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Evacuated Tubular Collectors

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Background

- 3-year research project
- Part of the research program “Sustainable Arctic Building Technology for the 21st century”
- Funded by the *VILLUM KANN RASMUSSEN FOUNDATION*
- 2/3 through the project

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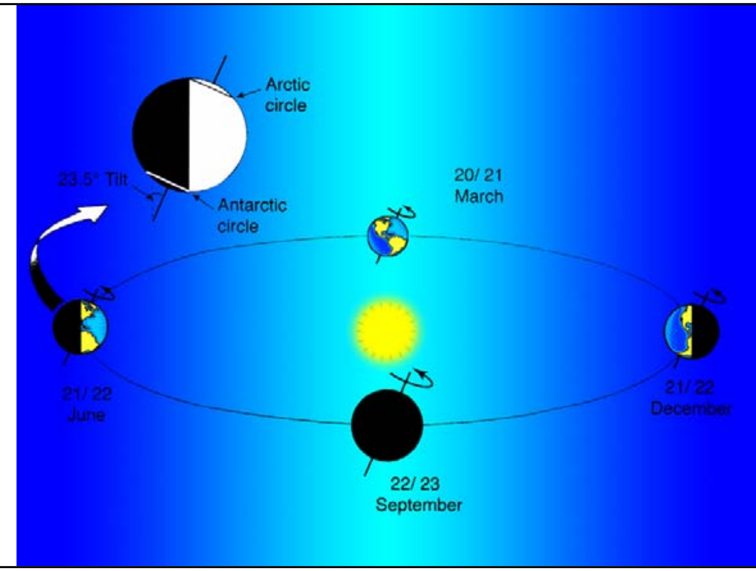
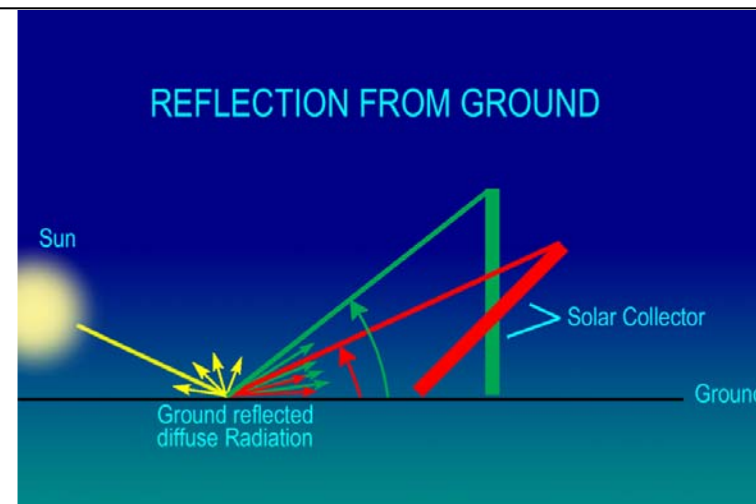
Solar energy at northern latitudes

- Large season variations
- Solar radiation from all directions



- High ground reflections due to snow
- Low ambient temperatures



Available solar radiation at northern latitudes

Solar Radiation on horizontal [kWh/m²/year]

0-800	
800-1000	
1000-1200	
1200-1400	
1400-1600	

Map Source: UNEP/GRID-Arendal, http://maps.grida.no/arctic/

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Solar collectors for northern latitudes

- When solar collectors are developed for northern latitudes, it is an advantage if the collectors:

  ☺ Can utilize solar radiation from all directions

  ☺ Have a low heat loss (due to low ambient temperatures)

  ☺ Utilize ground reflected radiation well (due to large ground reflection coefficient)

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Evacuated tubular collectors

☺ Low heat loss coefficient
- Vacuum insulation

☺ High efficiency
- Due to low heat loss

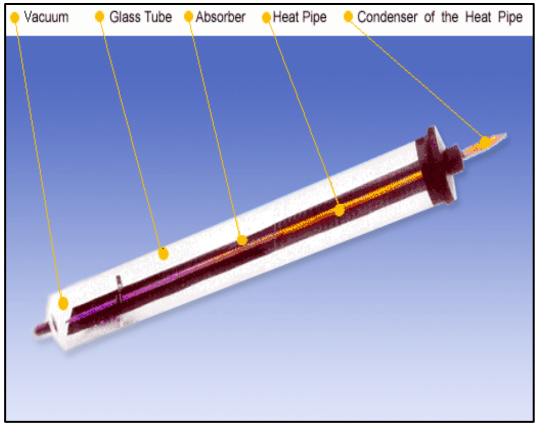
☺ Utilize solar radiation from all directions
- Absorber design

Different principles of evacuated tubular collectors

- Heat pipe evacuated tubular collectors
- All-glass evacuated tubular collectors
- Cheap, mass-produced in China

Two research examples

- Heat pipe evacuated tubular collectors
  - Two different designs in a solar heating plant



- All-glass evacuated tubular collectors
  - Flow and temperature patterns inside the tubes

