth rate as in PRIMES/EU Reference Scenario	Not included in the document
$GDPPOP_{ct}$	€2010/p	GDP per capita as in PRIMES/EU Reference Scenario	Not included in the document
$GDPPOP\ GR_{ct}$	Dmnl	GDP per capita growth rate as in PRIMES/EU Reference Scenario	Not included in the document
$GRCOOLDW_{ct,strc}$	Dmnl	Growth rate in cooling demand per heat demand category	23
$GRHEATDW_{ct,strh}$	Dmnl	Growth rate in heat demand per heat demand category	22
$GRHOTWDW_{ct,strw}$	Dmnl	Growth rate in hot water demand per hot water demand category	24
$HEATDW_{ct,da,dt}$	X/d	Heat demand per dwelling category from base year	17
$HOTWDW_{ct}$	X/d	Hot water demand per dwelling category from base year	18
$PERSHEV_{ct}$	Dmnl	Evolution in number of persons per dwelling	25
$POP\ GR_{ct}$	Dmnl	Population growth rate	Not included in the document
$PRCOOL_{ct,da,dt}$	Dmnl	Penetration of cooling in dwellings	26
$SHAREEXIS_{ct,dt}$	Dmnl	Share of existing dwellings on total, per dwelling type.	Not included in the document

4. Equations

4.1 Standard demand equations

The demand of energy services[3] is projected according to the methodology described in (1)[4] and (2). Those projections are driven by a series of inputs exogenous to the model (available from the current JRC-EU-TIMES dataset and from the latest EU Reference Scenario (3)[5]). The main drivers of energy demand are projections on:

- Population, and
- GDP, sectoral production, and household consumption

The current implementation of the demand projections overwrites the result of the demand equation (DEMAND $EQU_{ct,st}$) whenever real data (DEMAND $DAT_{ct,st}$) are available:

1	$DEMAND_{ct,st} =$ $IF\ THEN\ ELSE\left(DEMAND\ DAT_{ct,st} \neq NA^{6}, DEMAND\ DAT_{ct,st}, DEMAND\ EQU_{ct,st}\right)$

The general equation for projecting the demand from the previous period (DEMAND $DLY_{ct,st}$) into the current one is the result of multiplying that demand by three factors, namely: i) a term related to the main driver behind the growth in the energy service demand (DRIVER $TERM_{ct,st}$), ii) a cost term that represents an estimation of the path of the corresponding energy prices (COST $TERM_{ct,st}$), and iii) a price- and driver-

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[3] Or materials, in the case of energy intensive sectors: IIS, IAL, ICU, IAM, ICL, ICM, ILM, IGH, IGF (expressed in Mt), and transport activities: TCS,TCL,TBU,TBI,TFH,TFL,TMO,TTP,TTF,TTL,TAV,TAI,TNA,TNB (expressed in pkm or tkm).

[4] According to this methodology, the energy demand in period 1, E_1, is equal to the demand in period 0, E_0, multiplied by the growth in the driving demand (from D_0 to D_1, corrected by an income elasticity IE), the growth in energy costs (from P_0 to P_1, corrected by a price elasticity PE), and the autonomous energy efficiency improvement (AEEI):

$$E_1 = E_0 \cdot \left(\frac{D_1}{D_0}\right)^{IE} \cdot \left(\frac{P_1}{P_0}\right)^{PE} \cdot (1 - AEEI)$$

In subsequent periods the demand would be:

$$E_2 = E_1 \cdot \left(\frac{D_2}{D_1}\right)^{IE} \cdot \left(\frac{P_2}{P_1}\right)^{PE} \cdot (1 - AEEI) \rightarrow E_2 = E_0 \cdot \left(\frac{D_1}{D_0}\right)^{2\cdot IE} \cdot \left(\frac{P_1}{P_0}\right)^{2\cdot PE} \cdot (1 - AEEI)^2$$

$\vdots$

$$E_T = E_{T-1} \cdot \left(\frac{D_T}{D_{T-1}}\right)^{IE} \cdot \left(\frac{P_T}{P_{T-1}}\right)^{PE} \cdot (1 - AEEI) \rightarrow E_T = E_0 \cdot \left(\frac{D_1}{D_0}\right)^{T\cdot IE} \cdot \left(\frac{P_1}{P_0}\right)^{T\cdot PE} \cdot (1 - AEEI)^T$$

Rearranging:

$$E_T = E_0 \cdot \left(\frac{D_0 + D_1 - D_0}{D_0}\right)^{T\cdot IE} \cdot \left(\frac{P_0 + P_1 - P_0}{P_0}\right)^{T\cdot PE} \cdot (1 - AEEI)^T$$

$$E_T = E_0 \cdot (1 + DGR)^{T\cdot IE} \cdot (1 + PGR)^{T\cdot PE} \cdot (1 - AEEI)^T$$

In the case of having different growth rates from 0 to T, the previous equation reads:

$$E_T = E_0 \cdot \prod_{t=0}^{t=T}\left((1 + DGR_t)^{IE}\right) \cdot \prod_{t=0}^{t=T}\left((1 + PGR_t)^{PE}\right) \cdot \prod_{t=0}^{t=T}(1 - AEEI)$$

[5] http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2050_update_2013.pdf

[6] Keyword for "not available" in Vensim.

independent demand change due to autonomous efficiency improvements (EFFICIENCY $TERM_{st}$).

2	$DEMAND\ EQU_{ct,st} =$ $DEMAND\ DLY_{ct,st} \cdot DRIVER\ TERM_{ct,st} \cdot COST\ TERM_{ct,st} \cdot EFFICIENCY\ TERM_{st} + CORRECTION_{ct,st}$
3	$DEMAND\ DLY_{ct,st} =$ $FIXED\ DELAY\left(DEMAND\ DLY_{ct,st}, SAVEPER^{7}, DEMAND\ DAT_{ct,st}{}^{8}\right)$

4.1.1 Driver term

The driver term in the demand equation is calculated as the growth rate between two consecutive periods corrected by the driver elasticity:

4	$DRIVER\ TERM_{ct,st} =$ $\left(1 + \frac{DRIVER\ GR_{ct,st}}{100}\right)^{(SAVEPER \cdot Driver\ elasticity_{st})}$

The only exception is the driver for residential heat, which is corrected as well by the annual heat efficiency improvement on existing dwellings because of demolishing:

5	$DRIVER\ TERM_{ct,strh} =$ $\left(1 - EFFEXI_{ct} + \frac{DRIVER\ GR_{ct,strh}}{100}\right)^{(SAVEPER \cdot Driver\ elasticity_{strh})}$

The growth rate of the driver (DRIVER $GR_{ct,st}$) is calculated as the compounded annual growth rate of the driver ($DRIVER_{ct,st}$) between two consecutive periods, that is:

6	$DRIVER\ GR_{ct,st} =$ $100 \cdot \left(\left(\frac{DRIVER_{ct,st}}{DRIVER\ DLY_{ct,st}}\right)^{\left(\frac{1}{SAVEPER}\right)} - 1\right)$

The drivers are sector-dependent. In the case of agriculture, commercial, and industrial sectors the driver is the corresponding sectorial GDP. Residential demand is driven by household expenditure per capita.

[7] Time step in the calculations, annual.

[8] Value taken in the first calculation step.

7	$$DRIVER_{ct,sta} = \sum_{sp} \left(Mapping\ sectors_{sp,sta} \cdot GDP\ SECTOR_{ct,sp} \right)$$
	$$DRIVER_{ct,stc} = \sum_{sp} \left(Mapping\ sectors_{sp,stc} \cdot GDP\ SECTOR_{ct,sp} \right)$$
	$$DRIVER_{ct,sti} = (1 - EURS) \cdot \sum_{sp} \left(Mapping\ sectors_{sp,sti} \cdot GDP\ SECTOR_{ct,sp} \right) + EURS \cdot DEMAND\ EURS\ DAT_{ct,sti}$$
	$$DRIVER_{ct,str} = HOUSEHOLD\ EXPENDITURE\ POP_{ct}$$
	$$DRIVER_{ct,stt} = \sum_{sp} \left(Mapping\ sectors_{spt,stt} \cdot TRANSPORT\ ACTIVITY_{ct,spt} \right)$$

4.1.2 Cost term

The cost term in the demand equation is calculated as the growth rate between two consecutive periods corrected by the price elasticity:

8	$$COST\ TERM_{ct,st} = \left(1 + \sum_{sp} \left(Mapping\ sectors_{sp,st} \cdot \frac{ENERGY\ COST\ GR_{ct,sp}}{100} \right) \right)^{(SAVEPER \cdot Price\ elasticity_{st})}$$

The growth rate of the energy costs (ENERGY COST $GR_{ct,st}$) is calculated as the compounded annual growth rate of the costs (ENERGY $COST_{ct,sp}$) between two consecutive periods, that is:

9	$$ENERGY\ COST\ GR_{ct,sp} = 100 \cdot \left(\left(\frac{ENERGY\ COST_{ct,sp}}{ENERGY\ COST\ DLY_{ct,sp}} \right)^{\left(\frac{1}{SAVEPER}\right)} - 1 \right)$$

The energy costs are sector-dependent, and taken from the latest EU Reference Scenario.

