Modelling Solar Thermal Systems

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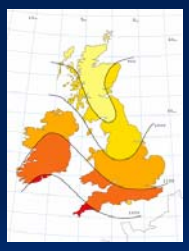

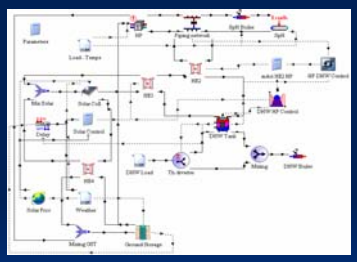

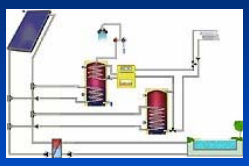

Outline

- Who am I ?
- Solar thermal systems
- Different tools for different purposes
- Sensitivity to input data
- Conclusions

Who am I ?

- Mechanical-Electrical engineer
- PhD in environmental sciences
  - Passive/active solar buildings
  - Model-based optimal control
- Consulting engineer
  - Low energy buildings, solar thermal systems
- TRNSYS coordinator
  - Modelling, simulation software development
- Post-doc researcher / lecturer
  - Net-zero energy houses, solar thermal, geothermal
- Lecturer

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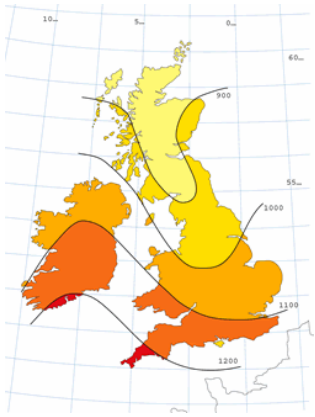
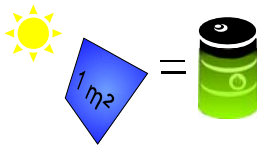
1. Solar Thermal Systems

Solar Resource

- A (very) little bit of background
  - UK: 900 to 1200 kWh/m^2-y (South, ∠ 30°)
  - 90 to 120 litres of oil per m^2 per year
    - 1 barrel = 159 litres



[Solar Trade Association, 2007]



- "Typical" UK house
  - ~3 persons
  - 3000 kWh/y DHW
  - 14000 kWh/y SpH

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Solar Thermal Systems

- Applications
  - Domestic Hot Water
  - Space heating (Combi-systems)
  - Other applications
    - Swimming pools
    - Process heat
    - Cooling

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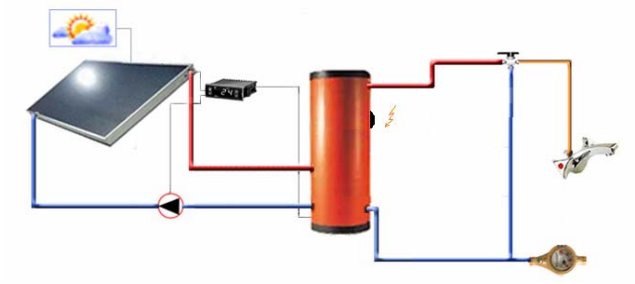
Solar Domestic Hot Water



- Most frequent application
- Small (housing) applications
  - Standard systems
  - "Design" = choosing a system
  - Retrofit sometimes more challenging
- Larger applications (housing, hotels, hospitals, etc.)
  - "Design" = figure out the DHW load, the roof space and the budget
  - Combination of standard components

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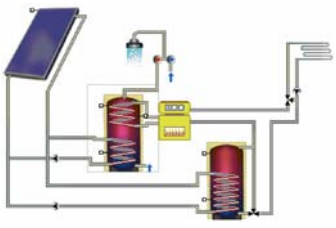
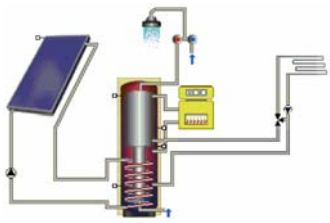
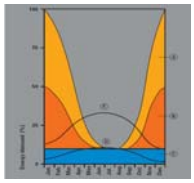
SDHW + Space Heating

(Combi-systems)





- Popular in Austria, Germany
  - Some interest in CH, NL, DK, SE, FR, etc.
- The basic problem
  - Demand <> Supply
  - Storage (typically few days)
  - Summer stagnation
- Standard systems
  - Components: advanced storage tanks
  - Design guidelines (IEA Task 26)
  - Integrated in design and optimisation tools



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Other applications

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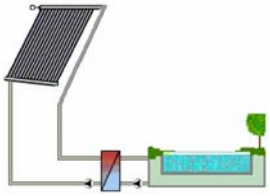
- Swimming pools
  - Unglazed collectors
  - Combined (glazed)
  - Standard systems
  - Included in design tools



- Other applications
  - Solar cooling
  - District heating (with long-term storage)
  - Hybrid geothermal systems
  - Process heat
  - Drying
  - Etc.