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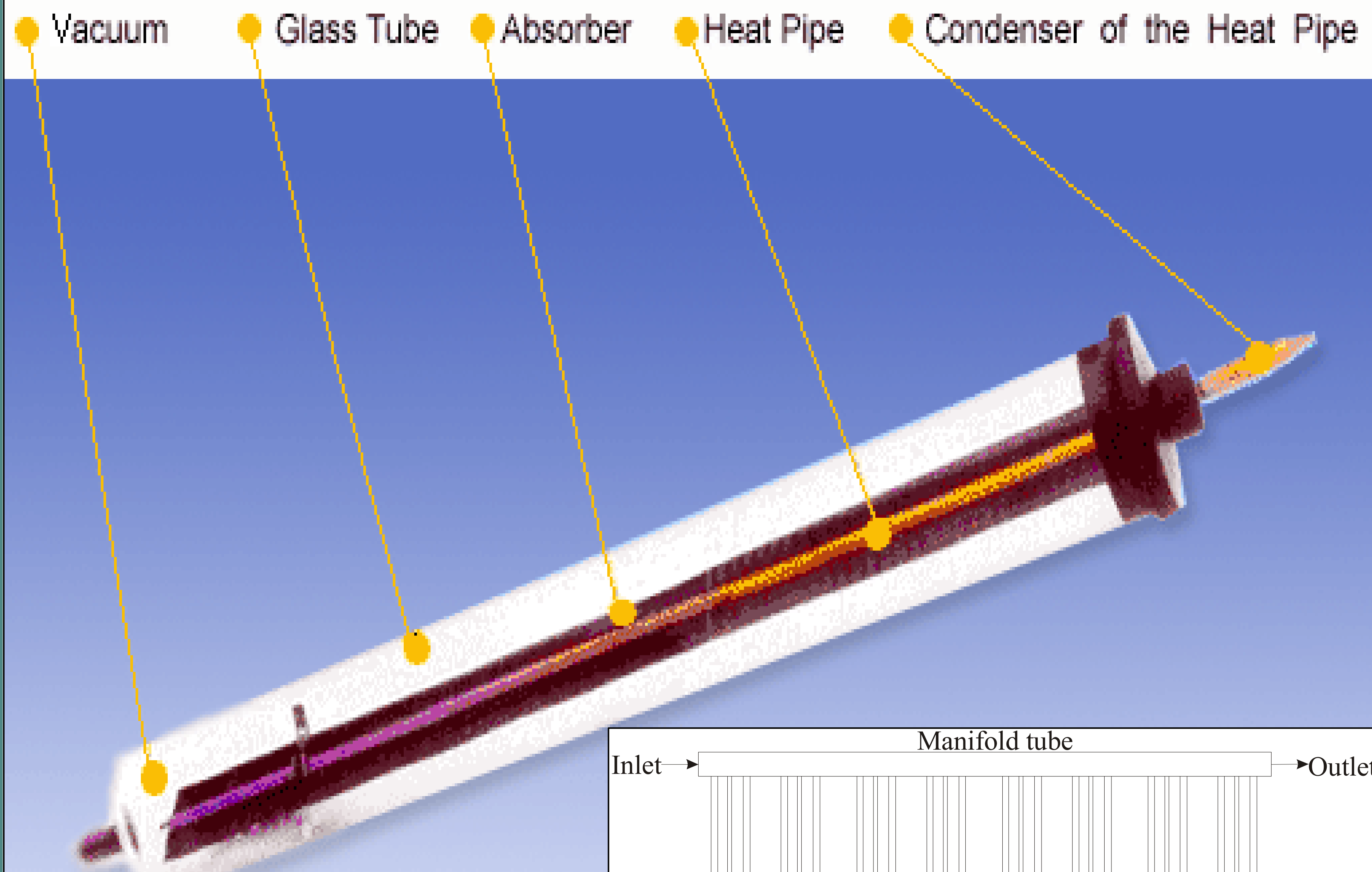
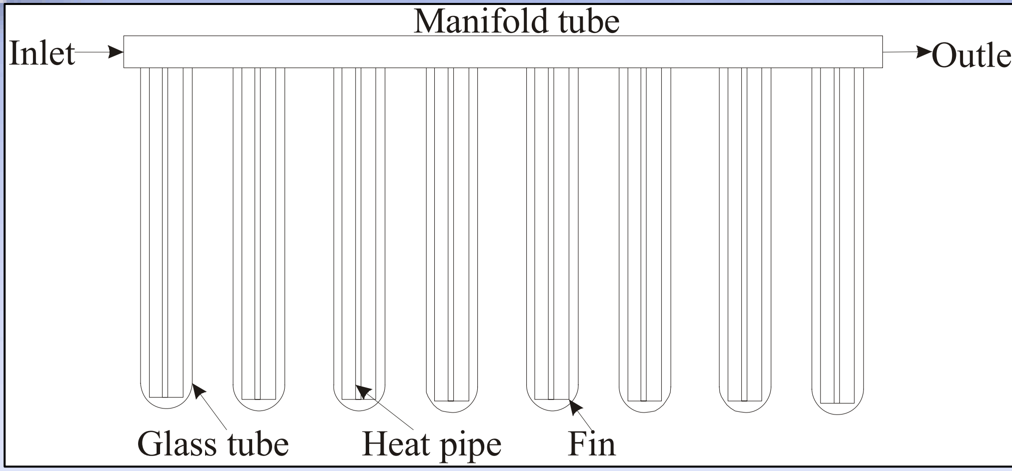
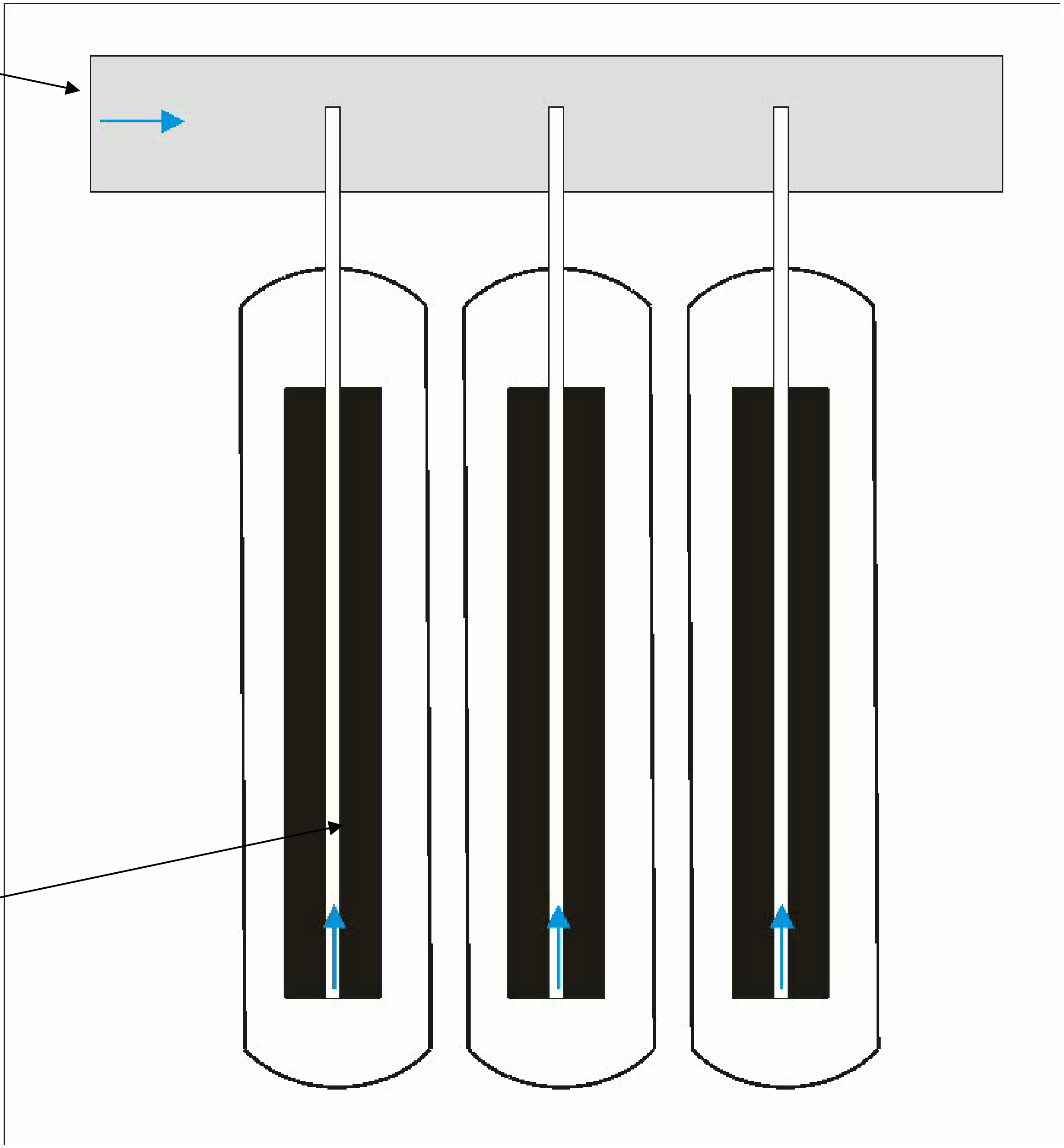


