Workshop - C2: Cyber-physical System Modeling using Modelica for Smart and Sustainable Communities

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Tutorial 1: Smart and Connected Community Library

The objective is to understand what a smart and connected community (SCC) is and how different infrastructures are related. This will be accomplished through modeling in the equation-based object-oriented language Modelica. The following open source libraries will be used in this tutorial:

Modelica Buildings Library (version 5.0.0)¹

Smart and Connected Community Library (version $1.1)^2$.

At the end of this workshop, you will be more familiar with the SCC library through an energy system example, and an energy and transportation system example. This guide has step-by-step instructions to accomplish these goals. Dymola 2020 in Linux system was used to create this tutorial.

Step-by-Step Guide

Example 1 will demonstrate how to use the energy system model within the SCC library.

1. Load the SCC library wherever it is stored on your system.

	<u>F</u> ile	Ed	it s	imula	ation	Plo	ot 🥖	<u>I</u> nima	tion	C	omm	ands	5 <u>W</u>	indo	w	<u>H</u> elp	Lir	neai	r ar	naly	sis
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2. Create a new model File > New > Model or Crtl+Shift+M.

<u>F</u> ile	<u>E</u> dit	Simulation	n <u>P</u> lot	Animatio	n <u>C</u> omma	ands _	<u>W</u> indow	<u>H</u> elp	Linear	analysis	
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¹ <u>https://simulationresearch.lbl.gov/modelica/downloads/archive/modelica-buildings.html</u>

² <u>https://www.colorado.edu/lab/sbs/scc-library</u>

3. Fill in model information and click OK.

Create New Model
Name:
EnergySystemTutorial
Description:
Example model that demonstrates the tutorial for the energy system within the SCC library.
Partial
Extends:
Insert in package:
· ₩ D
Open new class in:
New tab
Cancel OK

 Insert EnergyDistribution Block from the Package browser. Click on EnergyDistribution and drag into the diagram area. Your model should now look like this.



5. Rename energyDistribution block: Double click on energyDistribution block and fill in information like below.

					ге	sBlo ir	n Ener	gySyst	emTutorial				
General	Supply	Demand	Line	Battery	A	dd modi	fiers	Attribu	tes				
Component													Icon
Name	resBlo												
Comment	Resider	ntial block											Energy
Model													
Path	MultiInf	rastructure.0	CaseStud	y.EnergyS	Systen	n.BaseC	lasses	EnergyD	istribution				
Comment	Model o	f power sup	ply and o	lemand									
Parameters													
									10000	⊧ v		Nominal voltage(V_nom	ninal>=0)
V_nomina													
V_nomina f									60	► H	z	Nominal grid frequency	
V_nomina f lat									60	• H	z	Nominal grid frequency Latitude	

It is a good idea to add comments for future users to know what your component is. The grey values are default parameters that you can change.

					resBlo i	in Ener	rgySyster	nTuto	rial	
General Sup	oly Dem	and	Line	Battery	Add mod	difiers	Attribute	s		
٧s										
А							2	0000		Net surface area of PV
VPV_nominal								480	v	Nominal voltage of PV (VPV_nominal >= 0)
PV_nominal							-PLoa_no	ninal	W	Nominal power of PV panels
Vind Turbines										
VWin_nominal							480 • V	N	ominal	voltage of wind turbine (VWin_nominal >= 0)
PWin nominal					DI		ninal W	N	ominal	power pf the wind turbine
					resBlo	in Enei	rgySyste	nTuto	orial	
General Sup	oly Dem	and	Line	Battery	resBlo	in Ener	rgySyste Attribut	nTuto es	orial	
General Sup Parameters	oly Dem	and	Line	Battery	resBlo	in Ener	rgySyste Attribut	nTuto 95	orial	
General Sup Parameters PLoa_nominal	ply Dem PBb	and	Line nal + PE	Battery	resBlo Add mo	in Ener difiers	rgySyste Attribut	mTuto es minal perate	orial	of demand load (negative if consumed, positiv
General Sup Parameters PLoa_nominal PBb_nominal	ply Dem	and	Line nal + PE	Battery	resBlo Add mo	in Ener difiers	Attribut W No W No W No	mTuto es minal j herate minal j eneral	prial	of demand load (negative if consumed, positiv of building blocks (negative if consumed, posit
General Sup Parameters PLoa_nominal PBb_nominal PEv_nominal	PBb	and	Line nal + PE	Battery	resBlo Add mo al + PCt_nom -1500	in Ener difiers	rgySyste Attribut W ge W No W if ç W ge	mTuto es minal p merate minal p enerat minal p enerate	orial oower (d) oower (ed) oower (d)	of demand load (negative if consumed, positiv of building blocks (negative if consumed, posit of EV charging (negative if consumed, positive
General Sup Parameters PLoa_nominal PBb_nominal PEv_nominal PCt_nominal	PBb	and	Line	Battery	resBlo Add mo Add mo I + PCt_nom -1500 -70	in Ener difiers	rgySyste Attribut W No W No W No W No W No W No W No W No	mTuto es minal perate minal perate minal perate minal perate minal perate	orial oower (d) oower (ed) oower (d) oower (f gener	of demand load (negative if consumed, positiv of building blocks (negative if consumed, posit of EV charging (negative if consumed, positive of communication towers (negative if consume ated)
General Sup Parameters PLoa_nominal PBb_nominal PEv_nominal PCt_nominal	PBb	and	Line nal + PE	Battery	resBlo Add mo al + PCt_nom -1500 -70	in Ener difiers	rgySyste Attribut W ge W No No W ge W No No Po	mTuto es minal perate minal peneral minal perate minal pitive i	orial bower (d) bower (ced) bower (d) bower (f gener	of demand load (negative if consumed, positiv of building blocks (negative if consumed, posit of EV charging (negative if consumed, positive of communication towers (negative if consume ated)

eneral	Supply	Demand	Line	Battery	Add modifiers	Attributes			
rameter	rs								
I						200	•	m	Length of the main line in the energy model
1						200	•	m	Length of the line 1 in the energy model
2						200	0	m	Length of the line 2 in the energy model

Click the arrow, Edit Text, then enter the following:

redeclare

MultiInfrastructure.Buildings.Electrical.Transmission.MediumVoltageCables.Annealed_ Al_10 commercialCable

				-	resBlo in Ener	rgySystemT	utorial		
General	Supply	Demand	Line	Battery	Add modifiers	Attributes			
SOC_star	t						0.5		Initial charge
EMax							1.8e10 🕨	J	Maximum available charge
betDis							0.5 🕨		Discharging velocity coefficient
betCha							1)		Charging velocity coefficient
thrDis							-1.2e6 🕨	w	Discharging power threshold
thrCha							-7e5 🕨	w	Charging power threshold

Click OK at the bottom once all of the parameters have been changed.

6. Add in weather data.



Double click on weaDat and change the information as seen below.

		weaD	at in Ene	ergySy	stemTutorial		
General Add n	odifiers Attributes						
Component							Icon
Name weat	at						
Comment Wea	her data model						Rea
Model							
Path Multi	nfrastructure.Buildings.Bound	aryConditions.WeatherData.Read	lerTMY3				E
Comment Read	er for TMY3 weather data	-					
Parameters							-
computeWetBul	Temperature				false 🔻 🕨	If true, then this model computes the wet be	ulb temperature
filNam						Name of weather data file	
Data source							
pAtmSou	Buildings.Bou	ndaryConditions.Types.DataSourc	ce 🔻 🕨		Atmospheric pressu	ıre	
pAtm		1.0)1325 b	bar	Atmospheric pressu	re (used if pAtmSou=Parameter)	
ceiHeiSou	Buildings.Bou	ndaryConditions.Types.DataSourc	ce 🔻 🕨		Ceiling height		
ceiHei		2	20000) n	m	Ceiling height (used	d if ceiHei=Parameter)	
totSkyCoySou	Buildings Bou	ndaryConditions Types DataSourc			Total sky cover		

To load the weather file, click on the grey table icon called "edit". This will pull up a screen where you can choose the weather file.