Most of the time, no dedicated design tool

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2. Different Simulation Tools

Different tools for different purposes

- Pre-feasibility and Feasibility study
  - ***Restcreen, F-chart, web tools***
- Design of standard systems (DHW, space heating and swimming pools)
  - ***Web tools***, ***T*Sol express, manufacturer tools***
- System design and optimisation (various applications)
  - ***T*Sol, Polysun, TRNSYS***
- Component design and optimization
  - ***TRNSYS, dedicated (proprietary) tools***
- Detailed simulation, highly customized systems and applications
  - ***TRNSYS, other component-based tools***

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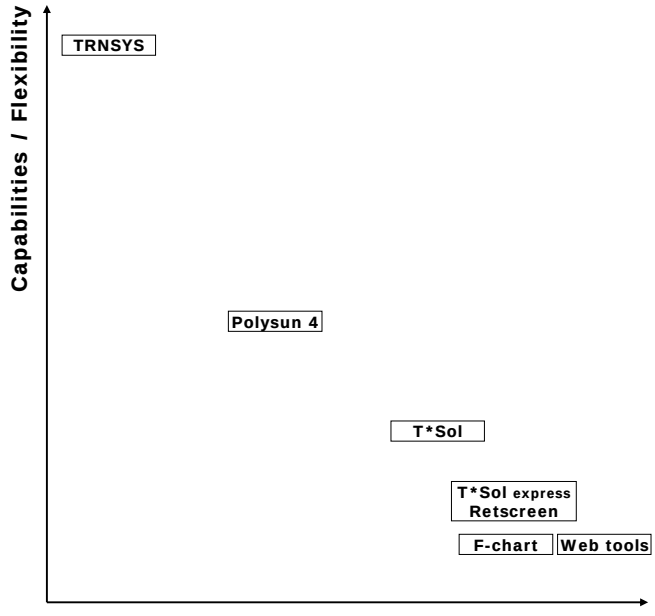
I want to be able to do everything...

What's the cost?



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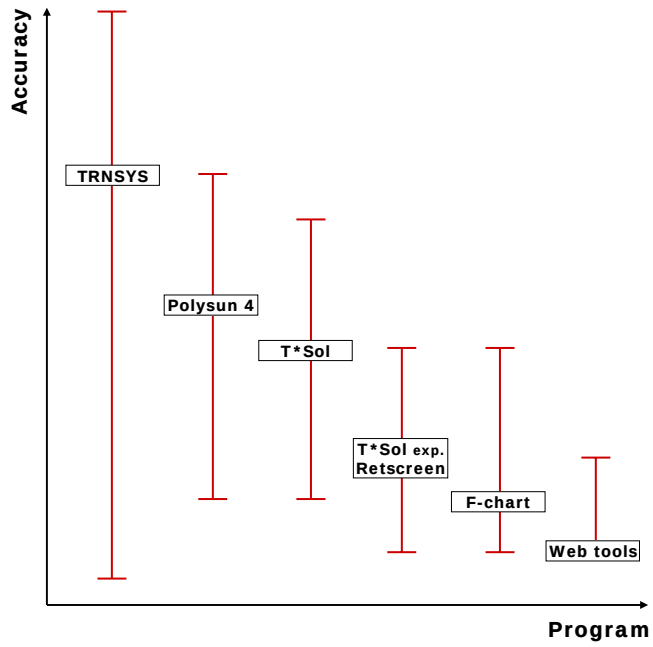
What about "accuracy" ?



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3. Let's play !