Heat pipe evacuated tubular collectors



Heat pipe principle

Manifold heat exchanger solar collector fluid (propylene glycol/water)



Heat pipe with working fluid (water)

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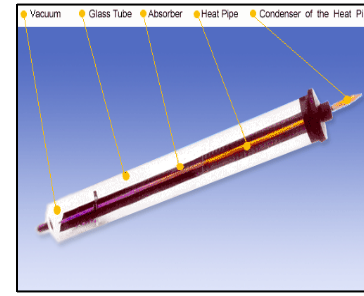
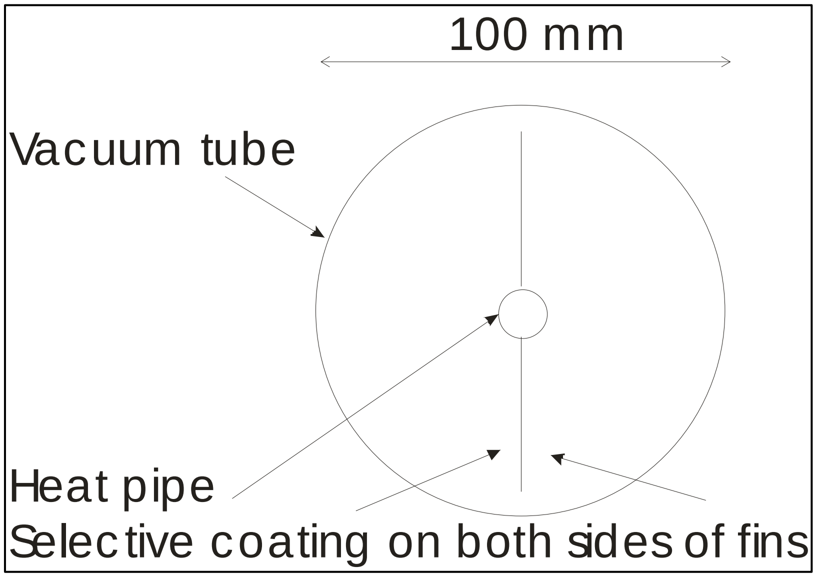
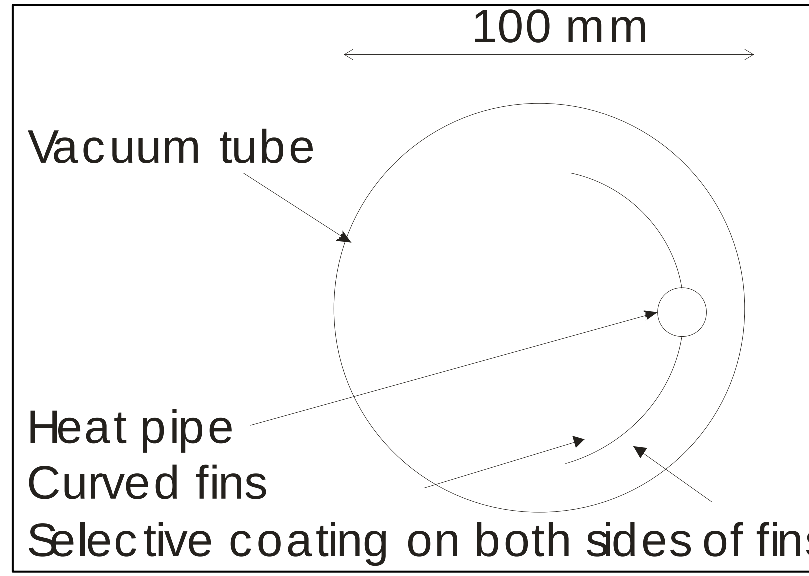
Heat pipe evacuated tubular collectors with flat or curved fins