Resources > WeatherData > USA_CA_San.Francisco.Intl.AP.724940_TMY3.mos

Click open and now your screen should look like this.

		weaD	at in Ei	nergyS	ystemTutorial	
General Add modi	ifiers Attr	ibutes				
Component					Icon	
Name weaDat						
Comment Weather	r data model				Rea.	
lodel						\sim
Path MultiInfra	astructure.B	ildings.BoundaryConditions.WeatherData.Read	erTMY3			
Comment Reader f	or TMY3 wea	ther data				
arameters						
computeWetBulbTe	emperature				false -> If true, then this model computes the wet bulb temperature	e
filNam		Resources/WeatherData/USA_CA_San.Francisco	o.Intl.AP	.724940	0_TMY3.mos") 📰 > Name of weather data file	
ata source						
pAtmSou		Buildings.BoundaryConditions.Types.DataSourc	ce 🔹 🕨		Atmospheric pressure	
pAtm		1.0	1325)	bar	Atmospheric pressure (used if pAtmSou=Parameter)	
ceiHeiSou		Buildings.BoundaryConditions.Types.DataSourc	ce 🔹 🕨		Ceiling height	
ceiHei		2	• 0000	m	Ceiling height (used if ceiHei=Parameter)	
totSkyCovSou		Buildings.BoundaryConditions.Types.DataSourc	ce 🔻 🕨		Total sky cover	
totSkyCov			0.5	1	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1	
totSkyCov opaSkyCovSou		Buildings.BoundaryConditions.Types.DataSourc	0.5) ce •)	1	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1 Opaque sky cover	
totSkyCov opaSkyCovSou opaSkyCov		Buildings.BoundaryConditions.Types.DataSourc	0.5 • ce • •	1	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1 Opaque sky cover Opaque sky cover (used if opaSkyCov=Parameter). Use 0 <= opaSkyCov <= 1	
totSkyCov opaSkyCovSou opaSkyCov TDryBulSou		Buildings.BoundaryConditions.Types.DataSource Buildings.BoundaryConditions.Types.DataSource	0.5) ce •) 0.5) te •)	1	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1 Opaque sky cover Opaque sky cover (used if opaSkyCov=Parameter). Use 0 <= opaSkyCov <= 1 Dry bulb temperature Dry bulb temperature	
totSkyCov opaSkyCovSou opaSkyCov TDryBulSou TDryBul TDowReiGeu		Buildings.BoundaryConditions.Types.DataSourc Buildings.BoundaryConditions.Types.DataSourc	0.5) ce •) 0.5) ce •) 20)	1 1 °C	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1 Opaque sky cover Opaque sky cover (used if opaSkyCov=Parameter). Use 0 <= opaSkyCov <= 1 Dry bulb temperature Dry bulb temperature (used if TDryBul=Parameter) Deu noiet temperature	
totSkyCov opaSkyCovSou opaSkyCov TDryBulSou TDryBul TDewPoiSou TDewPoiSou		Buildings.BoundaryConditions.Types.DataSourd Buildings.BoundaryConditions.Types.DataSourd Buildings.BoundaryConditions.Types.DataSourd	0.5) 0.5) ce •) 20) ce •)	1 1 °C	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1 Opaque sky cover Opaque sky cover (used if opaSkyCov=Parameter). Use 0 <= opaSkyCov <= 1 Dry bulb temperature Dry bulb temperature (used if TDryBul=Parameter) Dew point temperature (used if TDryBul=Parameter)	
totSkyCov opaSkyCovSou opaSkyCov TDryBulSou TDryBul TDewPoiSou TDewPoi TBlaSkySou		Buildings.BoundaryConditions.Types.DataSourd Buildings.BoundaryConditions.Types.DataSourd Buildings.BoundaryConditions.Types.DataSourd Buildings.BoundaryConditions.Types.DataSourd	0.5) 0.5) 0.5) 20) 20) 20) 20) 20) 20) 20)	1 °C °C	Total sky cover (used if totSkyCov=Parameter). Use 0 <= totSkyCov <= 1 Opaque sky cover Opaque sky cover (used if opaSkyCov=Parameter). Use 0 <= opaSkyCov <= 1 Dry bulb temperature Dry bulb temperature (used if TDryBul=Parameter) Dew point temperature (used if TDewPoi=Parameter) Blark-hody sky temperature	

Click OK.

7. Add latitude to resBlo: Double click on resBlo. Now that we have added in the weather data, we can add more information to the resBlo *lat* (Latitude) parameter. Type weaDat.lat into the *lat* parameter box and click OK.

					resBlo in Ene	ergySystemT	Tutorial		_	_	
General	Supply	Demand	Line	Battery	Add modifiers	Attributes					
omponent											con
Name	resBlo										
Comment	Residen	tial block									Energy
Iodel											
1odel Path Comment	MultiInfr Model of	astructure.C f power supp	aseStud ly and d	y.EnergySy emand	stem. Base Classe	s.EnergyDistri	bution				
1odel Path Comment arameters	MultiInfr Model of	astructure.C f power supp	aseStud ly and d	y.EnergySy emand	stem. Base Classe	s.EnergyDistri	bution				
Model Path Comment Parameters V_nominal	MultiInfr Model of	astructure.C f power supp	aseStud ly and d	y.EnergySy emand	stem.BaseClasse	s.EnergyDistri	bution	v	Nominal voltage(V	√_nomina	al>=0)
4odel Path Comment Parameters V_nominal f	MultiInfr Model of	astructure.C	aseStud: ly and d	y.EnergySy emand	stem.BaseClasse	s.EnergyDistri	10000 ► 60 ►	V Hz	Nominal voltage(\ Nominal grid frequ	V_nomina uency	al>=0)
Aodel Path Comment Parameters V_nominal f lat	MultiInfr Model of	astructure.C	aseStud	y.EnergySy emand	stem.BaseClasse	s.EnergyDistri	10000) 60) aDat.lat	V Hz rad	Nominal voltage(\ Nominal grid frequ Latitude	V_nomina uency	al>=0)

8. Connect weaDat and resBlo: You can see that weaDat and resBlo each have a yellow bus which can be connected. Click on the weaDat bus and drag it to connect with the resBlo bus. The location of the connection line is not that important, however, it is good practice to have the connection lines align with the grid lines.



9. Add the grid for electricity. Click on the Grid component and drag it into your model. Your screen should now look like this.



Double click on gri and edit the parameters f and V.

	_	gr	i in Energys	ystem Tut	orial	-		
General	Add modifiers	Attributes						
Componen	nt						Ico	n
Name Commer	gri Grid							Grid
4odel		uro Buildings	Electrical AC	ThreePhace	sBalanc	and Sources G	rid	
Path Commen	MultiInfrastruct nt Electrical grid	ure.buildings.	.Electrical.Ac	Theernase	Sbalant	eu.sources.or		
Path Commen Parameter	MultiInfrastruct nt Electrical grid 's	ure.buildings.	.Electrical.Ac	meernase	bulanc			

Now we need to define f and V. Since these parameters are also used in other components at the system level, they are considered system-level parameters.

This whole time we have been editing our model in the graphical representation called **Diagram**.

Models can also be edited in text mode called Modelica Text.

🚍 File Edit Simulation Plot Animation Commands Window Help Linearanalysis

Click on Modelica Text. The beginning lines of the text should be changed to the following.

```
model EnergySystemTutorial
    "Example model that demonstrates the energy system tutorial within the SCC library"
    extends Modelica.Icons.Example;
    parameter Modelica.SIunits.Voltage V_nominal = 10000 "Nominal grid voltage";
    parameter Modelica.SIunits.Frequency f = 60 "Nominal grid frequency";
```

These lines give the model an icon in the left panel and also define V_nominal and f.

extends Modelica.Icons.Example; parameter Modelica.SIunits.Voltage V_nominal = 10000 "Nominal grid voltage"; parameter Modelica.SIunits.Frequency f = 60 "Nominal grid frequency";

Switch back to **Diagram**. Again we see that the Grid (gri) and resBlo have matching connectors (electrical terminals), both green. Now, click on the green connector on gri and connect it to resBlo. Your model now should look like this.