Web-based tools

- Sponsored by government agencies, utilities, manufacturers, software developers

Examples

- Sol-gain (ESE, manufacturer)
  - www.ese-solar.com
  - Many default values
  - Pre-feasibility for general public
- "Online T*Sol" (Valentin software)
  - www.valentin.de
  - Allows combisystems, different types of solar collectors, etc.
  - Some design freedom
  - User level: general public+
- Example of missing feature: shading

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Pre-feasibility Feasibility

- RETScreen (Natural Resources Canada)
  - "Clean Energy Project Analysis Tool"
  - Free (Excel-based)
  - Solar Hot Water module
    - Monthly weather data
    - Based on the F-chart method
  - Not so many default values
    - Very good manual
  - Output = printed worksheets
  - Cost analysis
  - GHG module

Input data!

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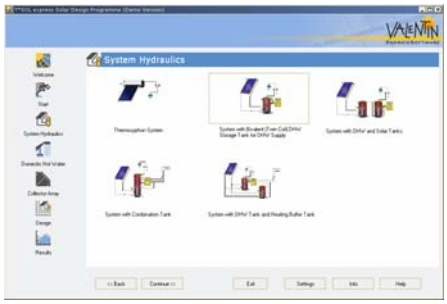
Basic design (feasibility)

- T*Sol express (Valentin EnergieSoftware)
  - Few (5) system designs
    - SDHW, Combisystem
  - Very simple interface
  - Automatic design
    - Storage tank, collector area
  - Simple, "straight-to-the-point" results
  - User level: general public, sales representative



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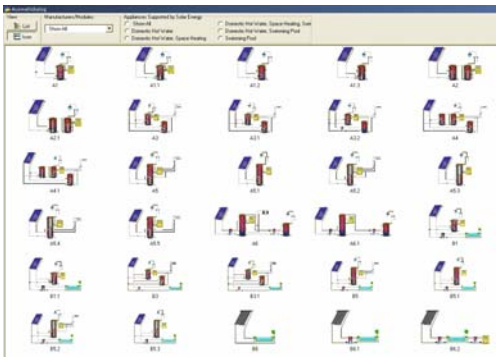
System Design and Optimization

- T*Sol (Valentin EnergieSoftware)
  - More than 30 system designs
    - SDHW, Combisystems, Swimming pools
    - Additional modules
    - Catalogue data
  - More detailed load profile
  - "System dialogs"
    - Solar collectors to boiler, pipes and controls
  - Outputs
    - Daily → yearly values
    - Economic analysis
    - Project report
  - User level:
    - sales representative
    - consultant, …



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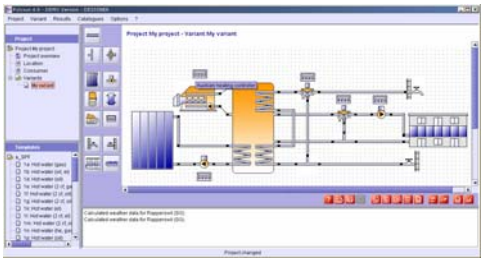
Component-based programs

- Polysun (SPF, Switzerland)
  - New with version 4
  - Approach similar to T*Sol but ability to modify systems
  - Different levels of users
    - Light
    - Professional
    - Designer
  - Extensive catalogue data
  - Outputs
    - Report generator
    - Economics
    - Etc.
  - Black-box
    - Components
    - System Simulation (e.g. long simulation runtime)



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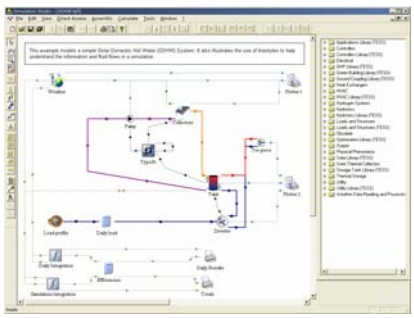
Highly customizable programs

- TRNSYS (Univ. of Wisconsin-Madison, Transsolar, CSTB)
  - Fortran calculation engine ("kernel" and components)
  - Visual interfaces (system, building)
  - Very flexible, steep learning curve
  - Component-based
    - Fortran
    - Other language (drop-in DLL's)
    - Other programs
      - Matlab, Excel, EES, etc.
  - Available components
    - Standard library
    - TESS libraries
    - Other non-standard components



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TRNSYS

- Inputs
  - Any weather / load / etc. data file
- Outputs
  - Online plot (debugging, immediate feedback)
  - Text files
  - No post-processing
- Standards
  - TRNSYS is the reference tool for SRCC ratings in the US
  - TRNSYS is mentioned in European standards on solar thermal systems (e.g. ENV-12977-2)
  - Most other tools (e.g. Polysun and T*Sol) present "validation results" against TRNSYS

