TILMedia Suite 3

TLK-Thermo GmbH

in cooperation with

Institut für Thermodynamik

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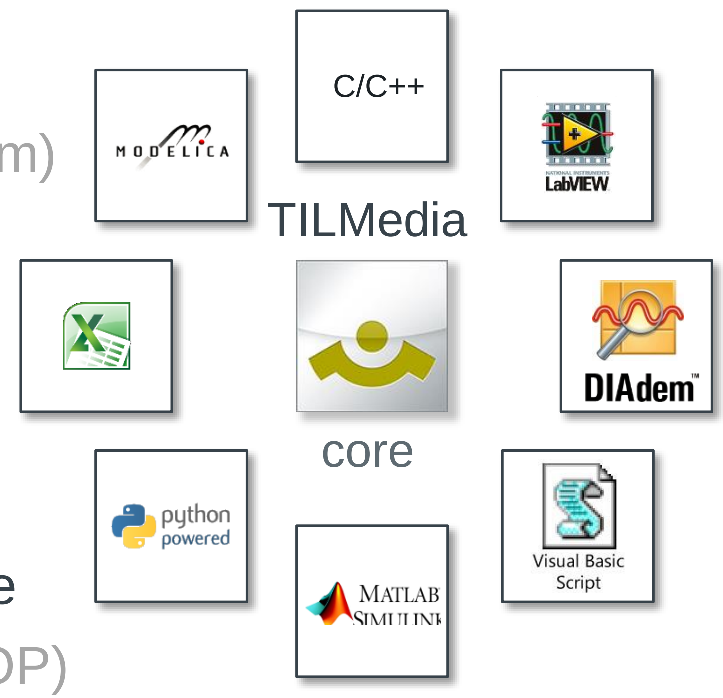
TIL Media Substance properties optimized for stable and extremely fast dynamic simulations

- Calculation methods to express thermophysical properties of:
  - Incompressible Liquids
  - Ideal Gases
  - Real Fluids (with vapor liquid equilibrium)
  - Mixtures
- Optimized mathematical equations with extremely high calculation speeds and high accuracies
- Several hundreds of substances available (also from external sources e.g. REFPROP)



- TILMedia Suite interfaces one property core for various software

TILMedia as Interface

Fluid Properties

- Optimized own implementations for transient simulations
  - Equations of State*
  - Set of curves
  - Table based properties
- Implementations described in the literature:
  - VDI-Heat Atlas
  - VDI-Guideline 4670
  - NASA Glenn coefficients
- External Libraries e.g. REFPROP

TILMedia Interfaces

- **VLEFluid** and VLEFluid Mixtures containing Vapor Liquid Equilibrium
- Incompressible **Liquid**
- Ideal **Gas** and Gas Mixtures

Applications

- C/C++
- COM-Interface:
  - DIAdem
  - Visual Basic for Applications
  - VB Script
- LabVIEW
- MATLAB
- Simulink
- Microsoft Excel
- Modelica:
  - Dymola
  - MapleSim
  - OpenModelica
  - SimulationX
  - SystemModeler
- Python

* In the following = EOS

- Not implemented jet

VLEFluids Available thermophysical properties

Interface for fluids containing a Vapor Liquid Equilibrium

The following VLEFluid properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- mass fraction
- mole fraction
- average molar mass

- steam mass fraction (quality)
- specific isobaric/isochoric heat capacity
- isobaric thermal expansion coefficient
- isothermal compressibility

- speed of sound
- derivative of density with respect to specific enthalpy
- derivative of density with respect to pressure
- derivative of density with respect to mass fraction
- heat capacity ratio / isentropic expansion factor
- molar mass of one component in mixture

- prandtl number
- thermal conductivity
- dynamic viscosity
- surface tension

- Saturation properties, critical properties & properties on dew and bubble line

As a function of:

- p, h, xi
- p, T, xi
- p, s, xi
- d, T, xi

with xi=1 for a single component

Available pure VLEFluids – EOS

Approaches optimized for simulation with EOS

- faster than REFPROP
- not exportable
- moderate memory requirement
- very good accuracy of calculations

- Ammonia
- Argon
- CO_2 (Span/Wagner and GERG)
- Ethanol
- Ethylbenzene
- M-Xylene
- Nitrogen
- Oxygen
- O-Xylene
- Propane
- P-Xylene
- R1234yf
- R125
- R134a (Tillner-Roth/Baehr and Astina/Sato)
- R143a
- R245fa
- R32
- R404A (PPF)
- R407C (PPF)
- R410A (PPF)
- R507A (PPF)
- Water (IAPWS 1995)

Available pure VLEFluids

Implementations with sets of curves:

- very fast
- exportable
- low memory requirement
- good accuracy of calculations

- CO2
- R1234yf
- R134a
- R407C
- R410A
- Water

Table based thermophysical properties*:

- very fast
- exportable
- high memory requirement
- very good accuracy of calculations

* Only available with the modelica library TIL

- Air (PPF)
- Methane
- R134a
- Table based properties of all REFPROP-Fluids possible on demand.