10. Add in building demand profiles for resBlo. Add in the CombiTimeTable to your model by clicking and dragging.



Double click on combiTimeTable to change some of the information.

Now we will load the building profile information. This data comes from the DOE Commercial Reference Buildings Models and Building America House Simulation Protocols. Fill out *tableOnFile* and *tableName* as seen below. To access the *fileName*, click the Edit button at the end of the line for table.

powBuiAllRes in Multiinfrastructure.CaseStudy.EnergySystem.Tutorial	8
General Add modifiers Attributes	
Component	Icon
Name powBuiAllRes	
Comment Power profile for all of the buildings in the residential building block	CombiTime
Model	
Path Modelica.Blocks.Sources.CombiTimeTable	
Table data definition	
tableOnFile true v = true, if table is defined on file or in tableOnFile 0 3119, -139018 1881; 23, -37865 276, -80807.46526, -116633 5399; 24, -31642 24665, -65489.46691, -93547.60327] III > Table matrix (time = first column; e. tableName Table fileName rces.loadResource(*modelica://MultiInfrastructure/Resources/Input/CaseStudy/EnergySystem/Tutorial/powBulAIRes.txt*) III verboseRead true v = true, if info message that file is loa	I function usertab g., table=[0, 0; 1, 1; 2, 4]) rtab (see docu) ading is to be printed
columns 2:size(table, 2) III > Columns of table to be interpolated	time y[1] y[2]
smoothness Modelica.Blocks.Types.Smoothness.Linear - Smoothness of table interpolation	
extrapolation delica.Blocks.Types.Extrapolation.Periodic 🔹 Extrapolation of data outside the definition range	
timeScale 3600 s Time scale of first table column	
offset (0) 顧 > Offsets of output signals	
startTime Output = offset for time < startTime	
shiftTime startTime s Shift time of first table column offset	columns
Info	Cancel OK

To open the proper txt file in *fileName*, go to:

Resources>Input>CaseStudy>EnergySystem>Tutorial>powBuiAllRes.txt

Then also fill in *extrapolation* and *timeScale* as seen above. Click OK.

11. Connect powBuiAllRes to resBlo using a script. Models in lower-level packages within the Energy System require 12 building loads connected to the resBlo. Instead of drawing 12 connections and picking the correct columns of data to use for each component, we will write a script to do that for us.

Click on Modelica Text. Add the following to the equation section.

Now, even if the connections are not shown via a line, they are connected via equations.

12. Add in electric vehicle (EV) charging profile. Drag another CombiTimeTable into your model like seen in step 10. The model path is Modelica.Blocks.Sources.CombiTimeTable. Double click on the table and fill in your information like so:

		nEv in MultiInfrastructure.CaseStudy.EnergySystem.Tutorial	8				
General Add mod	ifiers Attributes						
Component			Icon				
Name nEv							
Comment Number	of EV charging profile for a residential building block		CombiTime				
Model							
Path Modelica	a.Blocks.Sources.CombiTimeTable						
Comment Table loo	ok-up with respect to time and linear/periodic extrapol	ation methods (data from matrix/file)					
Table data definition			<u> </u>				
tableOnFile		true V	= true, if table is defined on file or in function usertab				
tableName	Table mark (time = trist coumning = table=(0, 0; 1, 1; 2, 4))						
fileName	nalReferences.loadResource("modelica://MultiInfr	structure/Resources/Input/CaseStudy/EnergySystem/Tutorial/nEv.txt") 🔢 🕨	File where matrix is stored				
verboseRead		true 🗸 🕨	= true, if info message that file is loading is to be printed				
Table data interpreta	tion						
columns	2:size(table, 2)	Columns of table to be interpolated	Y time (11) (21)				
smoothness	Modelica.Blocks.Types.Smoothness.Linear	Smoothness of table interpolation					
extrapolation	delica.Blocks.Types.Extrapolation.Periodic -	Extrapolation of data outside the definition range					
timeScale	3600	s Time scale of first table column					
offset	{0} II >	Offsets of output signals					
startTime	•	S Output = offset for time < startTime					
shiftTime	startTime	Shift time of first table column	offset				
			UNISCL V				
Info			Cancel OK				

Double click the Edit button at the end of the *fileName* parameter. Go to: Resources>Input>CaseStudy>EnergySystem>Tutorial>nEV.txt

Now the number of EVs charging should be loaded. Click OK. You should now be back to your model screen.

13. Connect nEv to resBlo



If you toggle your mouse over the blue triangles or inputs to resBlo you will see text descriptors appear which tell you what the input should be. After toggling, it is clear the second triangle is the one we need to connect nEv to. After connecting to the second input, this Create Connection screen appears. It is asking you what data you would like to connect with the input. The nEv data only has one column and thus put 1 in the box. Click OK.



At this point, your model is looking something like this.



- 14. Add in communication and connect to resBlo following these steps:
 - a. Add a new CombiTimeTable to your model. The *Name* is numPacSen. The *Comment* is "Number of packages sent for a residential building block".
 - b. Fill in the *tableOnFile*, *tableName*, *extrapolation* and *timeScale* parameters the same way as the past two tables.
 - c. Click the Edit button at the end of *fileName*. Open SCC_Workshop_Data and by going to Resources>Input>CaseStudy>EnergySystem>Tutorial>numPacSen.txt
 - d. Get back to your model. Determine which resBlo input numPacSen should be connected to and then connect them.
 - e. Another Create Connection box appears, this time with two options.

Create Conne	ction 😣
Connect to only scalar elements of the connect	ors, by giving integer indicies below.
connect(numPacSen .y [1] 🗘 resBlo .numSenPac [1] 🗘	,); <u>C</u> ancel <u>OK</u>

Again, numSenPac data has one column and resBlo.numSenPac has one column, so each should have a 1.

- on

 on
 </t
- f. Return to your model. Your model should now look something like this.

15. Check the model to see if the model can be translated. Click the check box as seen below to check.



The log window will look something like this:



16. Switch to Simulation mode.



This entire time, we have been in Modeling mode. Now switch to Simulation.

17. Simulation Setup settings: There is now a new ribbon at the top. Before running the simulation we have to choose the simulation settings.

 File Edit Simulation Plot Animation Commands Window Help Linear analysis

 File Edit Simulation Plot Animation Commands Window Help Linear analysis

 Prime Plot Animation Commands Window Help Linear analysis

 Prime Plot Animation Commands Window Help Linear analysis

 Prime Plot Animation Commands Window Help Linear analysis

Change the Simulation Setup box to look like below. We will first run this example for 86,400 seconds (one day). Click OK.

	Simulation Setup							
<u>G</u> eneral <u>T</u> ranslation	<u>O</u> utput	<u>D</u> ebug	<u>C</u> ompiler	<u>R</u> ealtime	FMI <u>E</u> xport	FMI <u>I</u> mport		
Experiment								
Model	MultiInfrast	ructure.Ca	seStudy.Ener	gySystem.Tu	torial			
Result	Tutorial							
Simulation interval								
Start time	0					s		
Stop time	86400					s		
Output interval								
Interval length	0					s		
Number of interval	ls 500							
Integration								
Algorithm	Cvode - va	riable orde	r			•		
Tolerance	0.0001							
Fixed Integrator Step	0							

18. Click Simulate.

File	Edit	Simulation	<u>P</u> lot	<u>Animation</u>	<u>C</u> ommands	<u>W</u> indow <u>H</u> elp	p Linear analysis		
	- 6	🕞 🔒 🤇) 4	tru 🦹	D: 🖛 🗔	1 🛃 🔳 🕨	▶ ◆ 🛢 100% → 🖾 🗇 🔽 🛇 \$ 🤤 🔤 🖓 🖓 🛱 🛤 🗌	ΣA	₽ -

19. Evaluate results:

- a. Go to resBlo.sup.PV.P and click the box next to it.
- b. Go to resBlo.sup.winTur.P and click the box next to it.