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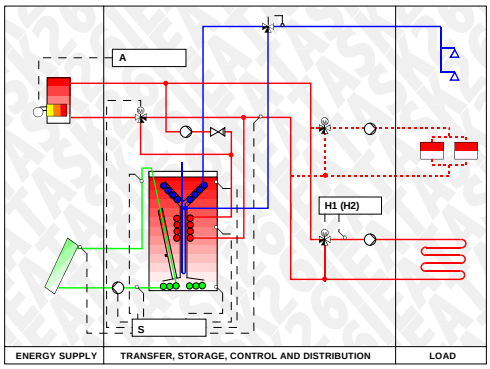
Why / when to use TRNSYS ?

- New components required
- IEA Task 26

#16 Atmospheric Tank with Three Heat Exchangers (Germany)



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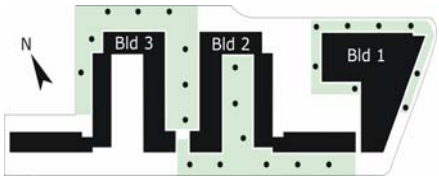
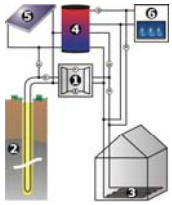
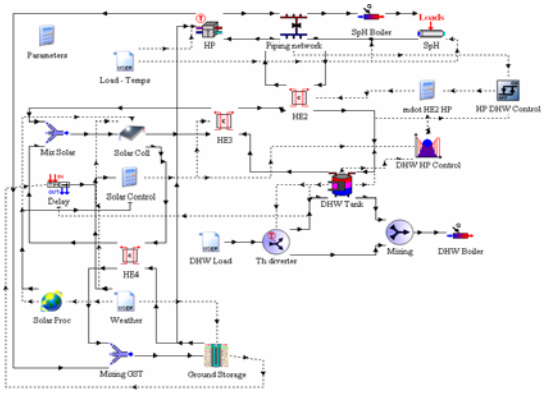
Why / when to use TRNSYS ?

- Flexibility in system designs, combination with other energy systems







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Why / when to use TRNSYS ?

- Need for other capabilities
  - Detailed building loads
  - Links with other programs
    - Or just read a file…
  - Batch runs
  - Optimisation (GenOpt)
  - Distributable applications
  - Re-use existing component models

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Why / when to use TRNSYS ?

- Open nature, "reference software"
  - Code is not "free software" but is visible
- Standard performance of systems on the market
  - According to EN 12976
  - Related to subsidies

SOLTHERM
Simulation des performances annuelles de chauffe-eau solaires

Consommation d'eau chaude à 45°C	80 l/j	140 l/j	200 l/j
Energie nette équivalente (Q_d) [1]	1120 kWh	1960 kWh	2800 kWh

Référence SOLTHERM	Nom commercial	Superficie des collecteurs [2]	Type des collecteurs	Volume de stockage	Energie nette d'appoint ($Q_{aux,net}$) [3]			Offres de prix
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	485 kWh	910 kWh	1410 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	490 kWh	910 kWh	1410 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	565 kWh	1050 kWh	1665 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	580 kWh	1110 kWh	1795 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	595 kWh	1140 kWh	1820 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	620 kWh	1175 kWh	1845 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	650 kWh	1145 kWh	1740 kWh	
FS000-500	SuperSolar 4.44 333	4,44 m²	Plan	333 l	755 kWh	1400 kWh	2170 kWh	

[4] Q_d est la **quantité nette d'énergie contenue dans l'eau chaude consommée annuellement**, exprimée en kWh. Cette quantité ne correspond pas à l'énergie primaire (gaz, mazout) consommée, le rendement de la chaudière intervenant entre les deux

[5] La superficie renseignée pour les collecteurs solaires est la superficie d'entrée, ou d'ouverture optique. Pour un collecteur plan classique, il s'agit de la superficie de la partie visible du vitrage. Celle-ci peut être significativement différente de la superficie brute, ou de la superficie d'absorbeur, qui sont parfois mentionnées dans les documentations commerciales. L'utilisation de la superficie d'entrée permet de comparer tous les systèmes sur une base objective.