Available VLEFluids – REFPROP

REFPROP (208 media, pure fluids and mixtures):

- 1-Butene
- Acetone
- Air
- Amarillo
- Ammonia (R-717)
- Argon (R-740)
- Benzene
- Butane (R-600)
- C1-CC6
- C2-Butene
- C3-CC6
- C4-F10 (R-3-1-10)
- C5-F12 (R-4-1-12)
- C11
- C12
- C-F3-I
- CO
- COS
- Cyclohexane
- Cyclopropane
- D2
- D4
- D5
- D6
- D2O
- DEE
- Decane
- DMC
- DME
- Ebenzene
- Ekofisk
- Ethane (R-170)
- Ethanol
- Ethylene (R-1150)
- Fluorine
- Glfcoast
- H2S
- HCL
- Helium (R-704)
- Heptane
- Hexane
- HighCO2
- HighN2
- Hydrogen (R-702)
- I-Butene
- I-Hexane
- I-Octane
- I-Pentane (R-601a)
- Isobutanol
- Krypton (R-784)
- MDN
- MD2M
- MD3N
- MD4N
- Methane (R-50)
- Methanol
- Methyl Linoleate
- Methyl Linolenate
- MM
- Methyl Oleate
- Methyl Palmitate
- Methyl Stearate
- M-Xylene
- N2O (R-744A)
- Neon (R-720)
- Neopentane
- NF3
- Ngsample
- Nitrogen (R-728)
- Nonane
- Novec649
- Novec7000
- Octane
- Orthohydrogen (R-702)
- Oxygen (R-732)
- Oxylene
- Parahydrogen (R-702p)
- Pentane (R-601)
- Propane (R-290)
- Propylene (R-1270)
- Propyne
- P-Xylene
- R-11
- R-12
- R-13
- R-14
- R-21
- R-22
- R-23
- R-32
- R-40
- R-41
- R-113
- R-114
- R-115
- R-116
- R-123
- R-124
- R-125
- R-134a
- R-141b
- R-142b
- R-143a
- R-152a
- R-161
- R-218
- R-227ea
- R-236ea
- R-236fa
- R-245ca
- R-245fa
- R-365mfc
- R-401A
- R-401B
- R-401C
- R-402A
- R-402B
- R-403A
- R-403B
- R-404A
- R-405A
- R-406A
- R-407A
- R-407B
- R-407C
- R-407D
- R-407E
- R-407F
- R-408A
- R-409A
- R-409B
- R-410A
- R-410B
- R-411A
- R-411B
- R-412A
- R-413A
- R-414A
- R-414B
- R-415A
- R-415B
- R-416A
- R-417A
- R-418A
- R-419A
- R-420A
- R-421A
- R-421B
- R-422A
- R-422B
- R-422C
- R-422D
- R-423A
- R-424A
- R-425A
- R-426A
- R-427A
- R-428A
- R-429A
- R-430A
- R-431A
- R-432A
- R-433A
- R-434A
- R-435A
- R-436A
- R-436B
- R-437A
- R-438A
- R-441A
- R-442A (RS-50)
- R-443A
- R-444A (AC5)
- R-500
- R-501
- R-502
- R-503
- R-504
- R-507A
- R-508A
- R-508B
- R-509A
- R-510A
- R-512A (Lemy 134)
- R-744
- R-1216
- R-1233zd
- R-1234yf
- R-1234ze
- R-C318
- RE143a (HFE-143m)
- RE245cb2 (HFE-245cb2)
- RE245fa2 (HFE-245fa2)
- RE347mcc (HFE-7000)
- SF6
- SO2 (R-764)
- T2-Butene
- Toluene
- Water
- Xenon

Table based properties (high speed) can be created of all 208 REFPROP-Fluids on demand.