These two items together show you how much renewable energy was produced that day. This is just a short overview of the results. Feel free to look at some of the other results. This concludes the first tutorial with the SCC Library.



Example 2 will show how to use the energy and transportation systems coupled in the SCC library.

1. New model

Open a new model and call it EnergyTransportationSystemTutorial. Description can be: Example model that demonstrates the tutorial for the energy and transportation systems within the SCC library.

- 2. Insert the TMY3 reader and load the weather file: See step 6 in the first tutorial. MultiInfrastructure.Buildings.BoundaryConditions.WeatherData.ReaderTMY3
- 3. Add the grid for electricity: See step 9 in the first tutorial. MultiInfrastructure.Buildings.Electrical.AC.ThreePhasesBalanced.Sources.Grid

	_	gri in Energ	yTransportationSys	temTu	torial	
General	Add modifiers	Attributes				
Component	t					Icon
Name	gri					
Comment	t					Grid
lodel						TT
Path	MultiInfrastruct	ure.Buildings.El	ectrical.AC.ThreePhase	sBaland	ed.Sources.Grid	
Comment	t Electrical grid					
Comment	t Electrical grid					
Comment Parameters	t Electrical grid		f	Hz	Frequency of th	ne source
Comment Parameters f V	t Electrical grid		f V_nominal	Hz V	Frequency of th RMS voltage of	ne source the source

4. Add in grid frequency, grid voltage, and the example icon in **Modelica Text**. Switch to **Modelica Text** and add the following lines:

extends Modelica.Icons.Example;

parameter Modelica.SIunits.Voltage V_nominal = 10000 "Nominal grid voltage"; parameter Modelica.SIunits.Frequency f = 60 "Nominal grid frequency";

5. Insert residential and commercial blocks: Insert two EnergyTransportation blocks: MultiInfrastructure.CaseStudy.EnergyTransportationSystem.BaseClasses.EnergyTran sportation

Notice that these blocks have one more set of input and output ports than the ones used in the last example.

6. Change the parameters on the first energyTransportation block to match the following images.

	energyTrans	portation in E	nergyTransportationSystemTutorial			
General	Energy Transportation	Add modifiers	Attributes			
Component				Icon		
Name resBlo						
Comment Residential block						
Model						
Path MultiInfrastructure.CaseStudy.EnergyTransportationSystem.BaseClasses.EnergyTransportation						
Comment Model that connects the energy and transportation system						

		res	Blo in EnergyTr	anspor	tationSyste	emTu	toria	ıl	8
General	Energy	Transportation	Add modifiers	Attribu	utes				
Parameters									_
lat				١	weaDat.lat	rad	L	atitude	
f					60)	Hz	N	Iominal grid frequency	
V_nomina	d 📃				10000	V	N	Iominal voltage(V_nominal>=0)	
Renewable	Generatio	n							
А			20000 ►		Net surface	area (of PV		
VWin_non	ninal 🗌		480	V	Nominal volt	tage o	of win	d turbine (VWin_nominal >= 0)	
PWin_non	ninal	-er	ne.PLoa_nominal	w	Nominal pov	ver pf	the v	vind turbine	
Battery									
SOC_start	t [0	.5 🕨		Initial charge	
EMax					1.8e1	• 0.	J	Maximum available charge	
betDis					0.	5 🕨		Discharging velocity coefficient	
betCha						1)		Charging velocity coefficient	
thrDis					-1.26	e6)	W	Discharging power threshold	
thrCha					-76	e5 🕨	w	Charging power threshold	

resBlo in EnergyTransportationSystemTutorial						8	
General	Energy	Transportation	Add modifiers	Attributes			
Parameter	rs						
numEV					850)	Number of initial EV in the block	¢
num			1)+	Number of	ports for transpo	ortation and communication system	1

7. Change the second energyTransportation block to match the following parameters.

	con	nBlo in MultiInfr	astructure.Case	Study.EnergyTransportatio	nSystem.Tutorial
General	Energy	Transportation	Add modifiers	Attributes	
Component					Icon
Name comBlo					
Comment	Comme	rcial block			EnergyTra
Model					a ^{TT} 8
Path	MultiInfr	astructure.CaseStu	dy.EnergyTranspo	rtationSystem.BaseClasses.Ener	gyTransportation
Comment	Model th	nat connects the en	ergy and transpor	tation system	

General Energy	Transportation	Add modifiers	Attrib	outes		
Parameters		1	1			
lat				weaDat.lat 🕨	rad	Latitude
f				60	Hz	Nominal grid frequency
V_nominal				10000	v	Nominal voltage(V_nominal>=0)
Renewable Genera	tion					
A		20000 •		Net surface	area of	PV
VWin_nominal		480	v	Nominal volt	tage of	wind turbine (VWin_nominal >= 0)
PWin_nominal	-61	ne.PLoa_nominal	W	Nominal pov	ver pf t	he wind turbine
Battery						
SOC_start				0	.5 •	Initial charge
EMax				1.8e1	0 ► J	Maximum available charge
betDis				0.	5 🕨	Discharging velocity coefficient
betCha	1 Charging velocity coefficient					
thrDis		-1.2e6 W Discharging power threshold				
thrCha				-76	e5 ► V	/ Charging power threshold

energyTransportation1 in EnergyTransportationSystemTutorial 🛛 😵							
General	Energy	Transportation	Add modifiers	Attributes			
Parameter	s						
numEV					850)	Number of initial EV in the block	c
num			1	Number of	ports for transpo	rtation and communication system	1

- 8. Connect weaDat to the resBlo and the comBlo.
- 9. Connect gri to the resBlo and the comBlo.
- 10. Add the building load data to resBlo and comBlo: Add two instances of Modelica.Blocks.Sources.CombiTimeTable to your model. On the first one, change the parameters to match the following image:

	powBuiR	s in MultiInfrastructure.CaseStudy.EnergyTransportationSystem.	Tutorial 😣
General Add modifi	iers Attributes		
Component			Icon
Name powBuiRe	es		
Comment Power pro	ofile for a residential building block		CombiTime
Model			
Path Modelica. Comment Table look	Blocks.Sources.CombiTimeTable k-up with respect to time and linear/periodic extrapol	tion methods (data from matrix/file)	
Table data definition			
tableOnFile table tableName	1825,40685; 19, -50450,39685; 20, -50320,518; 2	true ▼ . 48195.64265; 22, 44804.9175; 23, -37865.276; 24, -31642.24665] Tabler → tabler →	= true, if table is defined on file or in function usertab Table matrix (time = first column; e.g., table=(0, 0; 1, 1; 2, 4]) Table name on file or in function usertab (see docu)
verboseRead	sourcel"modelica://MultiInfrastructure/Resources/	put/CaseStudy/EnergyTransportationSystem/Tutorial/powBuiRes.txt*) E true	File where matrix is stored = true, if info message that file is loading is to be printed
Table data interpretati	ion		
columns smoothness	2:size(table, 2)] 10 Modelica.Blocks.Types.Smoothness.Linear	Columns of table to be interpolated Smoothness of table interpolation	y time y[1] y[2]
extrapolation	delica.Blocks.Types.Extrapolation.Periodic 💌	Extrapolation of data outside the definition range	
timeScale	3600 +	Time scale of first table column	
offset	{0} II •	Offsets of output signals	
startTime	•	Output = offset for time < startTime	
shiftTime	startTime)	Shift time of first table column	offset columns
Info			<u>C</u> ancel <u>O</u> K

The *fileName* can be loaded from:

Resources>Scripts>CaseStudy>EnergyTransportationSystem>Tutorial>powBuiRes.txt

The second instance of the CombiTimeTable can be adjusted like:

	powBuiCom	$in \ MultiInfrastructure. Case {\tt Study. Energy Transportation System. T}$	utorial
neral Add modifie	ers Attributes		
nponent			Icon
lame powBuiCo	m		
omment Power pro	file for a commercial building block		CombiTime
del			
ath Modelica.B comment Table look-	llocks.Sources.CombiTimeTable -up with respect to time and linear/periodic extrapolation	on methods (data from matrix/file)	
le data definition			
ableOnFile able ableName leName	106.9992138856.7877395590.3568467564.07/ ource(*modelica://MultiInfrastructure/Resources/Inpu	true v) 7/9: 2415106 9992139665 66037113199 517746268 58653 *table*) VCaseStudy/EnergyTransportationSystem/Tutorial/powBuiCom.txt*)	= true, if table is defined on file or in function usertab Table matrix (time = first column; e.g., table=[0, 0; 1, 1; 2, 4]) Table name on file or in function usertab (see docu) File where matrix is stored
ole data interpretatio	n.	<u>-</u> ,	
olumns	2:size(table, 2)	Columns of table to be interpolated	y time y[1] y[2]
xtrapolation	delica.Blocks.Types.Extrapolation.Periodic V	Extrapolation of data outside the definition range	
meScale	3600 × s	Time scale of first table column	
ffset	{0} III •	Offsets of output signals	
tartTime	s	Output = offset for time < startTime	
hiftTime	startTime) s	Shift time of first table column	offset
Info			<u>C</u> ancel <u>O</u> K

ThetablecanbeloadedfromResources>Scripts>CaseStudy>EnergyTransportationSystem>Tutorial>powBuiCom.txt

11. Connect powBuiRes and resBlo: Similar to the last tutorial we are going to write a script to perform the connections for us. Switch to **Modelica Text** and write the following script.

> for i in 1:12 loop connect(powBuiRes.y[1], resBlo.PBui[i]); end for;

You can copy and paste the below script if you like.

```
for i in 1:12 loop
    connect(powBuiRes.y[1], resBlo.PBui[i]);
end for;
```

12. Connect powBuiCom to comBlo.

Similar to the previous step, we will write a script that connects powBuiCom to comBlo. If you remember, powBuiCom has multiple columns with different data. This data corresponds to different building types. In this tutorial, we will only model one type of building. You could emulate the following script to test out different buildings or different columns of data.

```
for i in 1:12 loop
    connect(powBuiCom.y[1], comBlo.PBui[i]);
end for;
```

Feel free to copy and paste the following text:

```
for i in 1:12 loop
   connect(powBuiCom.y[1], comBlo.PBui[i]);
end for;
```

13. Add in the traffic data.

Add in two more instances of the CombiTimeTable to your model. Change the table to have the following name, description, and parameters.

	qOutR	esCom in MultiInfrastructure.CaseStudy.EnergyTransportationSystem	m.Tutorial
General Add modif	iers Attributes		
Component			Icon
Name	7 a ano.		
Comment Traffic ou	tflow for residential block1 to commercial block		CombiTime
Comment Traine of	the side has blocked to commercial block		
4odel			
Path Modelica. Comment Table lool	Blocks.Sources.CombiTimeTable 	nolation methods (data from matrix/file)	
Fable data definition		· · · · · · · · · · · · · · · · · · ·	
tableOnFile		true - k	tous if table is defined an file or in function usertab
table	, 124; 10, 82; 11, 59; 12, 55; 13, 65; 14, 82; 1	5, 75; 16, 77; 17, 58; 18, 46; 19, 70; 20, 58; 21, 21; 22, 16; 23, 15; 24, 16] []	Table matrix (time = first column; e.g., table=[0, 0; 1, 1; 2, 4])
tableName		"table" >	Table name on file or in function usertab (see docu)
fileName	urce("modelica://MultiInfrastructure/Resource	/Input/CaseStudy/EnergyTransportationSystem/Tutorial/qOutResCom.txt")	File where matrix is stored
verboseRead		true 💌	= true, if info message that file is loading is to be printed
Table data interpretati	on		
columns	2:size(table, 2)	Columns of table to be interpolated	y time u(11 u(21
smoothness	Modelica.Blocks.Types.Smoothness.Linear	 Smoothness of table interpolation 	
extrapolation	delica.Blocks.Types.Extrapolation.Periodic	Extrapolation of data outside the definition range	
timeScale	3600	Time scale of first table column	
anneseure .			
onset	{0}	Onsets or output signals	
startTime	(S Output = offset for time < startTime	columns
shiftTime	startTime	 s Shift time of first table column 	offset
Info			Cascal
iniv			

Next, hit the Edit button at the end of the *fileName* line to add in the matrix data. The table can be loaded from:

Resources>Scripts>CaseStudy>EnergyTransportationSystem>Tutorial>qOutResCom.txt

Hit OK and then you should return to your model.

14. Connect qOutResCom to resBlo.

When connecting qOutResCom to resBlo, it will have to be connected twice to the inputs in the second and third position as shown below.



Connect qOutResCom to the second input and a Create Connection box will pop up. Put 1 in each of the choices as shown below.



Now connect qOutResCom to the third input of resBlo. When the Create Connection box comes up again, also put 1 in each option as shown below.



15. Create qOutComRes and connect to comBlo.

On that second instance of the CombiTimeTable, change the parameters to look like the following.

	qOutComRe	s in MultiInfrastructure.CaseStudy.EnergyTransportationSystem.	Tutorial 🛛 🛞
General Add modifie	ers Attributes		
Component			Icon
Name qOutComF	Res		
Comment Traffic out	flow for commercial block to residential block		CombiTime
Model			
Path Modelica.B	Blocks.Sources.CombiTimeTable		
Comment Table look	-up with respect to time and linear/periodic extrapolation	on methods (data from matrix/file)	
table data definition			have if table is defined as file as is furnities used as
table	8; 10, 57; 11, 66; 12, 72; 13, 69; 14, 89; 15, 71; 16, 4	86; 17, 125; 18, 555; 19, 165; 20, 98; 21, 55; 22, 46; 23, 31; 24, 23]	Table matrix (time = first column; e.g., table=[0, 0; 1, 1; 2, 4])
tableName		"table" >	Table name on file or in function usertab (see docu)
fileName verboseRead	urce("modelica://MultiInfrastructure/Resources/Input/	/CaseStudy/EnergyTransportationSystem/Tutorial/qOutComRes.txt*)	File where matrix is stored = true, if info message that file is loading is to be printed
Table data interpretatio			
i able data interpretatio			
columns	2:size(table, 2)	Columns of table to be interpolated	y time y[1] y[2]
smoothness	Modelica.Blocks.Types.Smoothness.Linear	Smoothness of table interpolation	
extrapolation	delica.Blocks.Types.Extrapolation.Periodic	Extrapolation of data outside the definition range	
timeScale	3600 > s	Time scale of first table column	
offset	{0} II •	Offsets of output signals	
startTime	0) s	Output = offset for time < startTime	columns
shiftTime	startTime s	Shift time of first table column	offset
Info			<u>C</u> ancel <u>Q</u> K

Import the traffic data from:

 $Resources \!\!>\!\! Scripts \!\!>\!\! CaseStudy \!\!>\!\! EnergyTransportationSystem \!\!>\!\! Tutorial \!\!>\!\! qOutComRes.txt.$

Connect qOutComRes to the second and third inputs of comBlo, similar to what we did in the previous step. Fill in all of the Create Connection options with a 1.

Take a brief moment to check that your model looks something like the following. It is ok if all of the connections or placements of the blocks are different, but they should all be there.



16. Add in the probability of an EV charging to both resBlo and comBlo.

Similar to the previous steps, we will now add in two more instances of CombiTimeTable, add a name, description, parameters, data, and then connect to the respective block.