10	$$ENERGY\ COST_{ct,spi} = ENERGY\ COST\ INDUSTRY_{ct}$$
	$$ENERGY\ COST_{ct,spc} = ENERGY\ COST\ INDUSTRY_{ct}$$
	$$ENERGY\ COST_{ct,sp3} = ENERGY\ COST\ TERTIARY_{ct}$$
	$$ENERGY\ COST_{ct,spt} = ENERGY\ COST\ TRANSPORT_{ct}$$

4.1.3 Efficiency term

The efficiency term in the demand equation is calculated as the compounded growth rate due to efficiency improvements ($AEEI_{st}$) between two consecutive periods:

11	$EFFICIENCY\ TERM_{st} = (1 - AEEI_{st})^{(SAVEPER)}$

This term defines the price independent demand change due to autonomous efficiency improvements, and is an expert-based assumption. This is mainly used in the industrial sector to reflect intra-sectorial structural evolution not directly linked to changes in energy prices.

1.1.1 Elasticities

The evolution of the demand for energy services is linked to the changes in demand drivers' through elasticities. These elasticities are meant to reflect changing patterns in energy service demand in relation to economic growth, such as saturation in some energy end-use demand, increased urbanization or changes in consumption patterns once the basic needs are satisfied. Driver elasticities range from 0 to 1, and the lower the elasticity the less influence of the driver on the energy demand service. The values

- Passenger transport: there is shift from public transport towards private cars with increasing income; greater urbanisation would also contribute to a lesser increase in the passenger-km demand.
- Freight transport: accompanies more closely the growth of GDP with a slight model shift from road transport to other freight transport means.
- Residential demand: for space heating and cooling and for water heating the drivers are a combination of the evolution in the number of households, the population growth and disposable income per household. This combination is done after the GEM-E3 outcome. Within GEM-E3 the driver for the residential sector is only disposable income. For the other demand categories, the evolution in income is the dominant factor. In the long run, certain saturation and changes in consumption patterns will weaken this link.
- Commercial demand: follows the sectorial activity but with a decreasing link.
- Industrial and agriculture demand: the demand follows the sectorial production evolution.

Table 1: driver elasticities

Sector [code]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Iron and steel [IIS]	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Aluminium [IAL]	1	1	1	1	1	1	1	1	1	1
Copper [ICU]	1	1	1	1	1	1	1	1	1	1
Other non-ferrous metals [INF]	1	1	1	1	1	1	1	1	1	1
Chemicals [ICH]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Ammonia [IAM]	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Chlorine [ICL]	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Cement [ICM]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Lime [ILM]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Glass, hollow [IGH]	1	1	1	1	1	1	1	1	1	1
Glass, flat [IGF]	1	1	1	1	1	1	1	1	1	1
Other non-metallic minerals [INM]	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Pulp and paper, high quality [IPH]	1	1	1	1	1	1	1	1	1	1
Pulp and paper, low quality [IPL]	1	1	1	1	1	1	1	1	1	1
Other industries [IOI]	1	1	1	1	1	1	1	1	1	1
Non energy consumption, chemicals [NEC]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Non energy consumption, others [NEO]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Residential heating in existing rural dwellings [RHRE]	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential heating in existing urban dwellings [RHUE]	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential heating in existing multi-apartment dwellings [RHME]	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential cooling in existing rural dwellings [RCRE]	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Residential cooling in	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Sector [code]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
existing urban dwellings [RCUE]										
Residential cooling in existing multi-apartment dwellings [RCME]	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Residential hot water in existing rural dwellings [RWRE]	0.8	0.8	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential hot water in existing urban dwellings [RWUE]	0.8	0.8	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential hot water in existing multi-apartment dwellings [RWME]	0.8	0.8	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential heating in new rural dwellings [RHRN]	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential heating in new urban dwellings [RHUN]	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential heating in new multi-apartment dwellings [RHMN]	0.5	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential cooling in new rural dwellings [RCRN]	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Residential cooling in new urban dwellings [RCUN]	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Residential cooling in new multi-apartment dwellings [RCMN]	0.8	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Residential hot water in new rural dwellings [RWRN]	0.8	0.8	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential hot water in new urban dwellings [RWUN]	0.8	0.8	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Residential hot water in new multi-apartment dwellings	0.8	0.8	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Sector [code]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
[RWMN]										
Residential lighting existing [RLIG]	1.5	1.5	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Residential cooking existing [RCOK]	0.3	0.3	0.2	0.15	0.15	0.15	0.1	0.1	0.1	0.1
Residential refrigeration existing [RREF]	0.3	0.3	0.2	0.15	0.15	0.15	0.1	0.1	0.1	0.1
Residential cloth washing existing [RCWA]	0.3	0.3	0.2	0.15	0.15	0.15	0.1	0.1	0.1	0.1
Residential cloth drying existing [RCDR]	0.5	0.5	0.2	0.25	0.25	0.25	0.1	0.1	0.1	0.1
Residential dish washing existing [RDWA]	0.5	0.5	0.2	0.25	0.25	0.25	0.1	0.1	0.1	0.1
Residential other electric existing [ROEL]	2	2	0.8	0.5	0.5	0.5	0.25	0.25	0.25	0.25
Residential other energy existing [ROEN]	0.3	0.3	0.3	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Commercial small space heating existing [CHSE]	0.6	0.6	0.35	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Commercial large space heating existing [CHLE]	0.6	0.6	0.35	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Commercial small space cooling existing [CCSE]	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Commercial large space cooling existing [CCLE]	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Commercial small space hot water existing [CWSE]	0.6	0.6	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Commercial large space hot water existing [CWLE]	0.6	0.6	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Commercial lighting existing [CLIG]	1.5	1.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Commercial cooking existing [CCOK]	0.8	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Commercial refrigeration existing [CREF]	0.8	0.8	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Commercial	0.8	0.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Sector [code]	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
public lighting existing [CPLI]										
Commercial other electric existing [COEL]	2	2	1.5	1	1	1	0.6	0.6	0.6	0.6
Commercial other energy existing [COEN]	0.8	0.8	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Other non-energy [ONE]	0	0	0	0	0	0	0	0	0	0
Agriculture [AGR]	0.6	0.6	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Road car short distance [TCS]	1	1	1	1	1	1	1	1	1	1
Road car long distance [TCL]	0.9	0.9	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6
Road bus urban [TBU]	1	1	1	1	1	1	1	1	1	1
Road bus intercity [TBI]	1	1	1	1	1	1	1	1	1	1
Road freight heavy [TFH]	1	1	1	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Road freight light [TFL]	1	1	1	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Road motorcycles [TMO]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Rail passengers heavy [TTP]	1	1	1	1	1	1	1	1	1	1
Rail freight [TTF]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Rail passengers light [TTL]	1	1	1	1	1	1	1	1	1	1
Aviation generic [TAV]	1.2	1.2	1.2	1	1	1	1	1	1	1
Aviation international [TAI]	1.2	1.2	1.2	1	1	1	1	1	1	1
Navigation generic [TNA]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Navigation generic bunker [TNB]	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Besides the driver elasticities, the demand projections depend as well on price elasticities. There are no studies on price elasticities of energy service demand, except for transport. Therefore the price elasticities are derived from energy demand price elasticities.

At an aggregate level, energy demand (ED) is equal to the energy service demand (ES) multiplied by the energy efficiency of the process used to satisfy the energy demand (UE, the energy demand per unit of energy service demand, a function of capital and energy). Depending on the substitution possibilities between inputs and processes, the relation between the two elasticities will be different.

A	$ED = ES \cdot UE$

Assuming a fixed relation between capital and energy in the production function of energy services (Leontief structure), the price elasticity of energy demand (PED) is equal to the product of the price elasticity of energy service demand (PES) and the share of energy in the total cost of the energy service (SHC):

B	$PED = PES \cdot SHC$

Assuming substitution possibilities between capital and energy in the production function (a production function with constant elasticity of substitution), the price elasticity of energy demand will also depend on the substitution elasticity (SEL):

C	$PED = PES \cdot SHC - SEL \cdot (1 - SHC)$

Thus, the greater the share of energy in the total cost of the energy service, the closer both elasticities are, while they differ more the greater the substitution possibilities are.

Based on the relations and assumptions regarding the energy demand price elasticities and substitution possibilities the following energy services demand price elasticities are used in the JRC-EU-TIMES model. For transport there are estimates of the price elasticities of demand, although they do not cover all the regions and are sometimes related to the cost of energy and not the total transport cost. The values considered in JRC-EU-TIMES are from average figures for long term elasticities in OECD countries.

Table 2: price elasticities

Demand	Price elasticity of energy demand (PED)	Substitution elasticity (SEL)	Share of energy in energy service costs (SHC)	Price elasticity of energy service demand (PES)
Residential heating, cooling, and hot water	-0.45	0.70	0.80	-0.39
Residential cooking and refrigeration	-0.35	0.40	0.80	-0.34
Commercial heating, cooling and hot water	-0.55	0.70	0.80	-0.51
Commercial cooking and refrigeration	-0.40	0.40	0.80	-0.40
Energy intensive industries	-0.70	1.00	0.70	-0.57

Demand	Price elasticity of energy demand (PED)	Substitution elasticity (SEL)	Share of energy in energy service costs (SHC)	Price elasticity of energy service demand (PES)
Other industries	-0.40	0.40	0.80	-0.40
Private car				-0.70
Bus				-0.20
Train				-0.20
Motorcycles				-0.30
Navigation				-0.10
Air				-0.70
Trucks				-0.90
Train				-0.20
Navigation				-0.20

4.2 Energy demand in the residential sector

The approach used to project the demand from the residential sector is more specific, as described in the following. The energy service demands considered in the residential sector are listed below:

- Space heating,
- Space cooling,
- Water heating,
- Cooking,
- Refrigeration,
- Lighting,
- Cloth washing,
- Cloth drying,
- Dish washing,
- Other electric uses (equipment) and
- Other energy uses.