VLEFluid mixtures

Variable mixture calculations:

Fundamental EOS (very detailed, designed for transient simulations):

- Ammonia and Water (Tillner-Roth & Friend)

Cubic EOS:

- Argon
- CO2
- Ethanol
- Hydrogen
- Nitrogen
- Oxygen
- R134a
- Water
- and many more (VDI-Wärmeatlas)

All 208 REFPROP-Fluids with each other

Liquids Available thermophysical properties

Interface for incompressible liquids

The following liquid properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- specific isobaric heat capacity
- isobaric thermal expansion
- coefficient
- derivative of density with respect to specific enthalpy
- prandtl number
- thermal conductivity
- dynamic viscosity

As a function of:

- p, h
- p, T

Available Liquids

Polynomial fits, 1-dimensional, temperature dependent:

- Addinol XW15
- Glysantin (30%-60%)
- Oil Aral 0W30
- Oil 15W40
- Propylenglykol (30%-50%)
- SHC_XMP320 (Syntetic gear oil)
- Therminol 59
- Therminol 66
- Therminol D12
- Tyfocor 30
- Tyfocor 45
- Tyfocorl 33
- Water
- Zitrec M10
- Zitrec M20

All liquid mediums listed in VDI-Heat Atlas

Gases Available thermophysical properties

Interface for gases and gas-vapor mixtures

The following gas properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- mass fraction
- mole fraction
- average molar mass

- specific isobaric/isochoric heat capacity
- isobaric thermal expansion coefficient
- isothermal compressibility
- speed of sound
- relative humidity

- derivative of density with respect to specific enthalpy
- derivative of density with respect to pressure
- derivative of density with respect to mass fraction
- partial pressure of components
- mass fraction of gasoues condensing component

- prandtl number
- thermal conductivity
- dynamic viscosity

- Saturation properties

As a function of:

- p, h, xi
- p, T, xi
- p, s, xi

with xi=1 for a single component

Available pure gases

Approaches with EOS (high accuracy and fast):

- Dry Air
- Exhaust Gas
- Diesel Exhaust Gas

VDI-Guideline 4670:

- Dry Air
- Nitrogen
- Oxygen
- Argon
- Neon
- Water
- Carbon Dioxide
- Carbon Monoxide
- Sulphur Dioxide

All 275 mediums listed in VDI-Heat Atlas

All 2024 mediums listed by NASA Glenn coefficients

Gas mixtures

Variable gas mixture calculations with independent library choice (All pure gases can be mixed with each other):

- Approaches with EOS
- VDI-Guideline 4670
- VDI-Heat Atlas (275 media)
- NASA Glenn coefficients (2024 media)

Moist Air   Available thermophysical properties

Interface for moist air (specialized form of gas mixture)

The following moist air properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- molar mass

- specific isobaric heat capacity
- specific isochoric heat capacity
- partial pressures
- (saturation) water mass fraction
- (saturation) water content
- (saturation) humidity ratio
- relative humidity
- specific enthalpy 1+x
- specific enthalpy of pure gas
- specific enthalpy of vaporisation
- specific enthalpy of desublimation

- prandtl number
- thermal conductivity
- dynamic viscosity
- freezing point
- speed of sound
- mass fraction
- gaseous mass fraction

- isobaric thermal expansion coefficient
- isothermal compressibility
- density derivative WRT mass fraction
- density derivative WRT pressure
- density derivative WRT specific enthalpy

As a function of:

- p, h, xi
- p, s, xi
- p, T, xi
- p, T, humRatio
- p, T, phi

Available Moist Air

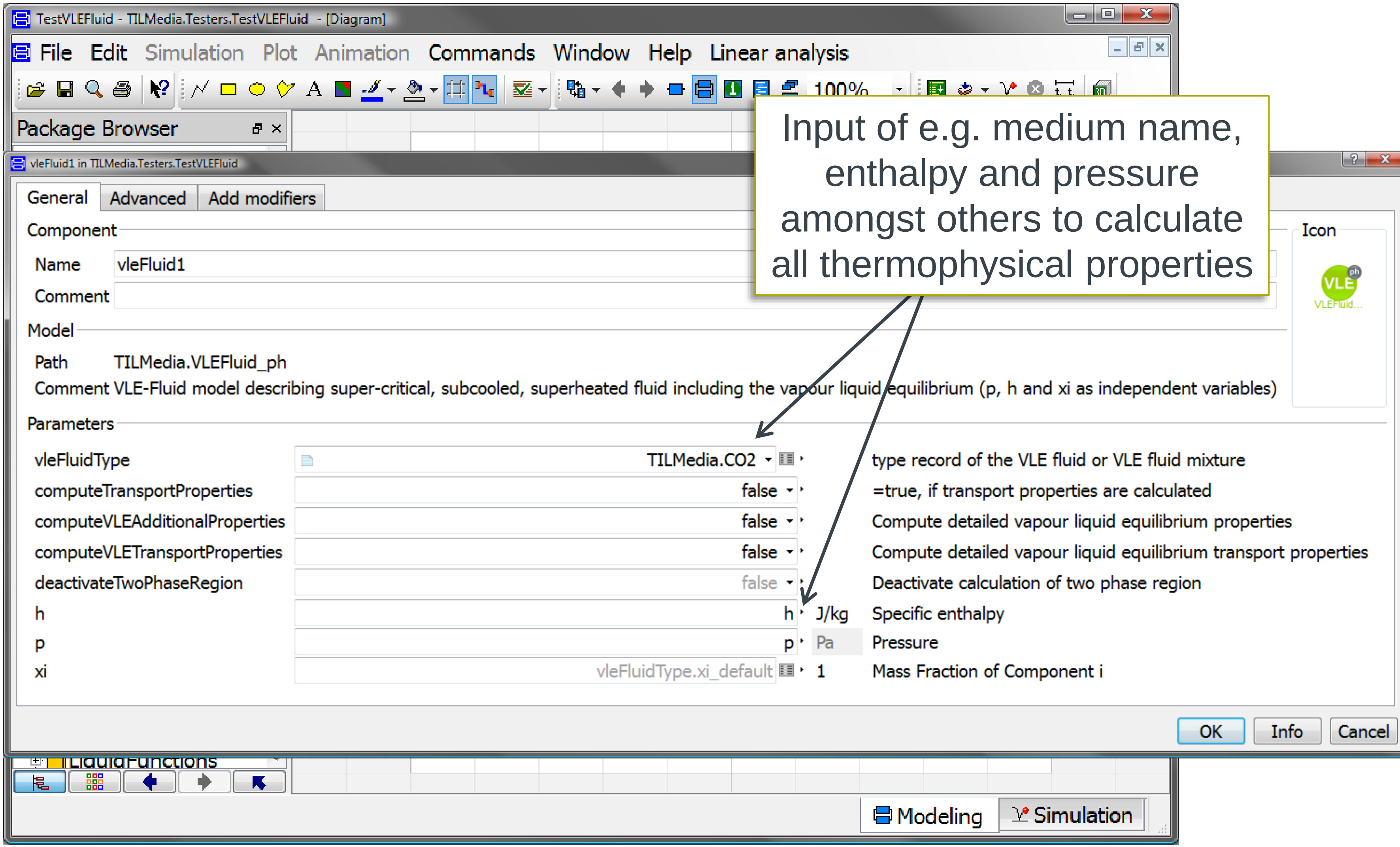
Moist Air – TLK and IfT:

- Gas vapor mixture
- Heat capacity of water is considered as constant
- Condensing and ice build up realized by constant enthalpy of evaporation and constant enthalpy of fusion
- Transport properties equal to those of dry air

VDI-Guideline 4670 for Moist Air and combustion gases:

- Gas vapor mixture
- Condensing and ice build up realized by temperature dependent enthalpy of evaporation and temperature dependent enthalpy of fusion
- Transport properties equal to those of dry air

Example in Modelica



Input of e.g. medium name, enthalpy and pressure amongst others to calculate all thermophysical properties