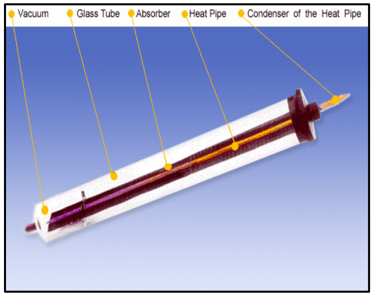


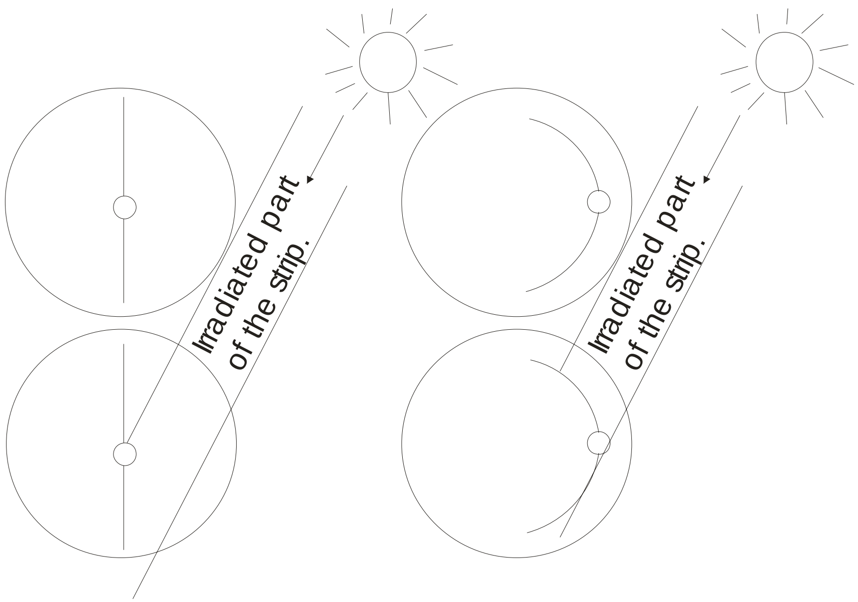




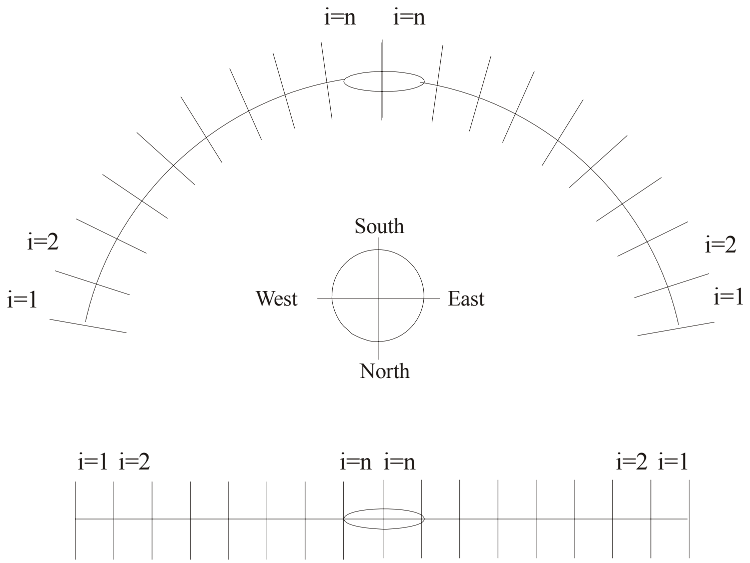
- Research work:
  - New collector theory is developed
  - Calculation yearly thermal performance is now possible
  - Detailed optimization of collector design is now possible

Detailed modeling of shadows temperature distribution





Depending on the position of the sun and the distance between the tubes, the tubes cast shadow on each other



Therefore, the solar irradiance varies along the fin and the fin temperature must be calculated in detail

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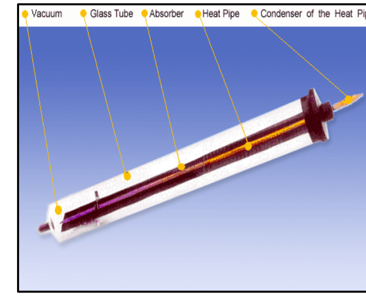
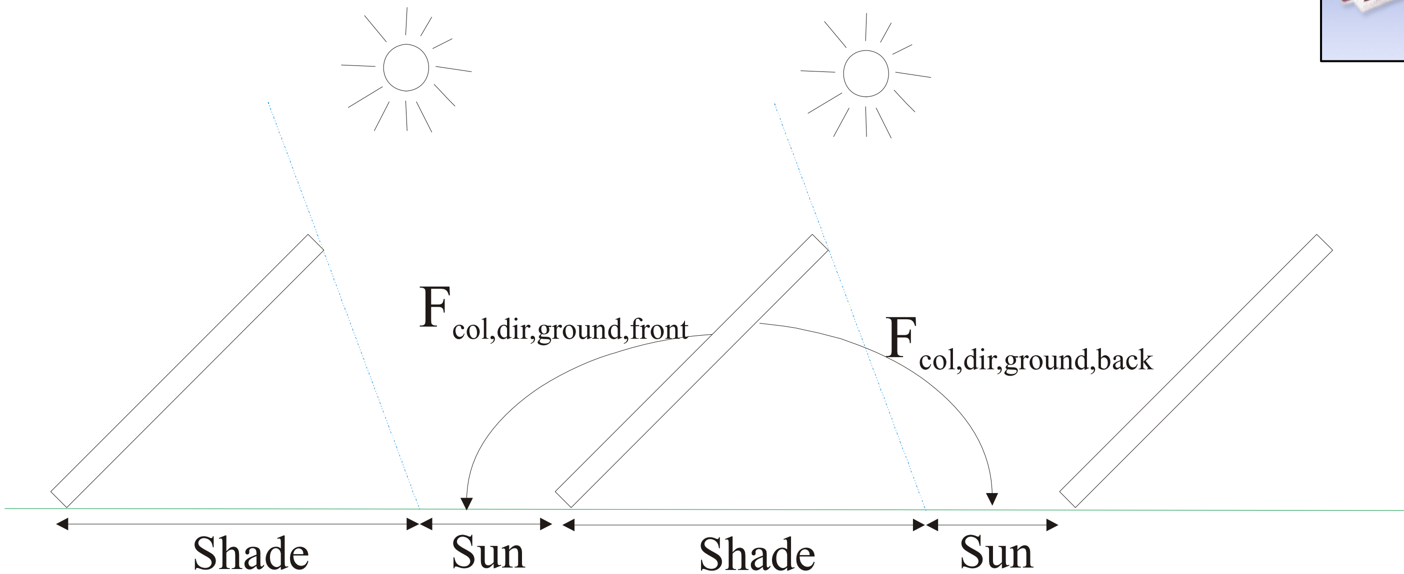
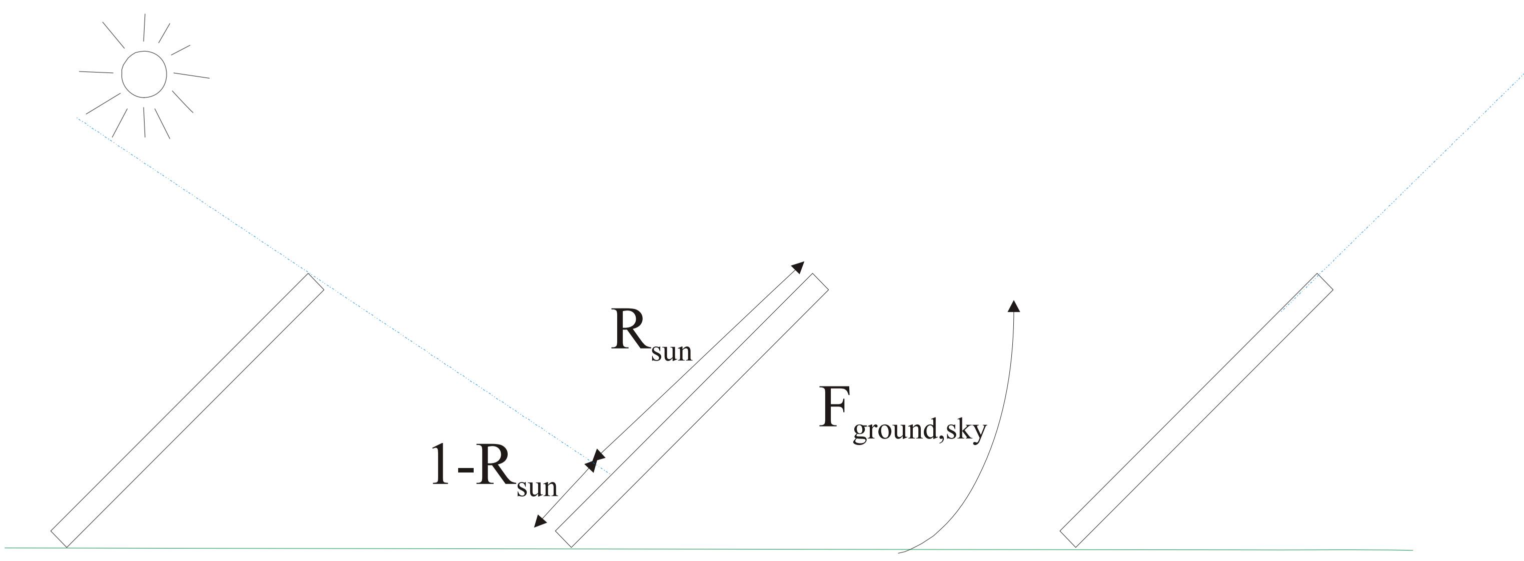
Collector rows and shadows