The demand for heating, cooling, and hot water is related to the characteristics of the dwellings and thus, in order to achieve a more detailed description, those demands are further disaggregated into three categories of buildings:

- Multi-family apartment buildings,
- Single houses in urban areas, and
- Single houses in rural areas.

Therefore the projection for the energy service demands from the residential sector is done in three steps:

- Projection of the number of dwellings, by category (section 0),
- Projection of the demand for heating, cooling, and hot water, per dwelling and by category (section 0),
- Projection of the total demand by combining the previous (section 0).

4.2.1 Stock of dwellings by category

The projected number of total households ($DWSTOCKTOT_{ct}$) is derived from the population level (POP_{ct}) and the number of persons per household ($DWPERS_{ct}$) assumed in the latest EU Reference Scenario, except in the initial year, when the stock of existing dwellings is taken from the calibrated template files (based on Eurostat data, where available, and on national experts input when not available):

12	$$DWSTOCKTOT_{ct} = IF\ THEN\ ELSE\left(Time = INITIAL\ TIME, \sum_{dt} DWSTOCKBASE_{ct,dt}, \frac{POP_{ct}}{DWPERS_{ct}}\right)$$

The number of existing dwellings remaining in each period ($DWSTOCK_{ct,EXISTING,dt}$) is computed as the difference between the previous stock ($DWSTOCK\ DLY_{ct,EXISTING,dt}$), the number of existing buildings demolished ($DEMOLEXI_{ct,dt}$), and the new dwellings ($DWSTOCK_{ct,NEW,dt}$):

13	$$DWSTOCK_{ct,dt} = IF\ THEN\ ELSE\big(Time = INITIAL\ TIME, DWSTOCKSHARE_{ct,dt} \cdot DWSTOCKTOT\ DAT_{ct}, max\big(0, DWSTOCK\ DLY_{ct,EXISTING,dt} - DEMOLEXI_{ct,dt} + DWSTOCK_{ct,NEW,dt}\big)\big)$$
14	$$DWSTOCK\ DLY_{ct,dt} = DELAY\ FIXED\big(DWSTOCK\ DLY_{ct,dt}, SAVEPER, DWSTOCKSHARE\ IV_{ct,dt} \cdot DWSTOCKTOT\ IV_{ct}\big)$$

The number of existing buildings demolished per category is calculated from the total share of demolitions[9] ($TOTDEMOL_{ct}$, exogenous) and the share of each dwelling category in demolition ($SHAREDEMOLEX_{ct,}$dt, exogenous):

15	$$DEMOLEXI_{ct,dt} = DWSTOCKTOT_{ct} \cdot TOTDEMOL_{ct} \cdot SHAREDEMOLEX_{ct,dt}$$

It is assumed that demolishing mainly affects the oldest dwellings with the highest unit heat demand thus inducing an 'efficiency' improvement for the average stock. In JRC-EU-TIMES a mixed approach was used to compute an efficiency improvement factor for existing stock. For countries for which detailed survey data on the housing stock

[9] With respect to the occupied dwellings.

structure and the demolishing rate is available, a specific factor was used. For other countries, the efficiency factor was estimated based on the assumption that there is no distinction for type of dwelling.

The number of new dwellings ($DWSTOCK_{ct,NEW,dt}$) by category is estimated by multiplying the share of each building category in new constructions ($SHARENEW_{ct,dt}$) by the difference between the projected total number of households ($DWSTOCKTOT_{ct}$), the total stock of existing dwellings remaining, and the demolished dwellings ($DEMOLEXI_{ct,dt}$) in each period:

16	$DWSTOCK_{ct,NEW,dt} = SHARENEW_{ct,dt} \cdot MAX\left(0, DWSTOCKTOT_{ct} - \sum_{dt} DWSTOCK_{ct,EXISTING,dt}\right) + DEMOLEXI_{ct,dt}$

The allocation of the total stock by building type is done with exogenous shares based on assumptions such as urbanisation trends and age pattern evolution. These assumptions were made by the several national experts involved in the NEEDS11 and RES202012 research projects.

4.2.2 Demand of energy services per dwelling

The starting point to generate the demand of energy services per dwelling is to calculate them according to the calibrated values for the base year in the residential template for each region in the model ($HEATDW_{ct,da,dt}$, $COOLDW_{ct,da,dt}$, $HOTWDW_{ct,da,dt}$). In the case of the demand for heating in existing buildings, the estimation is corrected (by the $TEMPCOR_{ct}$ factor) since for some countries 2010 was not an average year regarding heating and cooling degree days (in the current implementation the computation does not consider the possible impacts of future climate change on heating and cooling). The demand of heating from new dwellings is based on the demand from existing dwellings corrected by exogenous factors ($DIFHEAT_{ct,d}$):

17	$$HEATDW_{ct,EXISTING,dt} = TEMPCOR_{ct} \cdot \sum_{strh}\left(Mapping\ RD\ AGE\ DW_{strh,EXISTING,dt} \cdot \frac{DEMAND\ DAT_{ct,strh}}{DWSTOCKSHARE\ IV_{ct,dt} \cdot DWSTOCKTOT_{ct} \cdot PRHEAT\ BY_{ct}}\right)$$ $$HEATDW_{ct,NEW,dt} = DIFHEAT_{ct,dt} \cdot HEATDW_{ct,EXISTING,dt}$$
18	$$HOTWDW_{ct,da,dt} = \sum_{strw}\left(Mapping\ RD\ AGE\ DW_{strw,da,dt} \cdot \frac{DEMAND\ DAT_{ct,strw}}{DWSTOCKSHARE\ IV_{ct,dt} \cdot DWSTOCKTOT_{ct} \cdot PRCOOL\ BY_{ct}}\right)$$
19	$$COOLDW_{ct,da,dt} = \sum_{strc}\left(Mapping\ RD\ AGE\ DW_{strc,da,dt} \cdot \frac{DEMAND\ DAT_{ct,strc}}{DWSTOCKBASE_{ct,dt}}\right)$$

Once the base year demands per dwelling are calculated the projections ($DEMDW_{ct,str}$) are derived as follows. For existing dwellings the energy demands are the result of multiplying the average demand of existing and new dwellings added in the previous period by the growth rate in energy demand. In the case of new dwellings, the current energy demand is calculated as the product of the demand in the previous period by the growth rate.

20	$$DEMDW_{ct,strh} = IF\ THEN\ ELSE\left(\begin{array}{c} Time = INITIAL\ TIME, \\ \sum_{da,dt}(HEATDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strh,da,dt}), \\ \frac{DEMDW\ DLY_{ct,strh} \cdot DWSTOCK\ DLY_{ct,EXISTING,dt} + DEMDW\ DLY_{ct,strh} \cdot DWSTOCK\ DLY_{ct,NEW,dt}}{DWSTOCK\ DLY_{ct,EXISTING,dt} + DWSTOCK\ DLY_{ct,NEW,dt}} \cdot GRHEATDW_{ct,strh}\end{array}\right)$$ $$DEMDW_{ct,strh}(new) = IF\ THEN\ ELSE\left(\begin{array}{c} Time = INITIAL\ TIME, \\ \sum_{da,dt}(HEATDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strh,da,dt}), \\ DEMDW\ DLY_{ct,strh} \cdot GRHEATDW_{ct,strh}\end{array}\right)$$
	$$DEMDW_{ct,strw}(existing) = IF\ THEN\ ELSE\left(\begin{array}{c} Time = INITIAL\ TIME, \\ \sum_{da,dt}(HOTWDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strw,da,dt}), \\ \frac{DEMDW\ DLY_{ct,strw} \cdot DWSTOCK\ DLY_{ct,EXISTING,dt} + DEMDW\ DLY_{ct,strw} \cdot DWSTOCK\ DLY_{ct,NEW,dt}}{DWSTOCK\ DLY_{ct,EXISTING,dt} + DWSTOCK\ DLY_{ct,NEW,dt}} \cdot GRHOTWDW_{ct,strw}\end{array}\right)$$ $$DEMDW_{ct,strw}(new) =$$