Example in MATLAB

Anwendungserweiterung
- TILMediaMatlab321x64.dll
- TILMediaMatlab321Win32.dll

C/C++ Header
- TILMediaHeader4Matlab.h
- portable.h

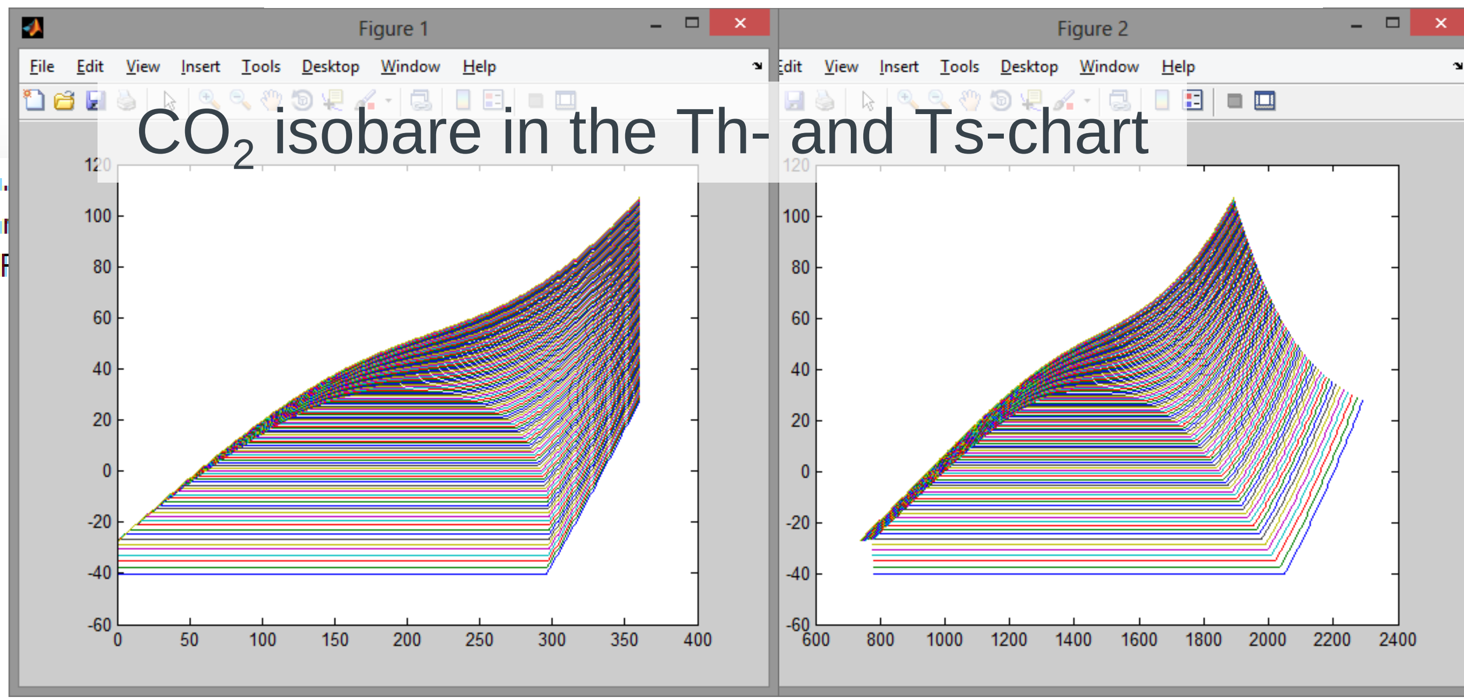
Class
- VLEFluid.m
- MoistAir.m
- Liquid.m
- Gas.m

Function
- loadTILMedia.
- checkInputVar
- calcCompute

```matlab
% Choise of substance:
vle_name = 'CO2';
% Input of enthalpy- and pressure-range:
h_vle = [140:1:500]'*1e3;
p_vle = [10:1:120]*1e5;
```