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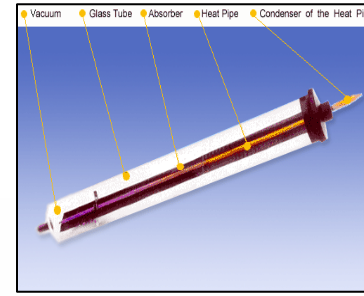
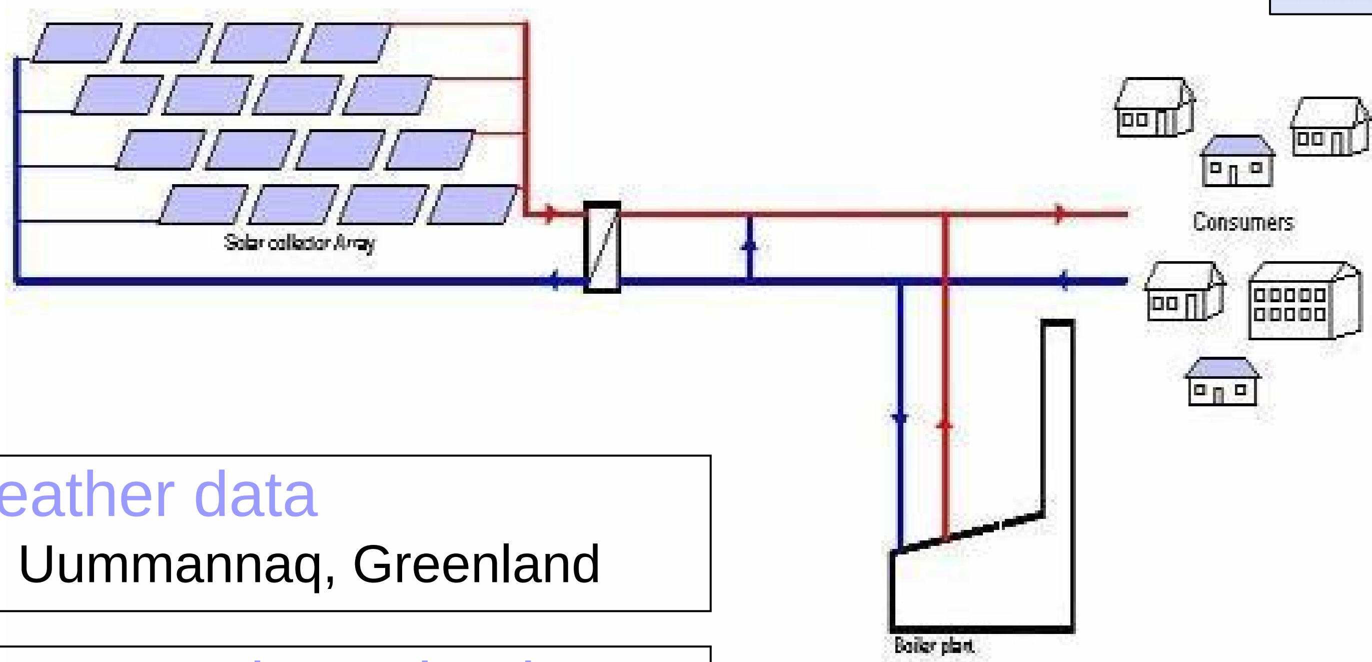
Using the new theory

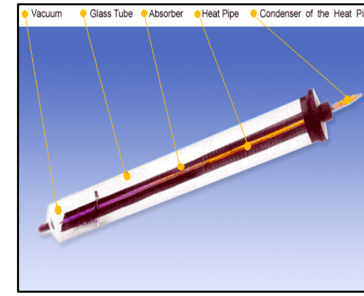
Collector array in a solar heating plant