For the first instance, change the parameters to match the following.

	proRes in	MultiInfrastructure.CaseStudy.EnergyTransportationSystem.Tut	orial 😣
General Add modi	fiers Attributes		
Component			Icon
Name proRes			
Comment Probabili	ity of charging for a single EV at different time in a reside	ential block	CombiTime
Model			
Path Modelica. Comment Table loo	.Blocks.Sources.CombiTimeTable k-up with respect to time and linear/periodic extrapolati	on methods (data from matrix/file)	
Table data definition			
tableOnFile table tableName fileName verboseRead	12, 0.05; 13, 0.05; 14, 0.05; 15, 0.05; 16, 0.05; 17, dResource("modelica://MultiInfrastructure/Resources	true + 0.05:18.005;19.005;20.015;21.015;22.03;23.03;24.03] III *table* + /Input/CaseStudy/EnergyTransportationSystem/Tutorial/proRestxt* III true +	= true, if table is defined on file or in function usertab Table matrix (time = first column; e.g., table=[0, 0; 1, 1; 2, 4]) Table name on file or in function usertab (see docu) File where matrix is stored = true, if info message that file is loading is to be printed
Table data interpretat	tion		
columns smoothness	2:size(table, 2)	Columns of table to be interpolated Smoothness of table interpolation	y time y[1] y[2]
extrapolation	delica.Blocks.Types.Extrapolation.Periodic 💌 🕨	Extrapolation of data outside the definition range	
timeScale	3600 × s	Time scale of first table column	
offset	{0} II •	Offsets of output signals	
startTime) s	Output = offset for time < startTime	
shiftTime	startTime s	Shift time of first table column	offset columns
Info			<u>C</u> ancel <u>O</u> K

Add in the data from:

Resources>Scripts>CaseStudy>EnergyTransportationSystem>Tutorial>proRes.txt.

Connect proRes to the fourth input on the left as shown below.



Put 1 in the Create Connection box that pops up.

For the second instance of the CombiTimeTable input the following parameters and copy the data from Resources>Scripts>CaseStudy>EnergyTransportationSystem>Tutorial>proCom.txt .

	proCon	in Multlinfrastructure.CaseStudy.EnergyTransportationSystem.T	utorial 🔗
General Add modifi	iers Attributes		
Component			Icon
Name proCom			
Comment Probability	y of charging for a single EV at different time in a co	nmercial block	CombiTime
Model			
Path Modelica.	Blocks.Sources.CombiTimeTable		
Comment Table look	-up with respect to time and linear/periodic extrapol	ation methods (data from matrix/file)	
Table data definition			
tableOnFile	0.08: 13.0.08: 14.0.08: 15.0.08: 16.0.08: 17.0	true ▼ ►	= true, if table is defined on file or in function usertab Table matrix (time = first column: e.g., table= $[0, 0; 1, 1; 2, 4]$)
tableName		"table"	Table name on file or in function usertab (see docu)
fileName	Resource("modelica://MultiInfrastructure/Resource	es/Input/CaseStudy/EnergyTransportationSystem/Tutorial/proCom.txt")	File where matrix is stored
verboseRead		true 🗸 🕨	= true, if info message that file is loading is to be printed
Table data interpretation	on		
columns	2:size(table, 2)	Columns of table to be interpolated	y time v[1] v[2]
smoothness	Blocks.Types.Smoothness.LinearSegments -	Smoothness of table interpolation	
extrapolation	delica.Blocks.Types.Extrapolation.Periodic 💌 🕨	Extrapolation of data outside the definition range	
timeScale	3600 >	5 Time scale of first table column	
offset	{0} =	Offsets of output signals	
startTime	0	5 Output = offset for time < startTime	
shiftTime	startTime	5 Shift time of first table column	offset columns
Info			<u>C</u> ancel <u>O</u> K

Connect proCom to the fourth input on comBlo and input 1 in the Create Connection box.

17. Add a road between the resBlo and the comBlo.

Add two instances of the road from:

MultiI in frastructure. Coupled System. Energy Distribution And Transportation Delay. Base Classes. Root Variable Delay

Change the parameters of one of the roads to look like the following.

	roadVariableDelay in EnergyTransportationSystemTutorial	
General	Add modifiers Attributes	
Component		Icon
Name	roal	
Comment	Road connecting the output of the residential block to the input of the commercial block	
Model		▶>
Path	${\sf MultiInfrastructure. Coupled System. Energy Distribution {\sf And Transportation {\sf Delay. Base Classes. Road Variable {\sf Delay}} }$	
Comment	Model of a road with variable delay based on the traffic condition	
arameters		
1 [9000 m Length of the road	
numIni	5 Initial number of v	ehicles the road

From the drop down menu of roaTyp make sure to pick DClassRoad20.

Connect the output of resBlo to the input of roa1. Enter 1 for the Create Connection box.

Connect the output of roa1 to the input of comBlo. Enter 1 for the Create Connection box. It should look something like this.



18. Add a road between comBlo and resBlo

For the second road instance, edit the parameters to look like the following.

_	roa2 in EnergyTransportationSystemTutorial	
General	Add modifiers Attributes	
Component		lcon
Name	roa2	
Comment	Road connecting the output of the commercial block to the input of the residential block	
4odel		▶>
Path Comment	MultiInfrastructure.CoupledSystem.EnergyDistributionAndTransportationDelay.BaseClasses.RoadVariableDelay Model of a road with variable delay based on the traffic condition	
arameters		
Parameters	9000 M Length of the road	d
arameters I numIni	9000 M Length of the road 5 M Initial number of v	d vehicles the road

Again, choose RoadDClass20 for the roaTyp. Hit ok and connect the output of comBlo to the input of roa2. Enter 1 into the Create Connection box.

Connect the output of roa2 to the input of resBlo. Enter 1 into the Create Connection box. It should look like this now.



Overall your model should now look something like this.



19. Check the model: Click the checkmark at the top of the ribbon to compile the model. It should look like this.



20. Simulate the model: Switch to simulation mode and enter in the following parameters.

	Simulation Setup
<u>G</u> eneral <u>T</u> ranslation Experiment	Output Debug Compiler Realtime FMI Export FMI Import
Model Result	EnergyTransportationSystemTutorial EnergyTransportationSystemTutorial
Simulation interval	
Start time Stop time	0 s 86400 s
Output interval	
Interval lengthNumber of interval	0 s 500
Integration	
Algorithm	Cvode - variable order 🔹
Tolerance	0.0001
Fixed Integrator Step	0 5
Store in Model 🗸 Autom	atically store General and Inline integration settings Cancel OK

Click Ok and click the Simulate button.

21. Evaluate results.

Here is one example of the results. The green and the red each represent the traffic flow on one of the roads.



There are many other interesting correlations to look at for the results. Take your time to explore. This concludes the second SCC tutorial.

Tutorial 2: Net-Zero Energy Community Library

This tutorial aims to provide a detailed step-by-step guide on building a heat pump system with control in Modelica. The following libraries will be used in this tutorial:

Modelica Buildings Library (version 5.0.1)³ Net-Zero Energy Community Library (version 1.1)⁴.

To implement the proposed heat pump system, three examples will be introduced: (1) RC room model with heat transfer through the envelope; (2) room model coupled with a heat pump system; (3) heat pump system model with speed control. The latter examples are built upon the former examples. After this tutorial, the users will be more familiar with the modeling of energy systems coupled with room models as well as the control implementations. The remainder of this tutorial introduces the three examples step-by-step. Dymola 2020 in Windows system was used to create this tutorial.

Figure of final system:



Figure 1 Modelica Diagram of the Heat Pump System with Control

³ <u>https://simulationresearch.lbl.gov/modelica/downloads/archive/modelica-buildings.html</u>

⁴ <u>https://www.colorado.edu/lab/sbs/nzec-library</u>

Example 1 – RC Room Model

This example builds an RC room model with heat convection and radiation from the room envelope (*Figure 2*).