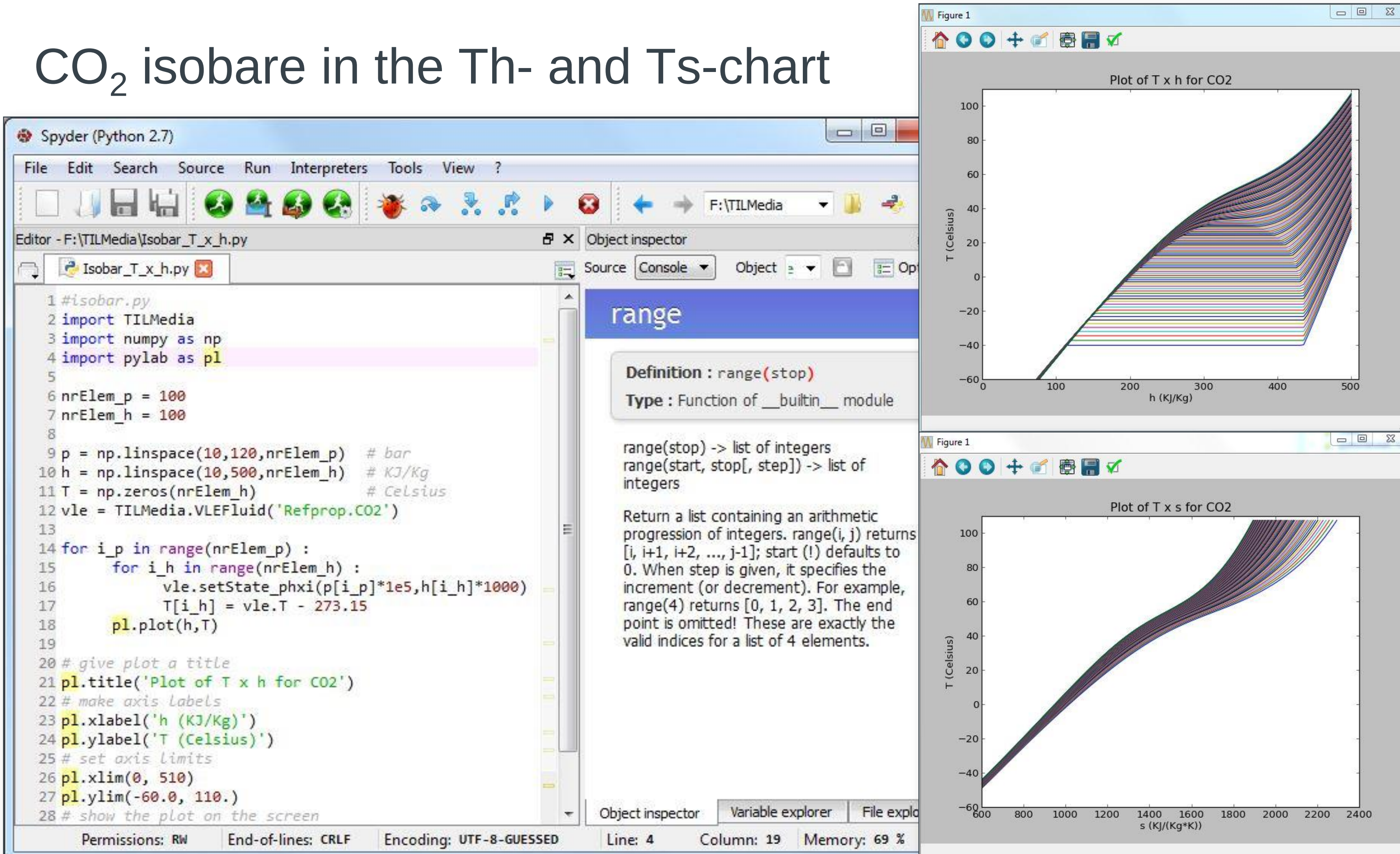
```matlab
% TILMedia-functions:
vle = VLEFluid();
vle = vle.setVLEFluidType(vle_name,1);
% Calculation-loop for thermophysical properties:
for i=1:length(p_vle)
    vle = vle.setState_phxi(p_vle(i)*ones(length(h_vle),1),h_vle);
    T_vle = [T_vle,vle.T];
    s_vle = [s_vle,vle.s];
end
```