	$IF\ THEN\ ELSE\left(\begin{array}{c} Time = INITIAL\ TIME, \\ \sum_{da,dt}(HOTWDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strw,da,dt}), \\ DEMDW\ DLY_{ct,strw} \cdot GRHOTWDW_{ct,strw} \end{array}\right)$
	$DEMDW_{ct,strc} =$ $IF\ THEN\ ELSE\left(\begin{array}{c} Time = INITIAL\ TIME, \\ \sum_{da,dt}(COOLDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strc,da,dt}), \\ \frac{DEMDW\ DLY_{ct,strc} \cdot DWSTOCK\ DLY_{ct,EXISTING,dt} + DEMDW\ DLY_{ct,strc} \cdot DWSTOCK\ DLY_{ct,NEW,dt}}{DWSTOCK\ DLY_{ct,EXISTING,dt} + DWSTOCK\ DLY_{ct,NEW,dt}} \cdot GRCOOLDW_{ct,strc} \end{array}\right)$ $DEMDW_{ct,strc}(new) =$ $IF\ THEN\ ELSE\left(\begin{array}{c} Time = INITIAL\ TIME, \\ \sum_{da,dt}(COOLDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strc,da,dt}), \\ DEMDW\ DLY_{ct,strh} \cdot GRCOOLDW_{ct,strc} \end{array}\right)$
21	$DEMDW\ DLY_{ct,strh} =$ $DELAY\ DIXED\left(\begin{array}{c} DEMDW_{ct,strh}, \\ SAVEPER, \\ \sum_{da,dt}(HEATDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strh,da,dt}) \end{array}\right)$
	$DEMDW\ DLY_{ct,strw} =$ $DELAY\ DIXED\left(\begin{array}{c} DEMDW_{ct,strw}, \\ SAVEPER, \\ \sum_{da,dt}(HOTWDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strw,da,dt}) \end{array}\right)$
	$DEMDW\ DLY_{ct,strc} =$ $DELAY\ DIXED\left(\begin{array}{c} DEMDW_{ct,strc}, \\ SAVEPER, \\ \sum_{da,dt}(COOLDW_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strc,da,dt}) \end{array}\right)$

The growth rates of the demand of energy services per dwelling are calculated as the product of the driver, costs, and efficiency terms (and also by the change in the number of persons per dwelling in the case of the demand of how water):

22	$GRHEATDW_{ct,strh} = DRIVER\ TERM_{ct,strh} \cdot COST\ TERM_{ct,strh} \cdot EFFICIENCY\ TERM_{strh}$
23	$GRCOOLDW_{ct,strc} = DRIVER\ TERM_{ct,strc} \cdot COST\ TERM_{ct,strc} \cdot EFFICIENCY\ TERM_{strc}$
24	$GRHOTWDW_{ct,strw} =$ $DRIVER\ TERM_{ct,strw} \cdot COST\ TERM_{ct,strw} \cdot EFFICIENCY\ TERM_{strw} \cdot \left(1 + \frac{PERSHEV_{ct}}{100}\right)^{SAVEPER}$

The change in the number of persons per dwelling ($PERSHEV_{ct}$) is calculated as:

25	$PERSHEV_{ct} = 100 \cdot \left(\left(\frac{DWPERS_{ct}}{DWPERS\ DLY_{ct}}\right)^{\frac{1}{SAVEPER}} - 1\right)$

4.2.3 Total demand of energy services

The demand of residential heat, cooling and hot water is calculated by multiplying the demand per dwelling ($DEMDW_{ct,str}$) by the corresponding stock of dwellings ($DWSTOCK_{ct,da,dt}$). In all cases the residential demand is mapped to the different dwelling types and ages by a constant ($Mapping\ RD\ AGE\ DW_{str,da,dt}$) taking 1-0 values (mapped-not mapped).

2	$DEMAND\ EQU_{ct,strh} =$ $\frac{DEMDW_{ct,strh}}{TEMPCOR_{ct}} \cdot \sum_{da,dt} \left(DWSTOCK_{ct,da,dt} \cdot PRHEAT_{ct} Mapping\ RD\ AGE\ DW_{strh,da,dt}\right)$
	$DEMAND\ EQU_{ct,strw} =$ $DEMDW_{ct,strw} \cdot \sum_{da,dt} \left(DWSTOCK_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strw,da,dt}\right)$
	$DEMAND\ EQU_{ct,strc} =$ $DEMDW_{ct,strc} \cdot \sum_{da,dt} \left(DWSTOCK_{ct,da,dt} \cdot PRCOOL_{ct,da,dt} \cdot Mapping\ RD\ AGE\ DW_{strw,da,dt}\right)$

In the case of the demand of residential heat, the demand for the first year is corrected by a factor ($TEMPCOR_{ct}$) that accounts for observed deviations from average temperatures and the penetration of heating in dwellings ($PRHEAT_{ct}$). The demand for residential cooling takes into account the penetration of cooling in dwellings ($PRCOOL_{ct,da,dt}$), which depends on its previous value and the difference between the cooling penetration target and the initial value in the base year:

26	$PRCOOL_{ct,da,dt} =$ $PRCOOL\ DLY_{ct,da,dt} + \frac{\left(TARGCOOL_{ct} - PRCOOL\ BY_{ct,da,dt}\right)}{TARGYEARCOOL_{ct}}$
	$PRHEAT_{ct,da,dt} =$ $PRHEAT\ DLY_{ct,da,dt} + \frac{(TARGHEAT_{ct} - PRHEAT\ BY_{ct})}{TARGYEARHEAT_{ct}}$

2

5 Results

5.1 Economic and demographic assumptions

Gross domestic product is expected to grow from 17.33 B€2010 in 2010 to 31.02 B€2010 by 2050, according the economic projections assumed by IRENA's "Renewable Energy Roadmap for the Republic of Cyprus"[10].

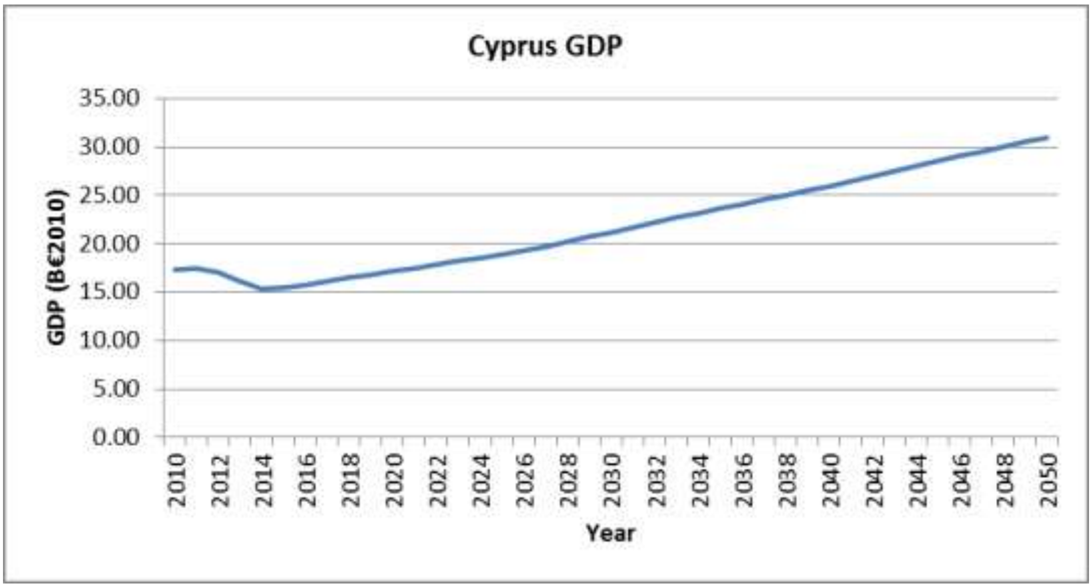

Figure 1: GDP projections

As regards population, it is expected to increase from 839800 inhabitants in 2010 to 888670 by 2050.

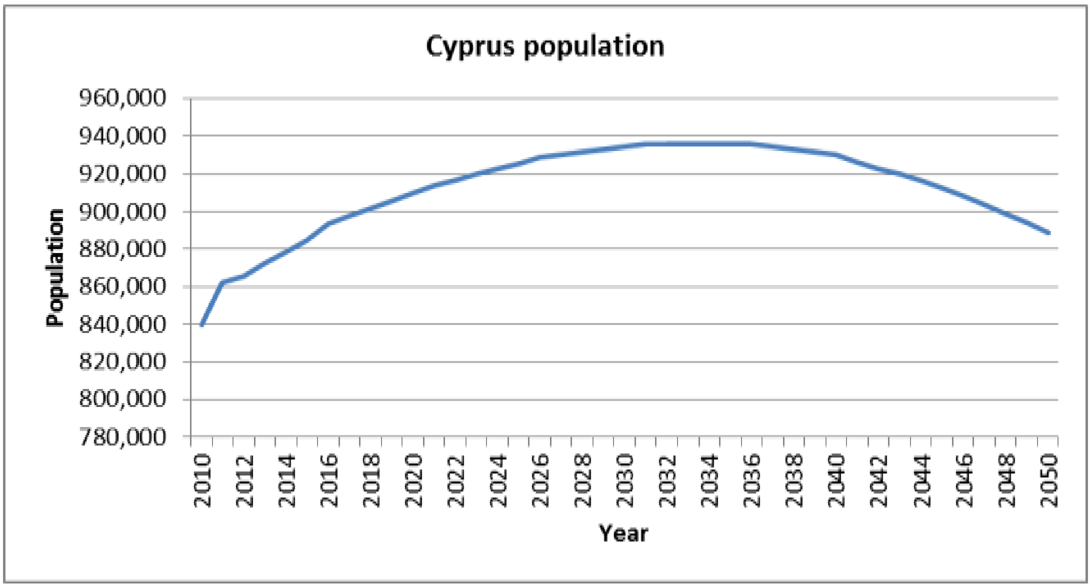

Figure 2: population projection

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10 http://www.irena.org/DocumentDownloads/Publications/IRENA_Cyprus_Roadmap_Report_2015.pdf

5.2 Industrial useful energy demand

The main energy consuming industry is the cement sector, which is assumed to increase its production from 0.86 Mt in 2013 to 1.18 Mt in 2050. This would translate into an useful energy consumption change from 2.85 PJ in 2013 to 3.92 PJ by 2050, assuming an energy intensity of 0.84 PJ/Mt throughout the projection period.