Figure 2 Modelica Diagram of Example 1: RC Room Model

This example is adapted from: Buildings.ThermalZones.ReducedOrder.Examples.SimpleRoomTwoElements.



Figure 3 Modelica Diagram of Buildings.ThermalZones.ReducedOrde Examples SimpleRoomTwoElements We reused this model with the following changes:

- (1) Ignoring the computation of the equivalent air temperature and using drybulb temperature as the boundary condition;
- (2) Ignoring the convective heat gain from machines.

The differences have been marked with orange rectangular in *Figure 3*. Additionally, we made the following changes to the parameters:

Name	Comment	Value
weaDat.filNam	Weather data	ModelicaServices.ExternalReferences.loadResource("modelica://GreenVilla ge/Resources/Weather/USA_FL_Tampa.Intl.AP.722110_TMY3.mos")
alpWinOut.k	Outdoor coefficient of heat transfer for windows	150
alpWalOut.k	Outdoor coefficient of heat transfer for walls	150
intGai.fileName	Internal heat gain	ModelicaServices.ExternalReferences.loadResource("modelica://GreenVilla ge/Resources/Input/Examples/HeatPump/InternalGain.txt")
intGai.columns	Columns of table to be interpolated	2:3
theZon.Medium	Medium of air	Buildings.Media.Air
theZon.VAir	Room air volume	rooLen*rooWid*rooHei
rooLen	Room length	8
rooWid	Room width	8
rooHei	Room height	10
theZon.nOrienta tions	Number of orientations	nOrientations
nOrientations	Number of orientations	2
theZon.AWin	Vector of areas of windows by orientations	{4,4}
theZon.ATransp arent	Vector of areas of transparent elements by orientations	{4,4}
theZon.gWin	Total energy transmittance of windows	0.6
theZon.AExt	Vector of areas of exterior walls by orientations	{rooLen*rooHei,rooWid*rooHei}
theZon.RExt	Vector of resistance of exterior walls, from inside to outside	{0.33142}
theZon.AInt	Area of interior walls	2*rooHei*rooLen
theZon.RInt	Vector of resistance of	{0.0168895}

Name	Comment	Value
	interior walls,	
	from port to	
	center	

All values are in SI units. The parameters not mentioned are the same as in the Buildings library example.

With the following simulation setup, you can get the results shown in *Figure 5*.

	Experiment								
	Model	UseCase	s.HeatPun	np.System1					
	Result	System 1	L						
	Simulation interval								
	Start time	0							s
	Stop time	86400							s
	Output interval								
	Interval length	0							s
	Number of intervals	500							
	Integration								_
	Algorithm	Dassl						•	
	Tolerance	0.0001							
	Fixed Integrator Step	0							s
	Store in Model V Automa	tically store G	General an	d Inline integ	gration setting	s	OK	Ca	incel
th	Store in Model V Automa eZon.TAir (*C) — Sy	tically store C <i>re 4 Si</i> stem1.weal	Seneral an	d Inline integ tion Se Bul-273.15	etup for	s C	ок aple 1	Ca	ancel
- th	Store in Model V Automa	tically store C	Seneral an	d Inline integ tion So Bul-273.15	etup for	s C	ок pple 1	عا (ا	incel
th	Store in Mode) V Automa	tically store C	Seneral an	d Inline integ	etup for	s C	ок aple 1		ince
th	Store in Model V Automa	tically store Q	Seneral an	d Inline integ	ration setting	s C	ok aple 1		
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	Seneral an	d Inline integ	etup for	s C	ok ople 1	7.9	incel
- th	Store in Model V Automa	tically store C re 4 Si stem1.weal	General an	d Inline Integ	etup for	s C	ок pple 1)	ncel
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	ieneral an	d Inline Integ	solution setting	s C	ox pple 1	7.5	ncel
	Store in Model V Automa	tically store C re 4 Si stem1.weal	ieneral an	d Inline Integ	solution setting	s C	ok pple 1	7.5	ncel
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	Seneral an	d Inline Integ	solution setting	s C	ox pple 1	7.5	ncel
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	Seneral an	d Inline Integ	station setting	s C	ok Iple 1	7.5	nncel
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	Seneral an	d Inline Integ	solution setting	s C	ok Iple 1	7.3	nncel
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	Seneral an	d Inline Integ	station setting	s C	ok Iple 1	7.9	nncel
th	Store in Model V Automa	tically store C re 4 Si stem1.weal	Seneral an	d Inline integ	station setting	s C	ok Iple 1	7.9	incel

If you go to "Commands" and click "Simulate and Plot". This will call a script that we prepared and automatically simulate and plot the model with exactly the same setup above.



This example adds a heat pump model on top of the RC room model we just built . The water cooled variable-speed heat pump is modeled as an instance of the class Buildings.Fluid.HeatExchangers.DXCoils.WaterCooled.VariableSpeed. The fan is modeled as an instance of the class Buildings.Fluid.Movers.SpeedControlled_y.



Figure 6 Modelica Diagram of Example 2: RC Room Model Coupled with Heat Pump 1. To define the condenser-side medium as water, we added the declaration in Text mode: replaceable package Medium2 = Buildings.Media.Water "Medium model at the condenser side";

This will allow the users to change the medium to other refrigerants later. Then, we also define the system-level parameters that are related to the heat pump. Declaring parameters at the top-level allows to propagate them to other models, and to easily change them at one location when revising the model.

```
replaceable parameter GreenVillage.Subsystems.HeatPump.WSHPPhysics.Data.HeatPump1 datHP
    "Performance data for heat pump";
parameter Boolean computeReevaporation=true
"Set to true to compute reevaporation of water that accumulated on coil";
parameter Real minSpeRat= 0.05 "Minimum speed ratio";
parameter Modelica.Slunits.PressureDifference dpEva_nominal=1000
"Pressure difference over evaporator at nominal flow rate";
parameter Modelica.Slunits.PressureDifference dpCon_nominal=40000
"Pressure difference over condenser at nominal flow rate";
```

Now, we instantiate Buildings.Fluid.HeatExchangers.DXCoils.WaterCooled.VariableSpeed and name it as varSpeHeaPum. Redeclare the heat pump parameters using the system-level parameters. // Heat pump related parameters Buildings.Fluid.HeatExchangers.DXCoils.WaterCooled.VariableSpeed varSpeHeaPum(redeclare final package MediumEva = Medium1, redeclare package MediumCon = Medium2, dpEva_nominal=dpEva_nominal, dpCon_nominal=dpEva_nominal, computeReevaporation=computeReevaporation, minSpeRat=minSpeRat, datCoi=datHP) "Variable speed heat pump";

2. To model the fan, we instantiate Buildings.Fluid.Movers.SpeedControlled_y and name it as *fan*. Then, we also define the fan related system-level parameters and redeclare the corresponding fan parameters using these system-level parameters.

```
// fan related parameters
replaceable parameter GreenVillage.Subsystems.HeatPump.WSHPPhysics.Data.FanHP1 perFan "Pe
rformance data for fan";
parameter Boolean addPowerToMedium=false
    "Set to false to avoid any power (=heat and flow work) being added to medium (may give
simpler equations)";
Buildings.Fluid.Movers.SpeedControlled_y fan(
redeclare package Medium = Medium1, addPowerToMedium=addPowerToMedium,
per=perFan.per);
```

3. To monitor the supply air temperature and the condenser inlet/outlet water temperature, we instantiate Buildings.Fluid.Sensors.TemperatureTwoPort three times and name them as *senSupAir, senConWatIn* and *senConWatOut*, respectively. Define the sensor related system-level parameters and apply them to all three sensor models.

```
// sensor related parameters
parameter Modelica.SIunits.MassFlowRate m_flow_nominal = datHP.sta[datHP.nSta].nomVal.mCo
n_flow_nominal
    "Nominal mass flow rate";
Buildings.Fluid.Sensors.TemperatureTwoPort senSupAir(redeclare final package
    Medium = Medium1, final m_flow_nominal=m_flow_nominal)
    "Supply air temperature sensor";
Buildings.Fluid.Sensors.TemperatureTwoPort senConWatIn(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
    "Inlet condenser water temperatureTwoPort senConWatOut(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
    "Inlet condenser water temperatureTwoPort senConWatOut(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
    "Inlet condenser water temperatureTwoPort senConWatOut(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
    "Inlet condenser water temperatureTwoPort senConWatOut(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
    "Inlet condenser water temperatureTwoPort senConWatOut(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
    "Inlet condenser water temperatureTwoPort senConWatOut(redeclare final
package Medium = Medium2, final m_flow_nominal=m_flow_nominal)
```