CO_2 isobare in the Th- and Ts-chart

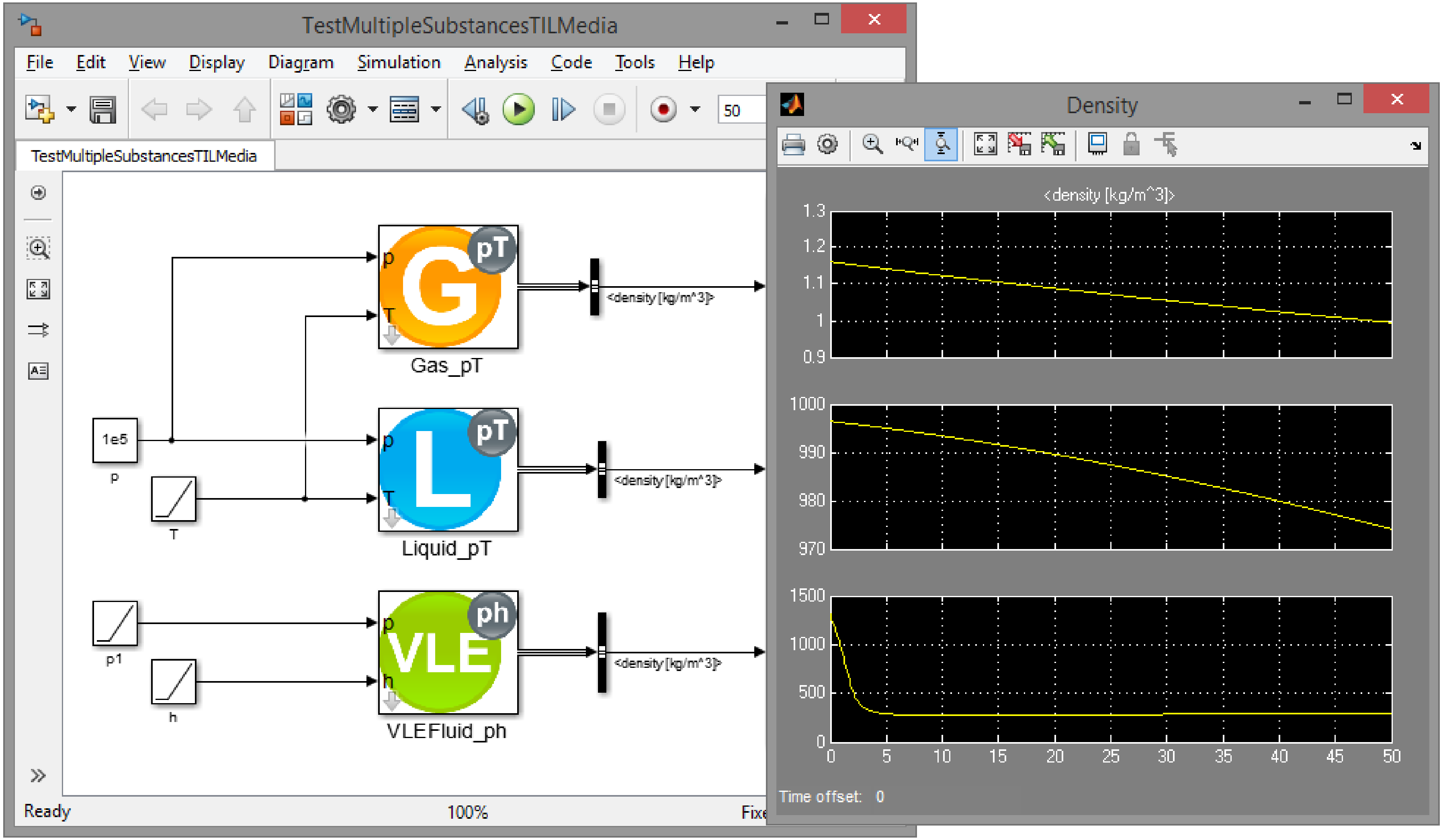


Example in Python

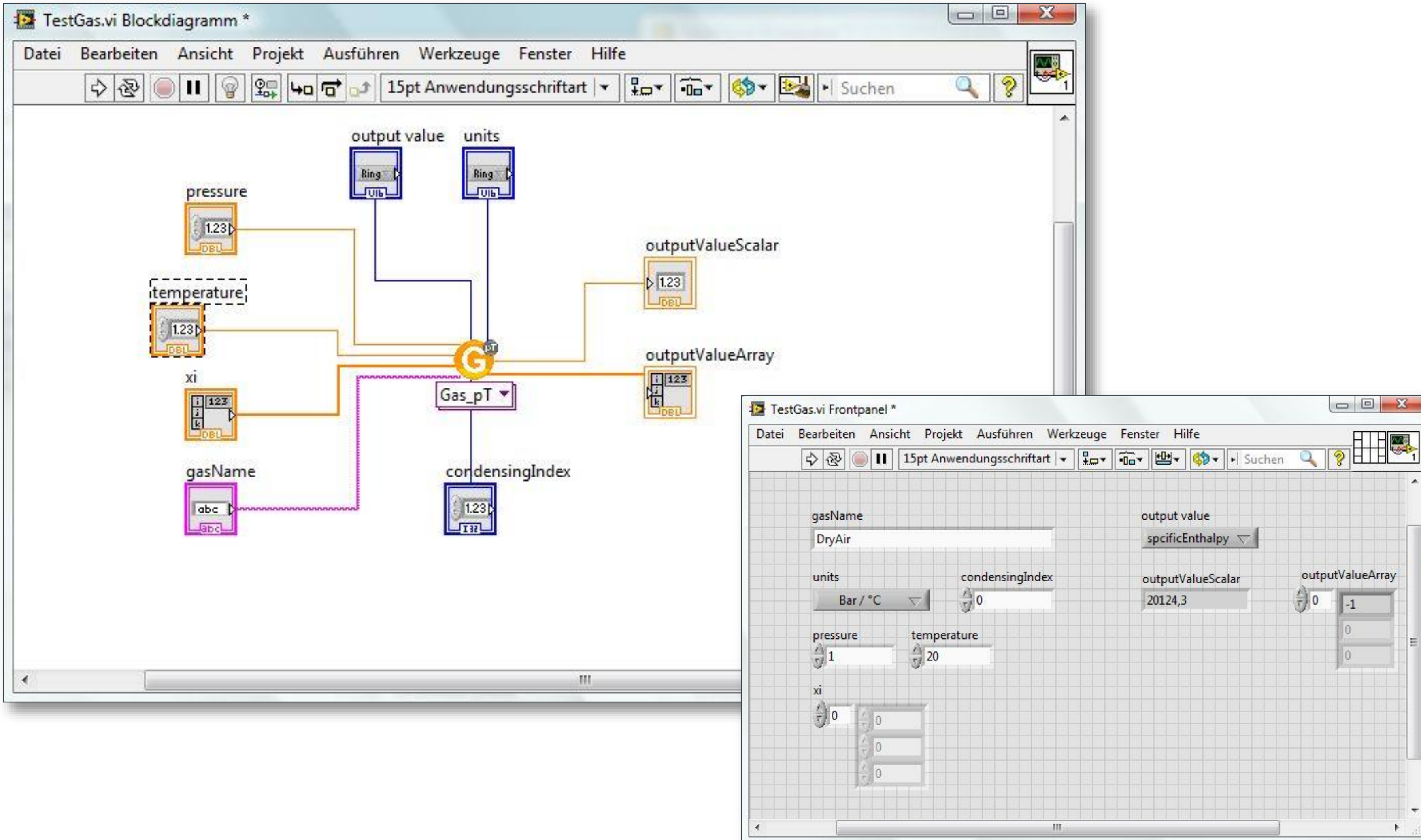
CO_2 isobare in the Th- and Ts-chart



Example in Simulink



Example in LabVIEW



Example in Excel

BEREICHE | =Liquid_density_T(A3;C5)

	A	B	C	D
1	**Description**	**Variable**	**Value**	**Unit**
2	**Inputs:**			
3	Glysantin_50			
4	Pressure	p	1.01E+05	Pa
5	Temperature	T	300	K
6	**Calculation:**			
7	Density	rho	=Liquid_density_T(A3;C5)	
8	Entropy	s	-567.3796701	J/(kg K)
9	Enthalpy	h	89323.76775	J/kg
10	Specific isobaric heat capacity	cp		
11	Isobaric thermal expansion coefficient	beta		
12	Dynamic viscosity	eta		
13	Thermal conductivity	lambda		
14	Prandtl number	Pr		

Calculation of density of water-glycol 50:50 at 300 K (and normal pressure)

Funktionsargumente

Liquid_density_T

LiquidName: A3 = "Glysantin_50"

T: C5 = 300

= 1065.506241

'Density' in [kg/m^3] as a function of T.

LiquidName Liquid name.

Formelergebnis = 1065.506241

Hilfe für diese Funktion

OK | Abbrechen

Examples using Windows COM-Interface

Visual Basic for Applications (VBA) and Visual Basic Script (VBS)

```
'creating two variables
Dim obj, msg As String
'creating a liquid-object
Set obj = CreateObject("TILMedia.Liquid")
'set medium to water-glycol-mixture 50:50
Call obj.setLiquidType("Glysantin_50")