[6] $Q_{aux,net}$ est la **quantité nette d'énergie d'appoint annuelle restant à fournir**. Plus elle est faible pour une même consommation journalière d'eau chaude, plus la contribution solaire du système est importante

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Input data

Input data

- Load
  - Domestic hot water load
  - Space heating load
  - Yearly average and profile
    - Time of the day
    - Repeatability
    - Holidays
- Weather data
  - Measured solar radiation not always available
  - Shading (when designed, 20 years later)
- System operation
  - Setpoints
  - Bypasses
  - Hot water recirculating loop
- Component data
  - Performance of solar collectors
  - Storage tanks, piping, pumps, etc.

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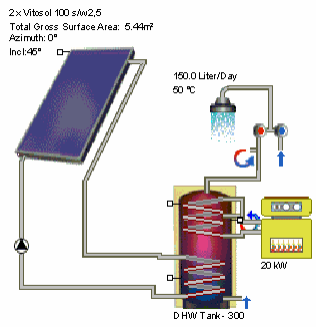
Sensitivity: DHW load

- Base case



  - Solar fraction: 67%
  - Gas saved: 225 m³
  - Net Present Value: -£218
- Load = 100 l/day instead of 150
  - Solar fraction: 75%
  - Gas saved: 190 m³
  - Net Present Value: -£620

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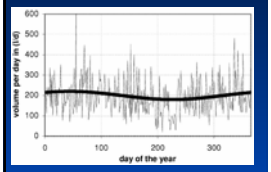
Sensitivity: Load profile



- Some compensating factors
  - If tank warmer, solar collector less efficient
- But
  - Some storage tanks have advanced stratification devices
- Jordan & Vajen, 2000: comparative study
  - Standard draws (prEN12977) at different times
  - Realistic draws
  - Fractional energy savings can go from 0.25 to 0.21 (a 15% difference)
  - Also differences between standard load profiles at different times of the day
    - Best = early afternoon
    - Differences larger when collectors not facing due South

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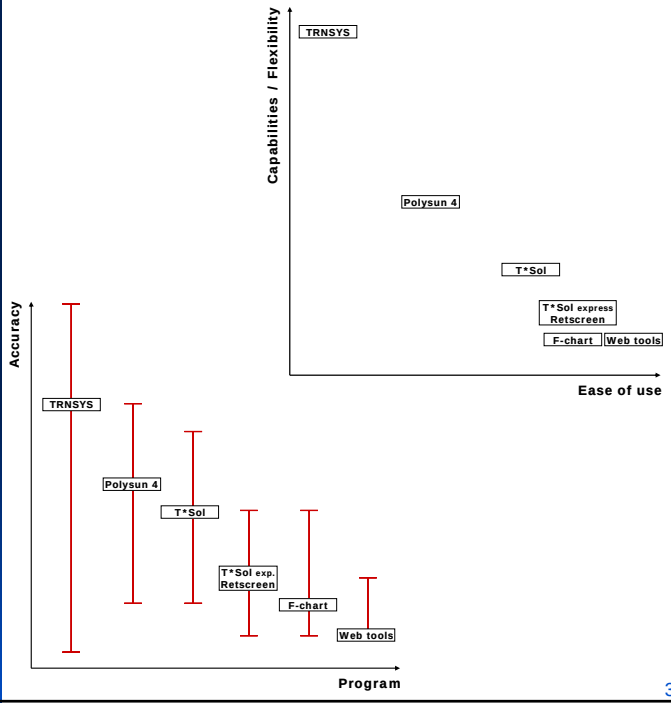
Conclusions



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A few links

- General Solar Thermal Information

IEA Solar Heating and Cooling Programme: www.iea-shc.org/

European Solar Thermal Industry Federation: www.estif.org

Solar Trade Association: www.greenenergy.org.uk/sta/

The SolarServer: www.solarserver.de/index-e.html

- Software developers
  - RETScreen: www.retscreen.net
  - T*Sol: www.valentin.de
  - Polysun: www.spf.ch
  - TRNSYS: sel.me.wisc.edu/trnsys

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A few books

Solar Engineering of Thermal Processes, 3rd Edition
John A. Duffie, William A. Beckman
Wiley, 2006.

Solar Thermal Systems. Successful Planning and Construction.
Felix A. Peuser, Karl-Heinz Remmers, Martin Schnauss
Solarpraxis AG, Berlin, 2002.

Solar Heating Systems for Houses – A Design Handbook for Solar Combisystems (IEA Task 26)
Werner Weiss, Ed.
James and James Science Publishers, 2003.

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