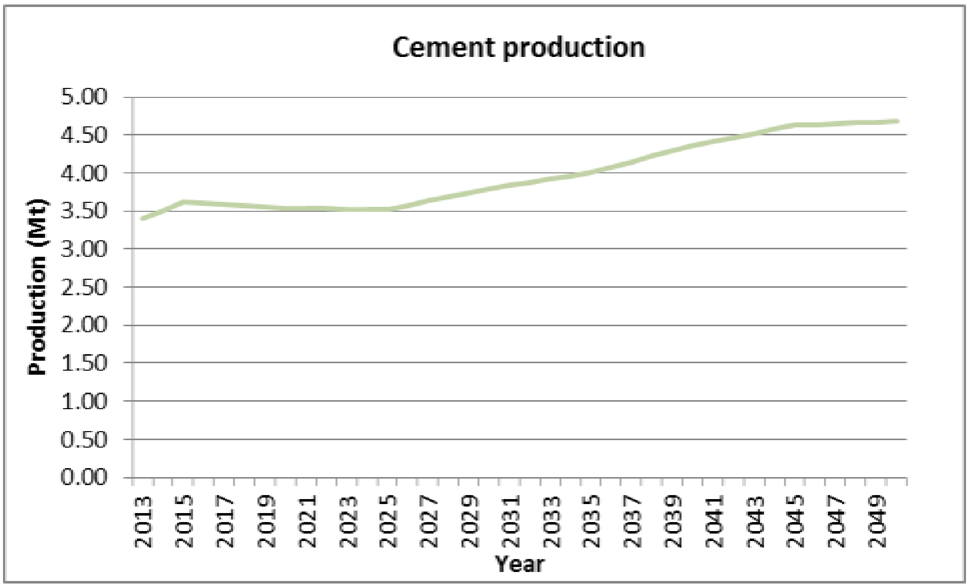


Figure 3: projected cement production

Other sectors with significant energy consumption would be the chemical industry, the non-metallic minerals sector (manufacturing of bricks), and other industries (small workshops). The later would increase 2.43 PJ in 2013 to 4.15 PJ by 2050. Energy consumption from the non-metallic minerals sector would change from 0.49 PJ to 0.67 PJ in the same period, while the chemical sector would increase from 0.19 PJ to 0.33 PJ.

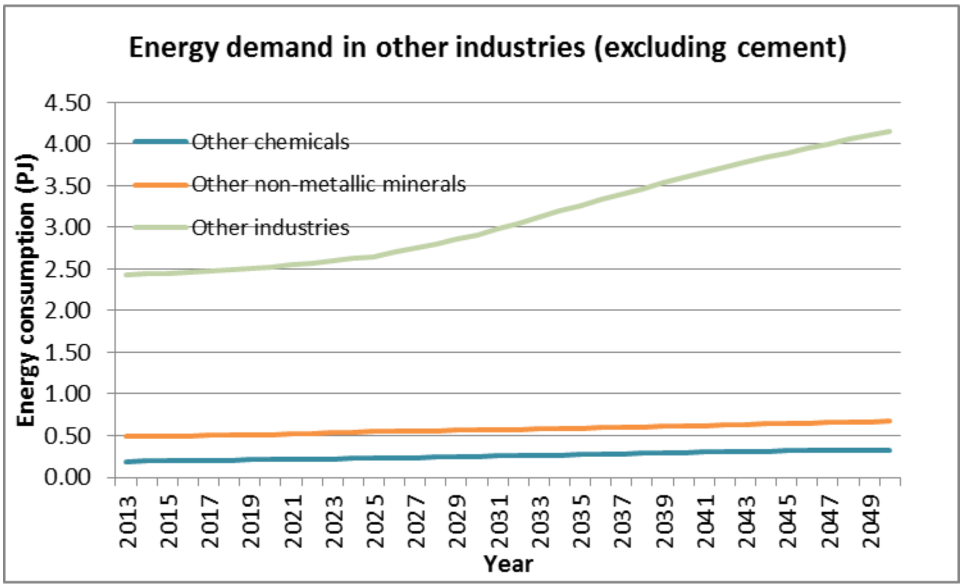
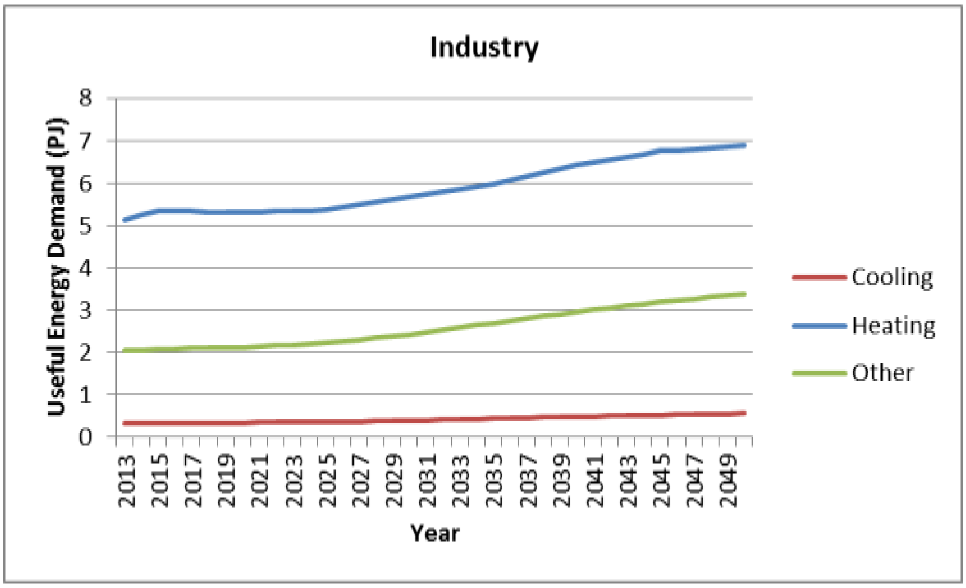


Figure 4: energy demand projections

Heating and other applications would be main industrial energy uses throughout the whole projection period, changing respectively from 5.15 PJ in 2013 to 6.89 PJ in PJ, and from 2.04 PJ to 3.89 PJ.



5.3 Residential energy demand

Residential energy demand is driven by the evolution of the dwelling stock and the expected occupancy rate per dwelling. This rate would decrease from 2.88 persons per dwelling in 2013 to 2.69 by 2050.

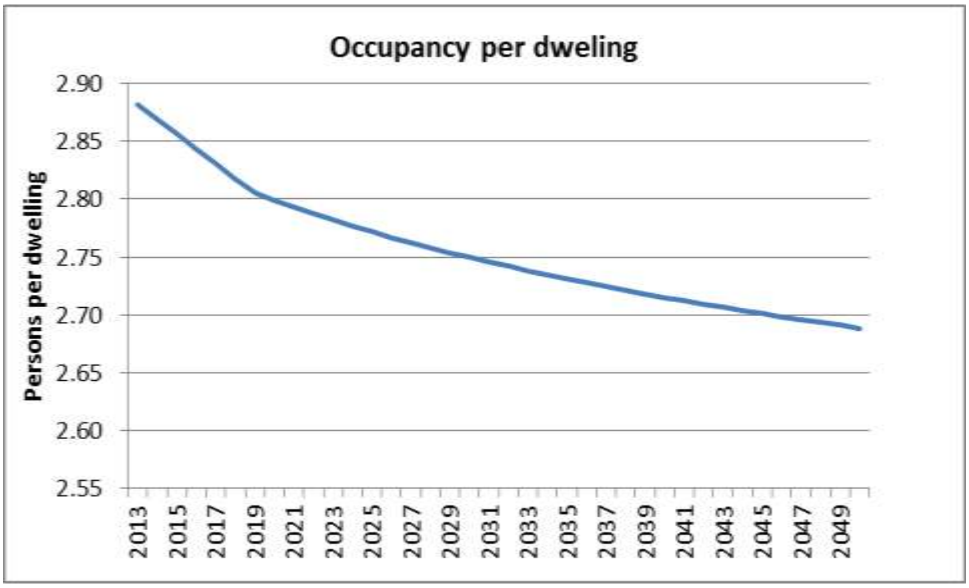


Figure 5: expected occupancy per dwelling

As regards the dwelling stock by the end of the year, it would increase from 302692 dwellings in 2013 to 330522 in 2050.