'calculating properties with pressure = 1
      bar and temperature = 300 K
Call obj.setState_pTxi(1e5, 300)
'constructing a message:
msg = "The density of Glysantin_50 is "
      + str(obj.d)
msg = msg + " under the conditions
      pressure = " + str(obj.p)
msg = msg + " and temperature = "
      + str(obj.T)
MsgBox msg 'displaying a message
```

DIAdem

```
'loading a data file with values for pressure
      and temperature
Call DataFileLoad(CurrentScriptPath
      &"Example_pT.TDM", "TDM", "Load")
'creating four variables
Dim obj, array_p, array_T, chnName_d(0)
'creating a vector-liquid-object
Set obj = CreateObject("TILMedia.VectorLiquid")
'set medium to water-glycol-mixture 50:50
Call obj.setLiquidType("Glysantin_50")
'store pressure values of channel to array
array_p = ChnToValue("channelName_p")
'temperature values from channel to array
array_T = ChnToValue("channelName_T") Call
'calculating properties with pressure and
      temperature array in SI units
obj.setState_pTxi(array_p, array_T)
'set new channel name (vector) to "density"
chnName_d(0) = "density"
'saving density values in channel
Call ArrayToChannels(obj.d, chnName_d, true)
```

red colored = DIAdem-specific functions

Thank you

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If you have any questions,
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