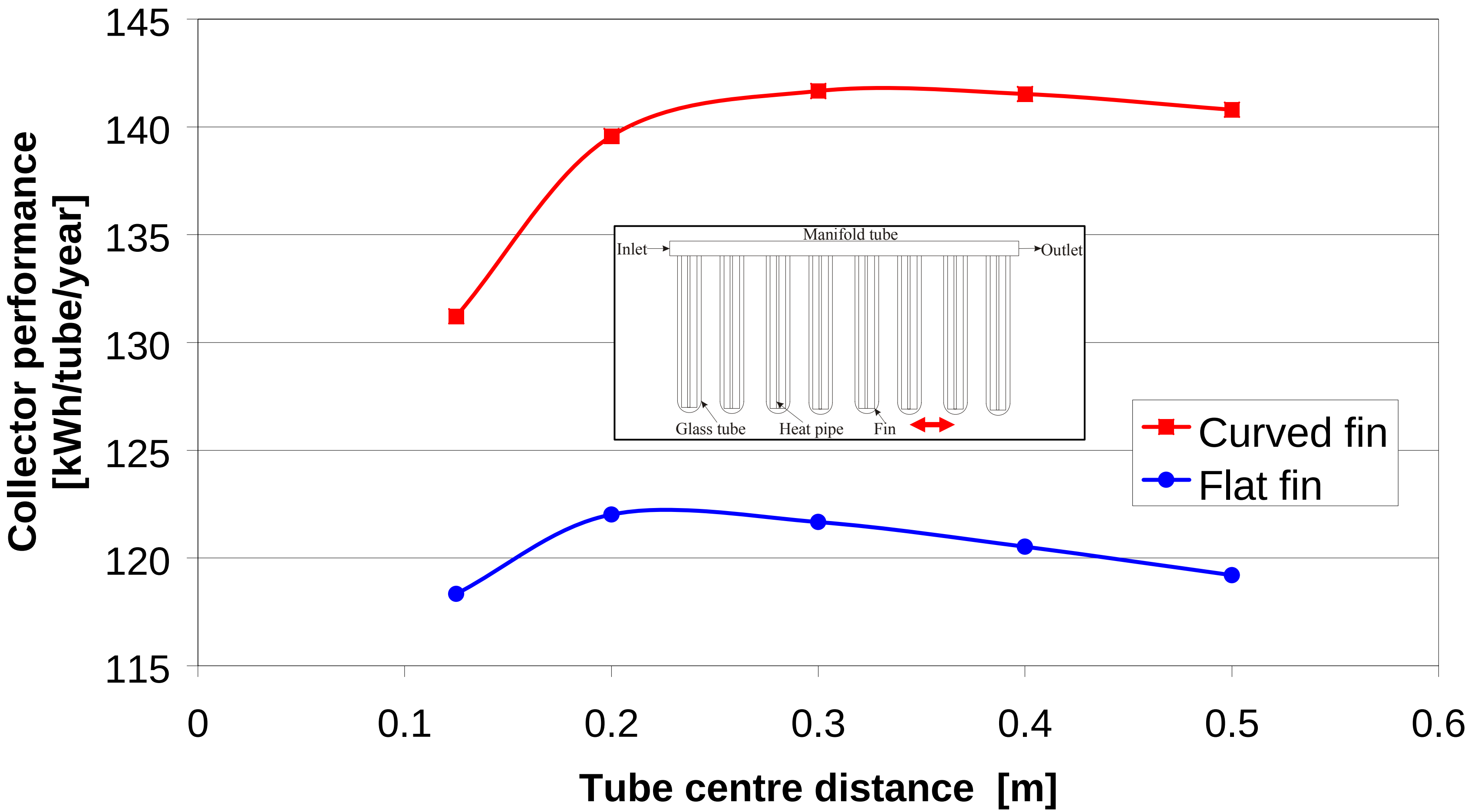




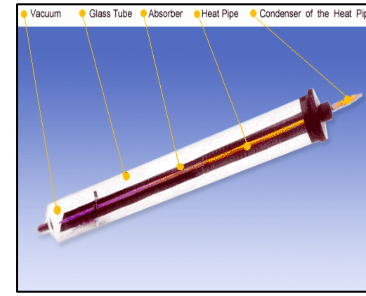
- Weather data
  - Uummannaq, Greenland
- Parameter investigations:
  - Tube centre distance
  - Collector row distances
- Operation data
  - Operating temperature: 50°C
- Collector data
  - Tube length: 2 m
  - Tube diameter: 0.1 m
  - Tilt: 60°, Orientation: South

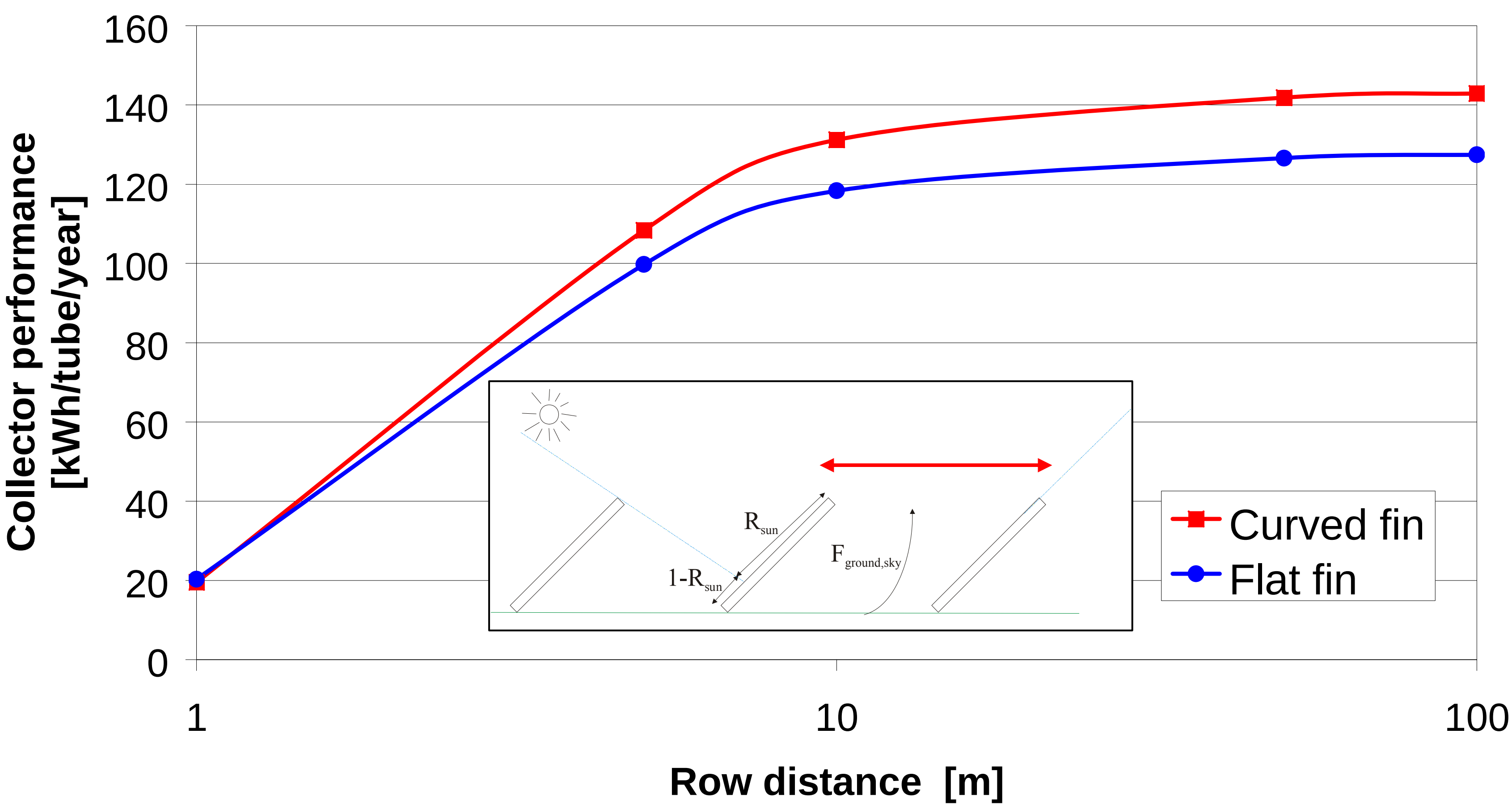
Tube centre distance





Row distance





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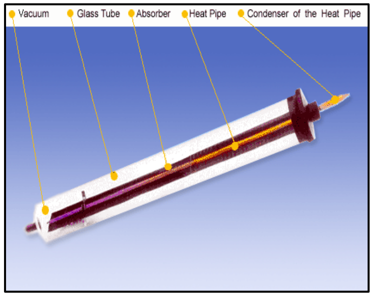
Energy production from a solar collector field