4. For the model to run, we still need a water source and a water sink, which are instances of Buildings.Fluid.Sources.MassFlowSource_T and Buildings.Fluid.Sources.Boundary_pT. We name them as *souWat* and *sinWat*, respectively. Configure the two models using the following parameters in **Text** mode.

```
Buildings.Fluid.Sources.MassFlowSource_T souWat(
   redeclare package Medium = Medium2,
   use_T_in=false,
   use_m_flow_in=false,
   m_flow=m_flow_nominal,
   T=298.15,
   nPorts=1) "Source on water side";
Buildings.Fluid.Sources.Boundary_pT sinWat(
   redeclare package Medium = Medium2,
   nPorts=1,
   p(displayUnit="Pa")) "Sink on water side";
```

Connect the water loop and air loop. Positive design flow direction is from port_a to port_b.

5. Lastly, we need to provide inputs for heat pump speed ratio as well as the fan speed ratio. Here, we use the instance *fanSpeRat* of Modelica.Blocks.Sources.Constant to model a constant fan speed ratio. Similarly, we use the instance *heaPumSpeRat* of Modelica.Blocks.Sources.Ramp to model a ramped change in the heat pump speed ratio. The following screenshots show the parameter configuration of the two inputs.

fanSpeRat in GreenVillage.Examples.HeatPump.System2	8 ×	heaPumSpeRat in GreenVillage.Examples.HeatPump.System2	8
General Add modifiers Attributes		General Add modifiers Attributes	
Component	Icon	Component Name heaPumSpeRat	Icon
Name fanSpeRat		Comment Heat pump speed ratio	Ramp
Comment Fan speed ratio	Constant	Model	
Model	_	Path Modelica.Blocks.Sources.Ramp Comment Generate ramp signal	duration=
Path Modelica.Blocks.Sources.Constant	k=	Parameters	
Comment Generate constant signal of type Real		у у	
Parameters		neight 1. Height orramps	
У		duration 600 • s Duration of ramp (= 0.0 gives a Step)	height
		affset 0 • Offset of output signal y	duration
k 1 Constant output value K		startTime 6000 • s Output y = offset for time < startTime	startTime time
	time		
ок	ancel Info		OK Cancel Info

Figure 7 Parameters for fanSpeRat and heaPumSpeRat

6. Run the simulation from Day 200 to Day 201 (summer condition). You will see the following results. Compare your results with our pre-run results.



Parameters (use default value if parameter is not listed in table)

Name	Comment	Value		
varSpeHeaPum.Me diumEva	Heat pump evaporation side medium	Buildings.Media.Air		
varSpeHeaPum.Me diumCon	Heat pump condensation side medium	Buildings.Media.Water		
varSpeHeaPum.dp Eva_nominal	Heatpumpevaporationsidepressure drop	1000		
varSpeHeaPum.dp Con_nominal	Heat pump condensation side pressure drop	40000		
varSpeHeaPum.co mputeReevaporatio n	Whethertocomputereevaporationinheat pump	true		
varSpeHeaPum.mi nSpeRat	Minimum speed ratio of heat pump	0.05		
varSpeHeaPum.dat Coi	Heat pump data	datHP		
datHP	Heat pump data	replaceable parameter GreenVillage.Subsystems.HeatPump.WSHPPhysics.Data .HeatPump1		
fan.Medium	Fan medium	Buildings.Media.Air		
fan.addPowerToM edium	Whether to add power to medium in fan simulation	false		
fan.per	Fan performance data	perFan.per		
perFan	Fan performance data	replaceable parameter GreenVillage.Subsystems.HeatPump.WSHPPhysics.Data .FanHP1		
senSupAir.Medium	Supply air temperature sensor medium	Buildings.Media.Air		
senSupAir.m_flow _nominal	Supply air temperature sensor mass flow rate	m_flow_nominal		
senConWatIn.Medi um	Water inlet temperature sensor medium	Buildings.Media.Water		
senConWatIn.m_fl ow_nominal	Water inlet temperature sensor mass flow rate	m_flow_nominal		
senConWatOut.Me dium	Water outlet temperature sensor medium	Buildings.Media.Water		
senConWatOut.m_ flow_nominal	Water outlet temperature sensor mass flow rate	m_flow_nominal		
m_flow_nominal	System mass flow rate	datHP.sta[datHP.nSta].nomVal.mCon_flow_nominal		
souWat.Medium	Water source medium	Buildings.Media.Water		

Name	Comment	Value
souWat.use_T_in	Whether to use temperature input in water source	false
souWat.use_m_flo w_in	Whether to use mass flow rate input in water source	false
souWat.m_flow	Water source mass flow rate	m_flow_nominal
souWat.T	Water source temperature	298.15
sinWat.Medium	Water sink medium	Buildings.Media.Water
heaPumSpeRat.dur ation	Heat pump speed ratio input duration	600
heaPumSpeRat.star tTime	Heat pump speed ratio input start time	6000
heaPumSpeRat.hei ght	Heat pump speed ratio input height	0.1
heaPumSpeRat.off set	Heat pump speed ratio input offset	0
fanSpeRat.k	Fan speed ratio input value	0.1

Example 3 – Heat Pump System with Control

This example adds fan on/off control and heat pump speed control on top of Example 2. The control logic we will implement here is as follows.

- 1. The fan and heat pump will only be on when the room is occupied.
- 2. The heat pump speed ratio is controlled with a PI controller based on the room air temperature setpoint and the measured room air temperature.
- 3. The room air setpoint will be constant for simplicity reasons.

The final diagram of the model will look like the following figure.



Figure 8 Modelica Diagram of Example 3: Heat Pump System with Control

Step 1: We model the occupancy schedule *occSch* as an instance of Buildings.Controls.SetPoints.OccupancySchedule. Because the first entry of the occupancy indicates a change from unoccupied to occupied, we will choose true for the *firstEntryOccupied*.

Here, we also need to use an instance *booToRea* of Buildings.Controls.OBC.CDL.Conversions.BooleanToReal to convert the occupancy from boolean signal to real signal. Connect *booToRea.y* to *fan.y*.

Step 2: The control block we will use here is an instance of GreenVillage.Subsystems.HeatPump.WSHPPhysics.BaseModels.FanSpeedControl. This controller can do P, PI, PD, and PID control as the user prefers. Choose the controllerType as PI controller and set Ti to 60 s, reverseAction to true for cooling.

Step 3: We model the constant room air setpoint as an instance of Buildings.Controls.OBC.CDL.Continuous.Sources.Constant. Set the value of k to 273.15+20 to represent a constant room air temperature setpoint at 20 °C.

Step 4: Make the rest connections as indicated in *Figure 8*. Run the simulation from Day 200 to 201 with default settings and compare the results to our pre-run results by clicking "Commands-Simulate and Plot". The pre-run results will look like in the following figures.



Parameters (use default value if parameter is not listed in table)

Name	Comment	Value
occSch.firstEntryOccupied	Set to false as first entry denotes a change from occupied to unoccupied.	true
heaPumSpeCon.controllerType	Type of controller	Modelica.Blocks.Types.Simp leController.PI
heaPumSpeCon.Ti	Time constant of Integrator block	60 s
heaPumSpeCon.reverseAction	Set to true for cooling	true
rooAirSet.k	Constant output value	273.15+20

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