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

1. Solar Thermal Systems
Solar Resource

- A (very) little bit of background
  - UK: 900 to 1200 kWh/m²·y (South, ∠ 30°)
  - 90 to 120 litres of oil per m² per year
    - 1 barrel = 159 litres

  ![Solar Resource Map]

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

Solar Thermal Systems

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

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
### Other applications

- **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**
  - *Restscreen, 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*

### I want to be able to do everything...

**What's the cost?**

[Diagram showing a 2D scatter plot with axes labeled 'Ease of use' and 'Capabilities / Flexibility'. Points labeled 'TRNSYS', 'Polysun 4', 'T*Sol', 'T*Sol express', 'Retscreen', 'F-chart', 'Web tools'.]
What about "accuracy"?

3. Let's play!
Web-based tools

Examples

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

- 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

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!
Basic design (feasibility)

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

System Design and Optimization

- **T*Sol** (Valentin EnergieSoftware)
  - More than 30 system designs
    - SDHW, Combsystems, 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, ...
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)

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
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

Why / when to use TRNSYS?

- New components required
- IEA Task 26

#16 Atmospheric Tank with Three Heat Exchangers (Germany)
Why / when to use TRNSYS?

- Flexibility in system designs, combination with other energy systems

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
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

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.

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
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

Conclusions
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

A few books

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

  Felix A. Peuser, Karl-Heinz Remmers, Martin Schnauss

  Werner Weiss, Ed.