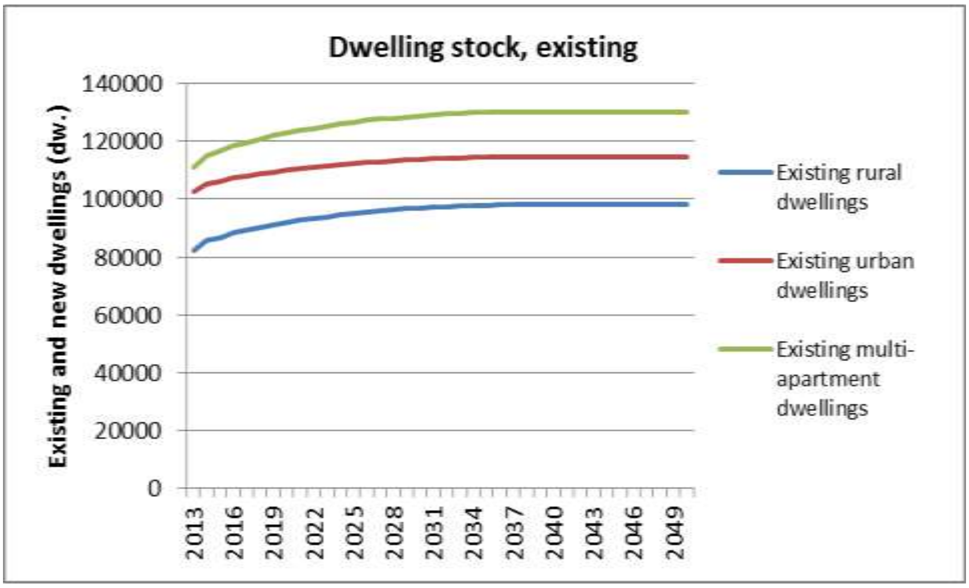


Figure 6: number of dwellings at the end of the year

Assuming a yearly demolition rate of 0.00025 % of stock at the end of the previous year, the amount of demolished dwellings would increase from 75 to 85.

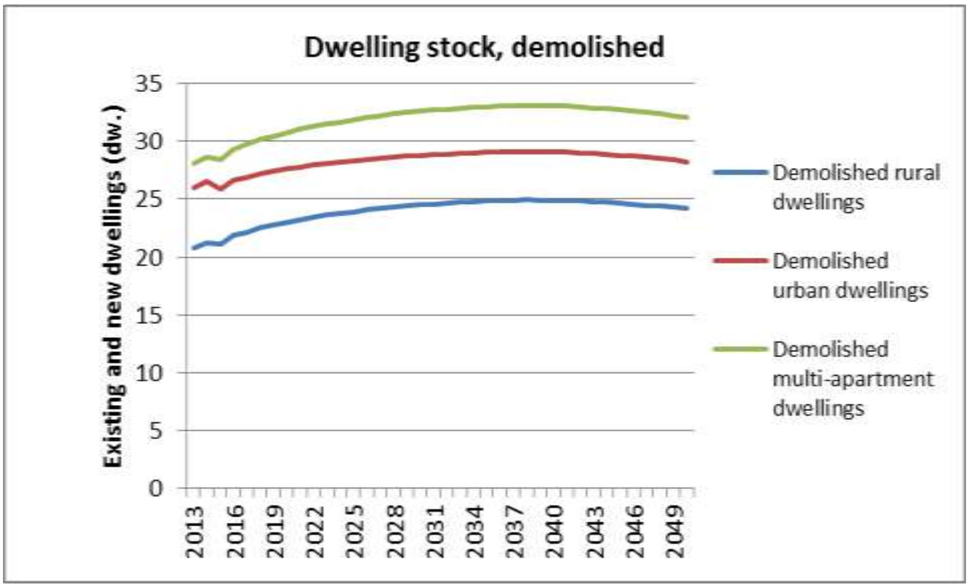


Figure 7: dwellings demolished during the year

New additions to the dwelling stock would therefore increase from 1995 in 2013 to 85 by 2050.

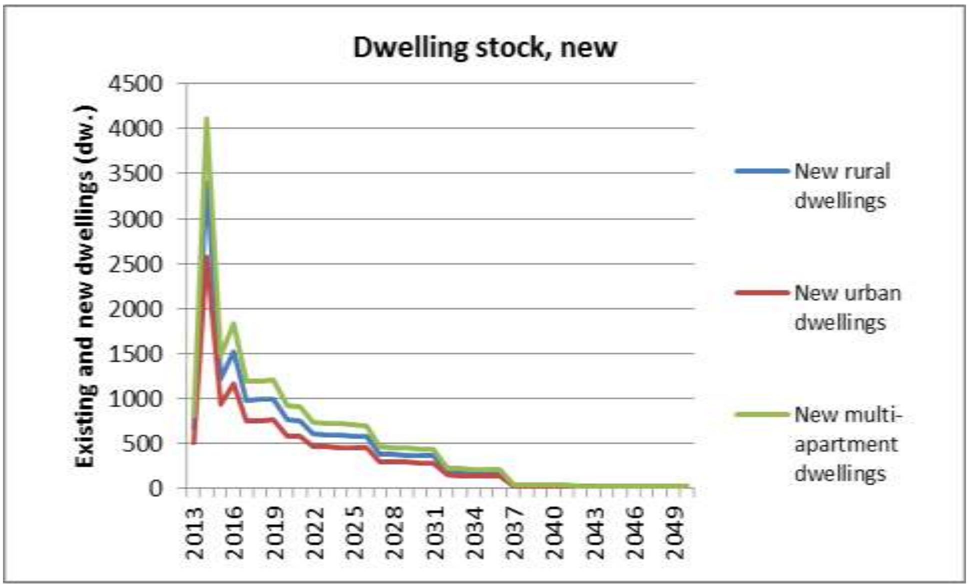


Figure 8: new dwellings

Total energy for residential uses would increase from 15.99 PJ in 2013 to 24.27 PJ in 2050. Demand from new dwellings would be negligible, according the assumptions used. Most of the energy would be used for cooling, varying from 6.06 PJ in 2013 to 12.85 PJ in 2050.

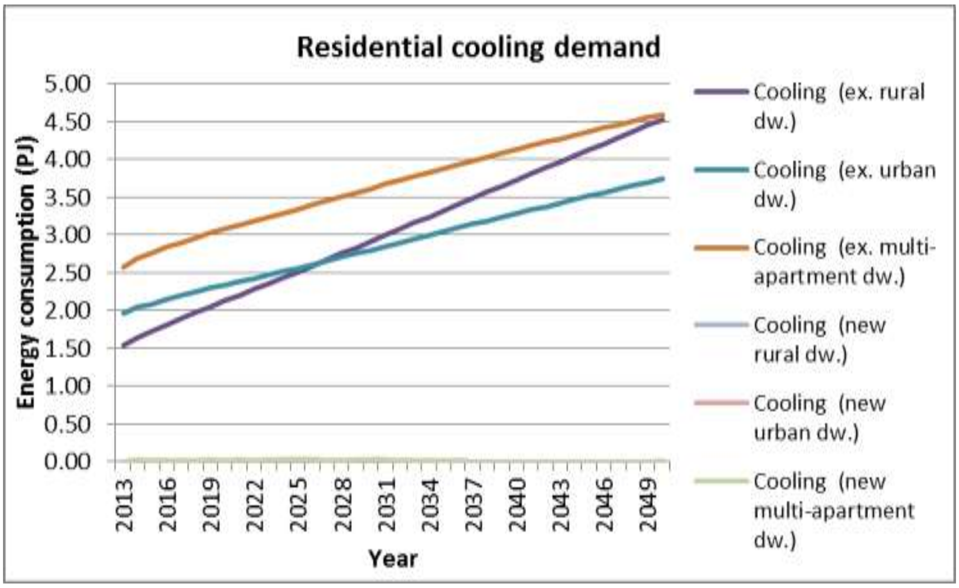


Figure 9: residential cooling demand

The second most important use would be heating, which would increase from 5.19 PJ in 2013 to 5.96 PJ in 2050.

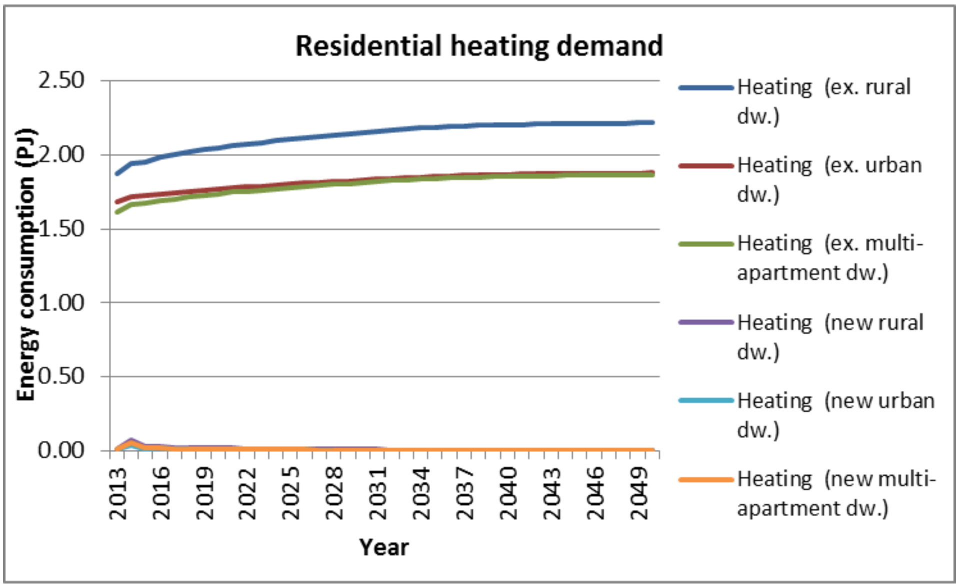


Figure 10: residential heating demand

Energy demand for hot water would increase from 1.88 PJ in 2013 to 2.23 PJ in 2050.