- Collector row distance: 5 m
- Tube centre distance: 0.125 m
- 8000 tubes on a ground array with the size of a football court
- Yearly energy production: 1100 MWh/year
- District heating production in Sisimiut: 25000 MWh/year


Marstal Solar Heating Plant
(~ 10 football courts)

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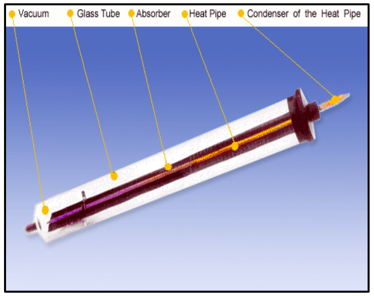
Summary of research example



- New theory for heat pipe evacuated tubular collectors developed
- The theory includes in detail heat transfer processes of the absorber fins
- Detailed optimization of collector design now possible

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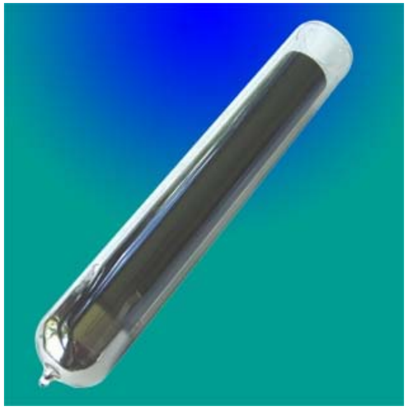
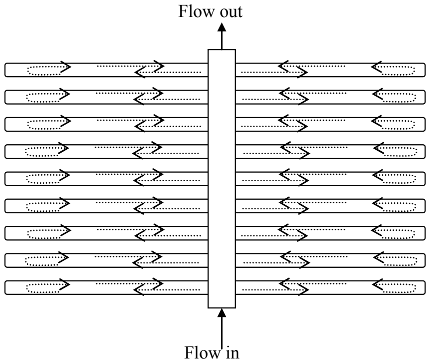
All-glass evacuated tubular collectors

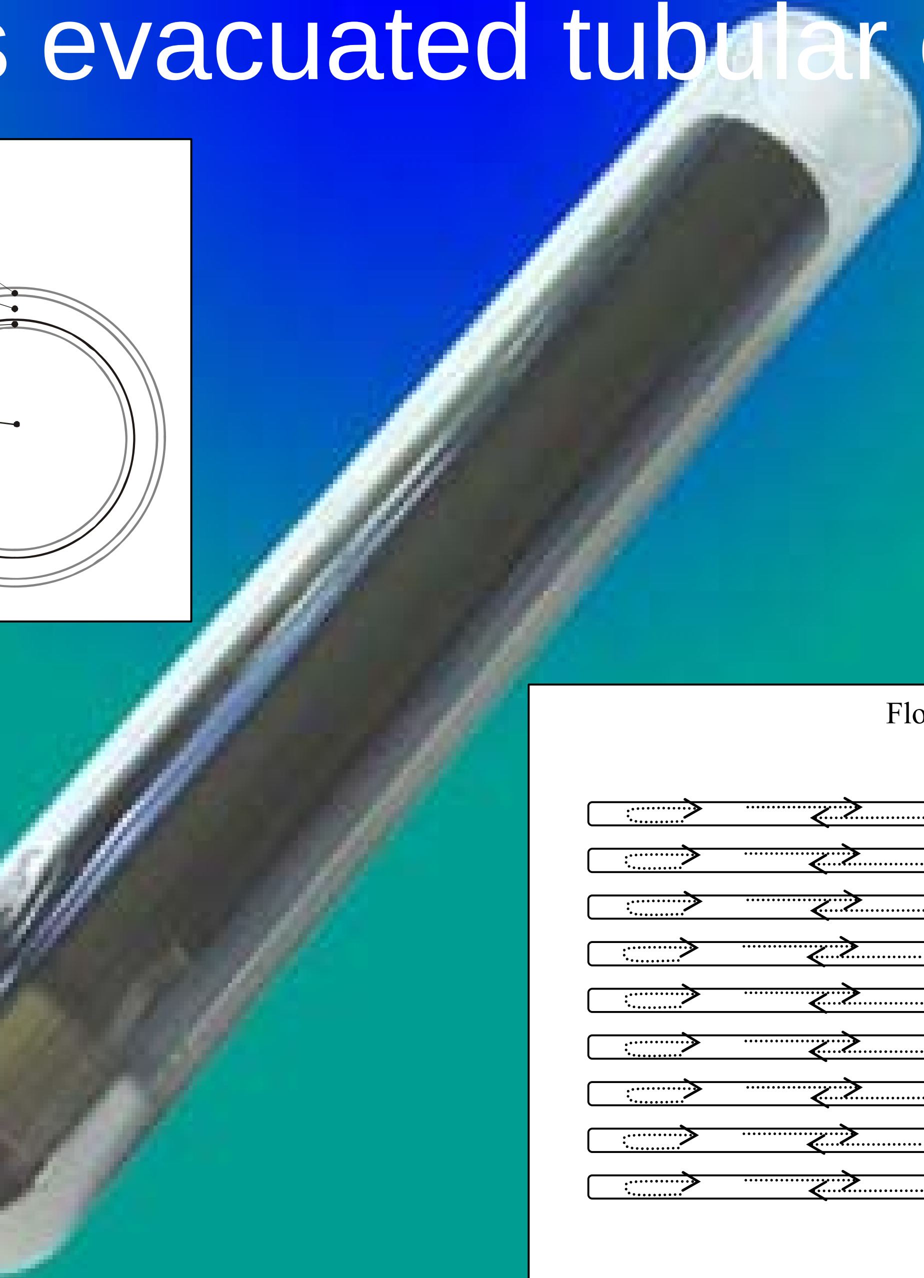
Investigation of flow and temperature patterns inside the tubes

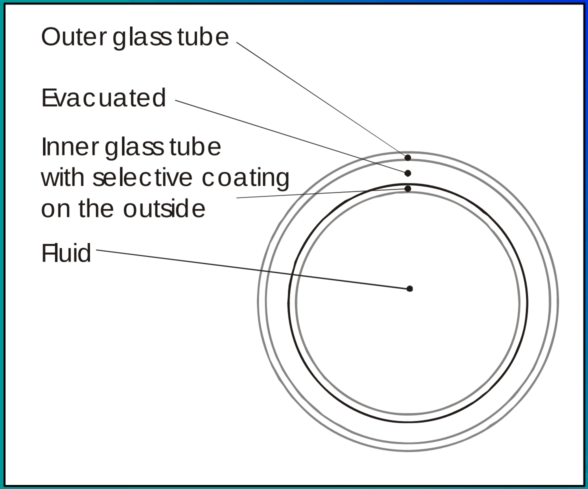
- All-glass collector
- Heat transfer
- Flow structures