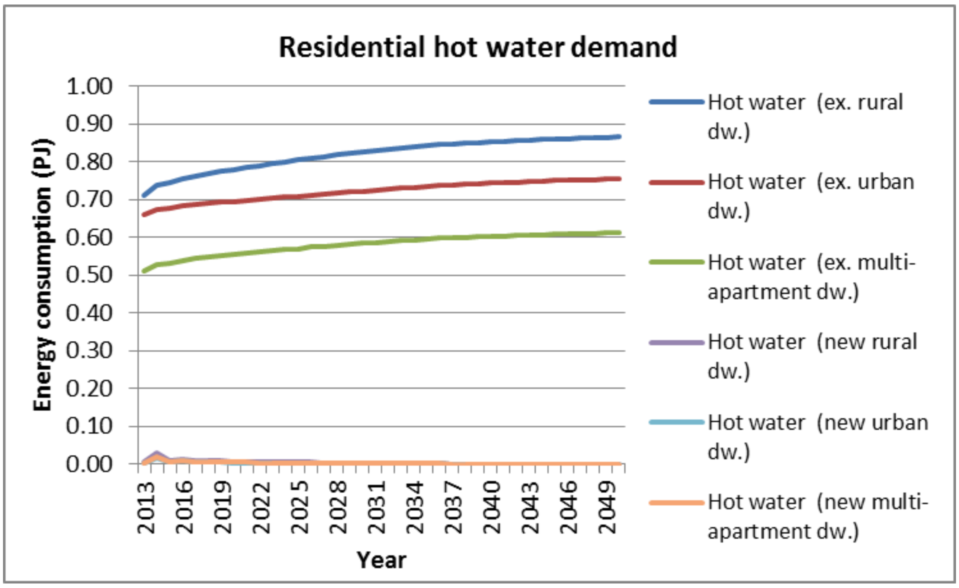


Figure 11: residential hot water demand

Energy demand for lighting and appliances would increase from 2.84 PJ in 2013 to 3.21 PJ in 2050.

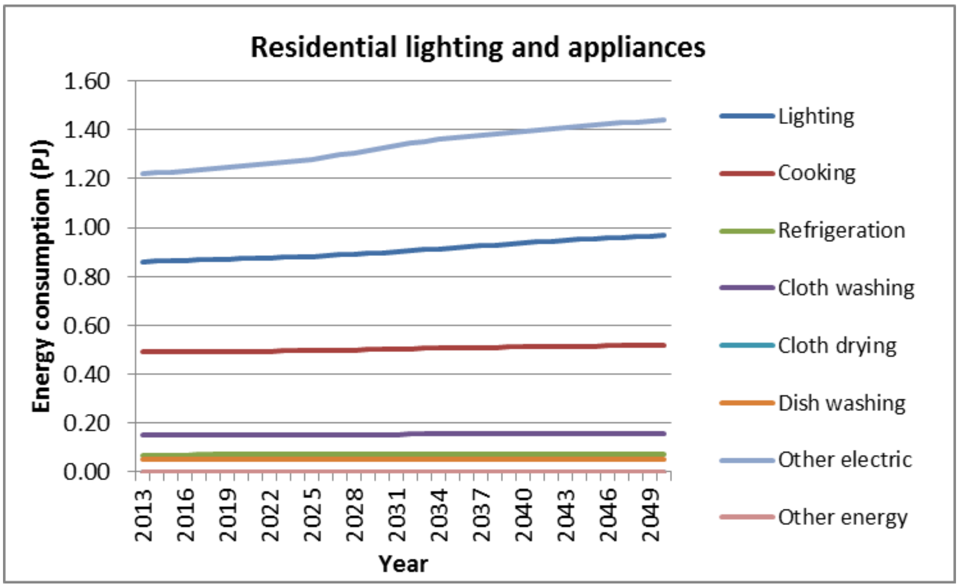
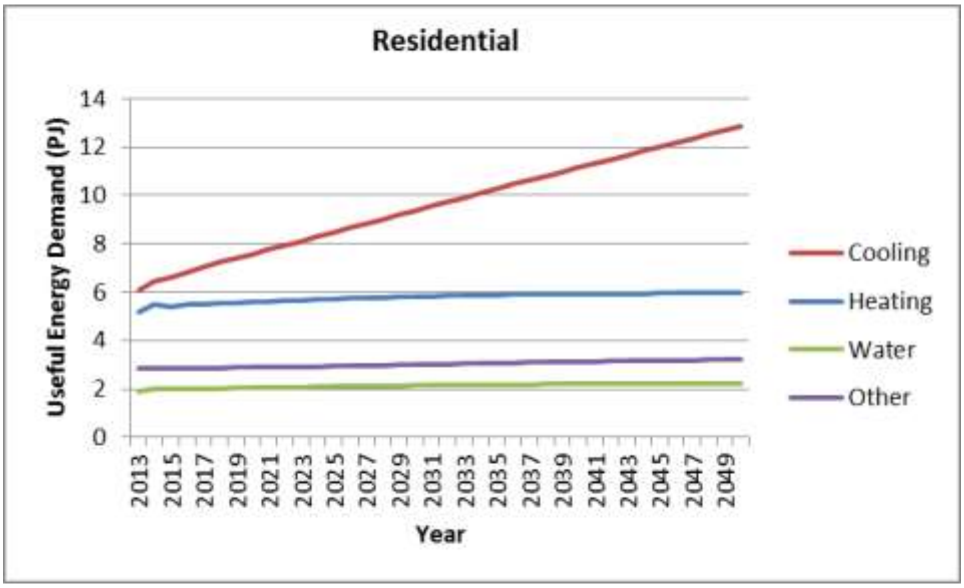


Figure 12: residential demand from lighting and use of appliances

During the simulation period all residential energy uses are expected to increase very moderately, except cooling which would roughly double from 6.06 PJ in 2013 to 12.86 PJ in 2050.



5.4 Commercial energy demand

In the commercial sector, energy use would grow from 12.16 PJ in 2013 to 15.35 PJ in 2050. Most of that energy would be consumed for cooling, changing from 5.85 PJ in 2013 7.49 PJ in 2050.

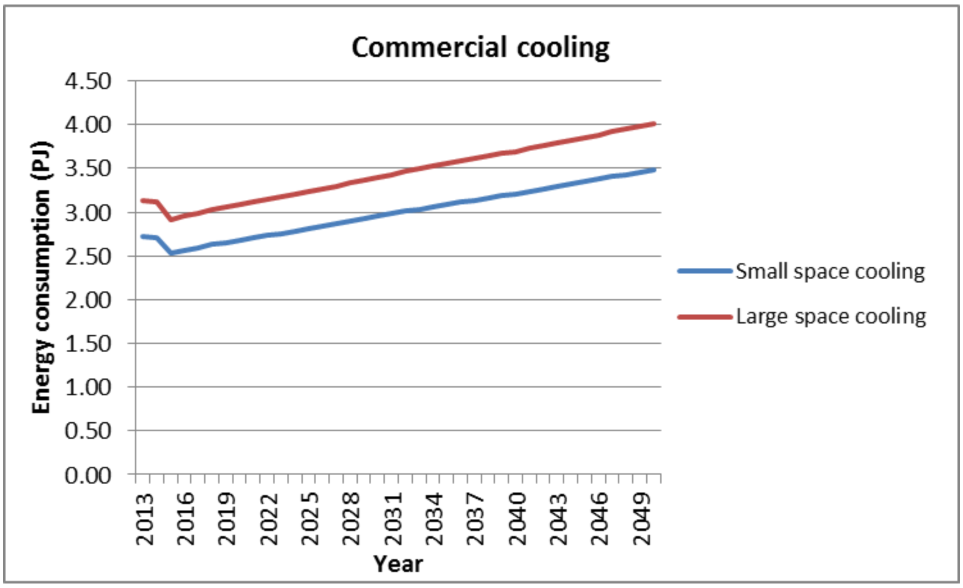


Figure 13: commercial demand for cooling

Lighting and other services would the second most important use, increasing from 3.35 PJ in 2013 4.49 PJ in 2050.

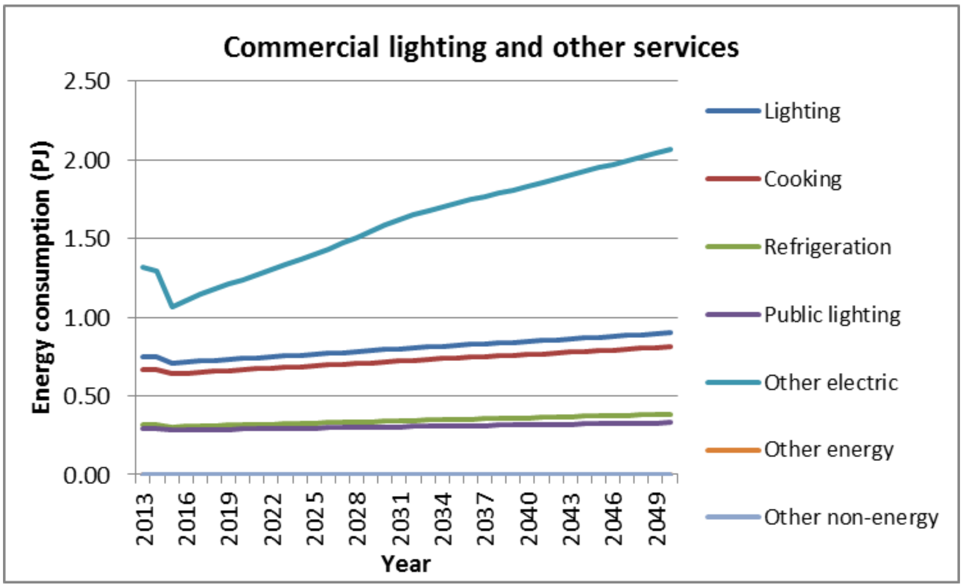


Figure 14: commercial demand for lighting and other services

Commercial heating would change from 2.24 PJ in 2013 to 2.51 PJ in 2050.

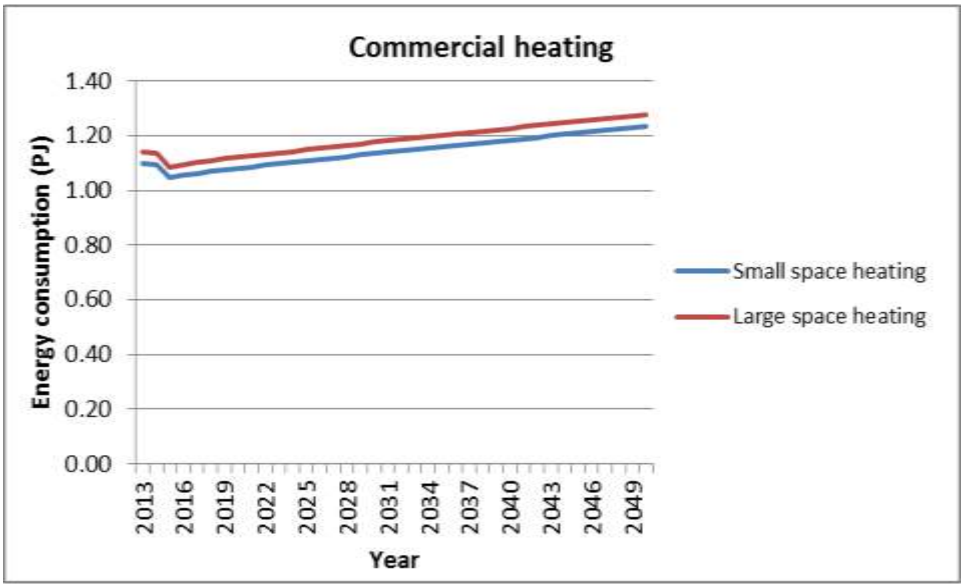


Figure 15: commercial demand for heating

Commercial hot water demand would slightly increase, from 0.72 PJ in 2013 0.86 PJ in 2050.

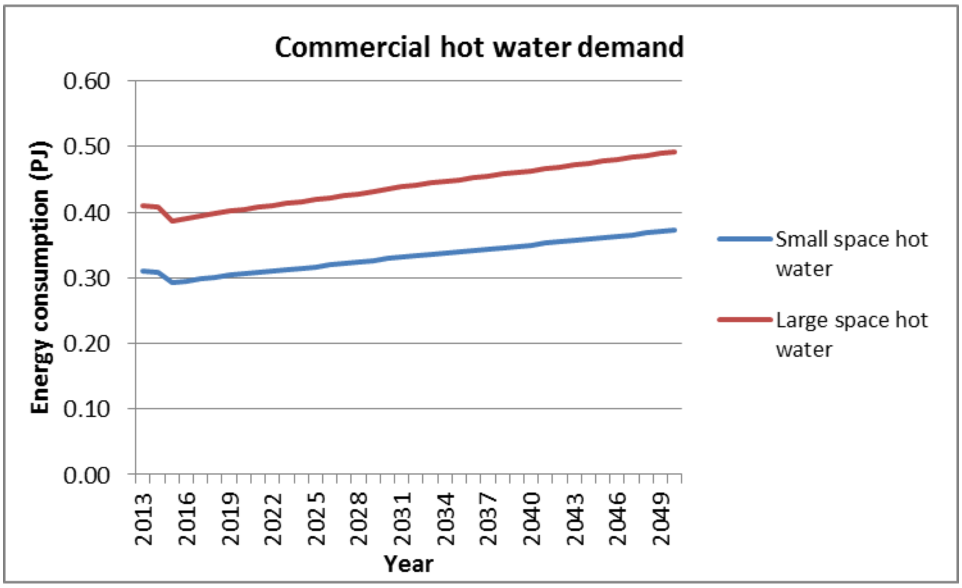
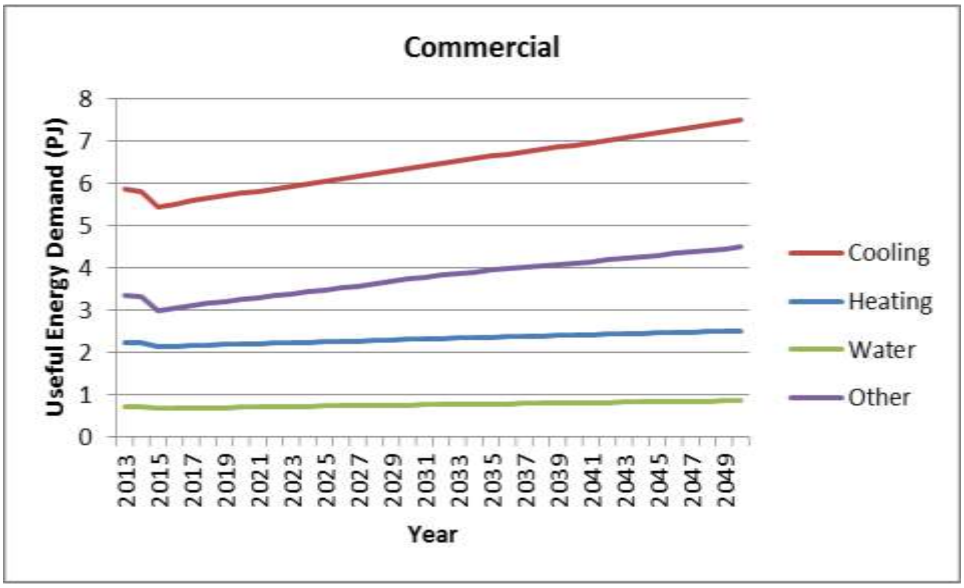


Figure 16: commercial hot water demand

As in the case of the residential sector, cooling would be the energy use experiencing the most significant growth during the simulation period, increasing from 5.85 PJ in 2013 to 7.49 PJ in 2050.



5.4 Agriculture

Energy use in the agricultural sector would remain virtually constant around 1.44 PJ throughout the whole simulated period.

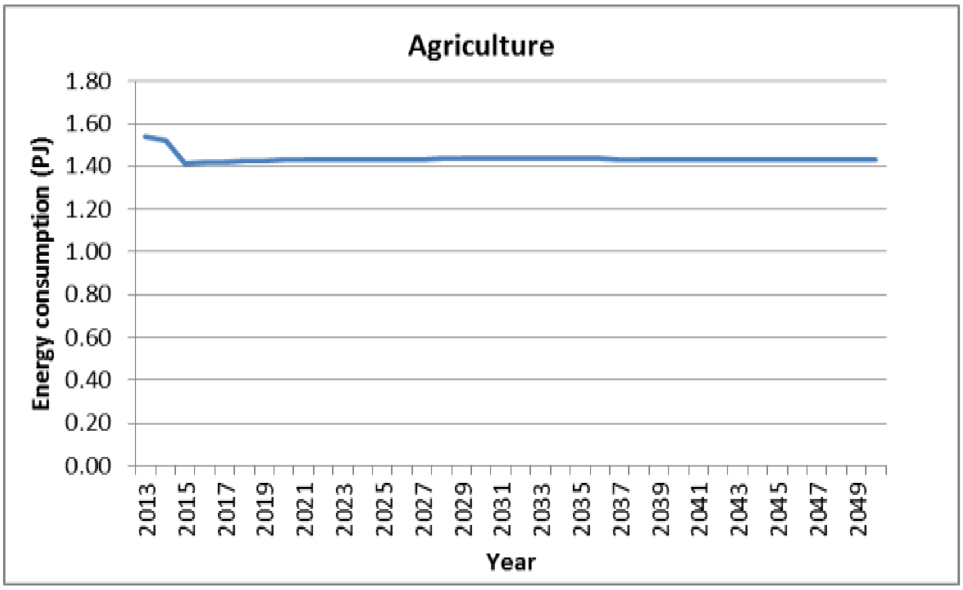


Figure 17: demand from agriculture

6 References

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