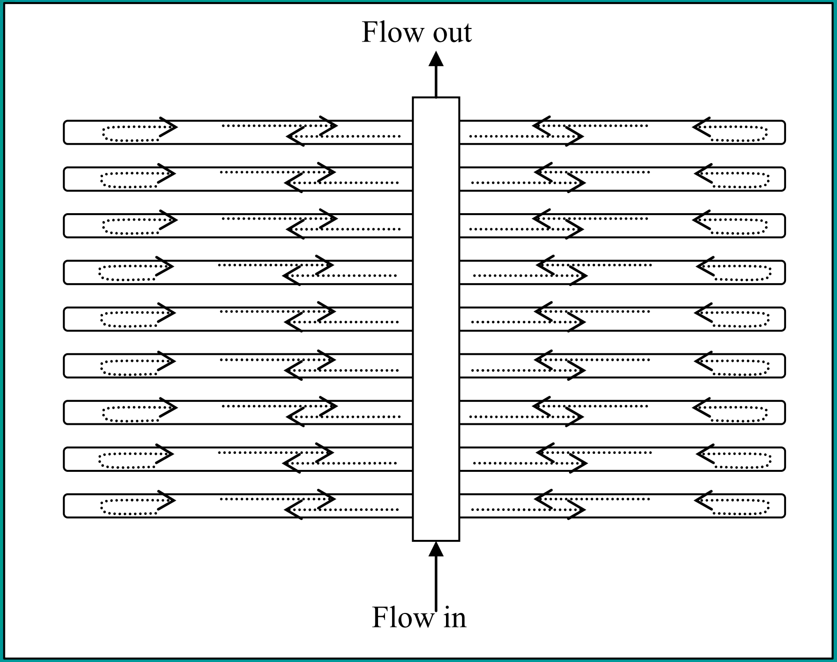




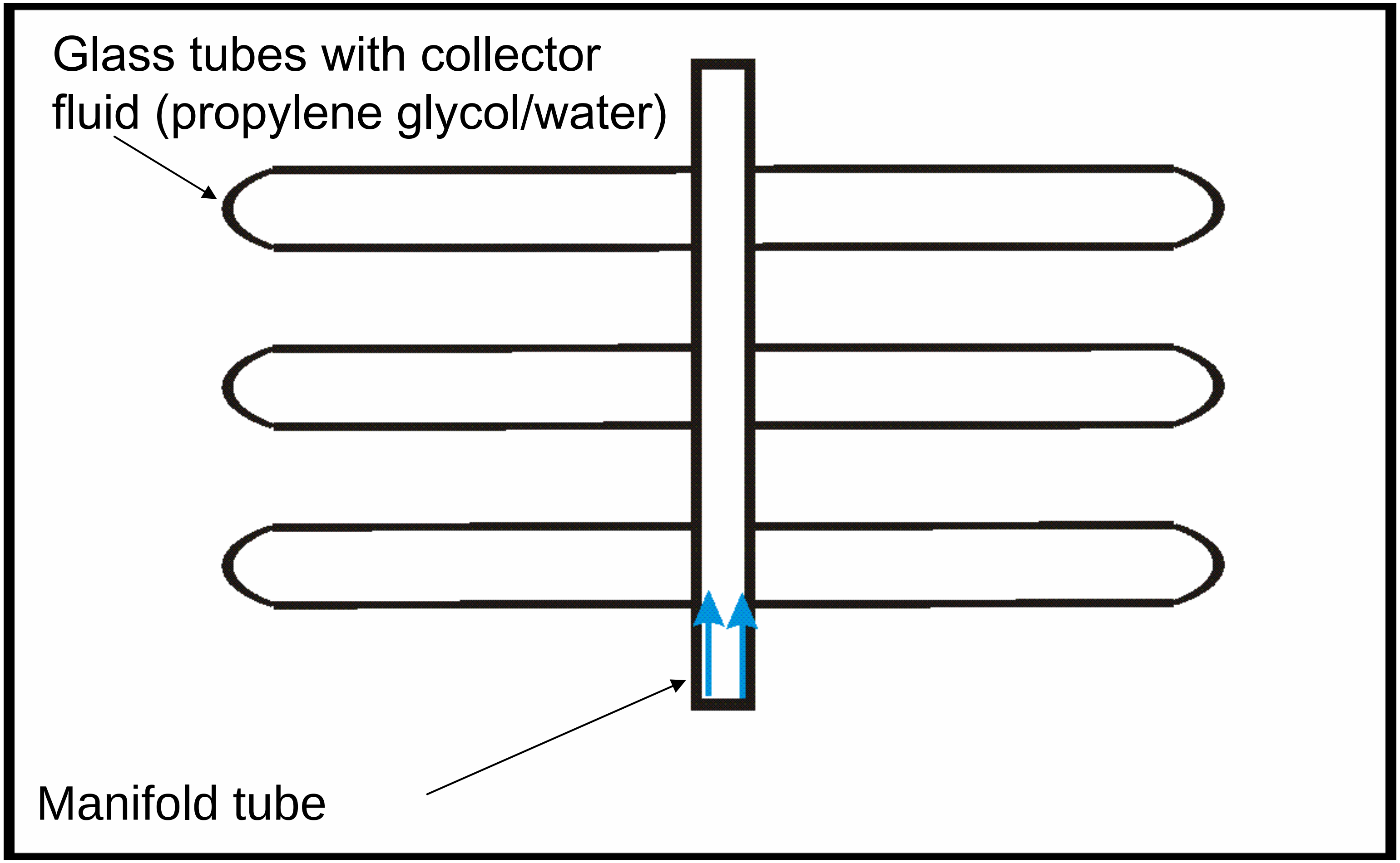
All-glass evacuated tubular collectors



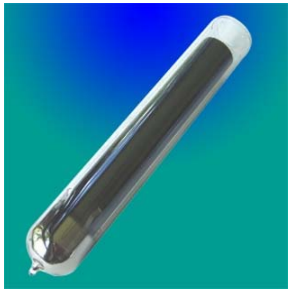




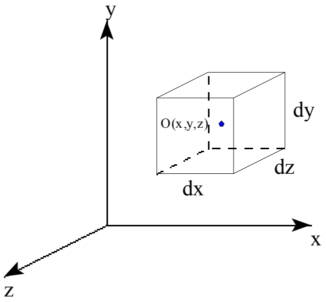
All-glass working principle

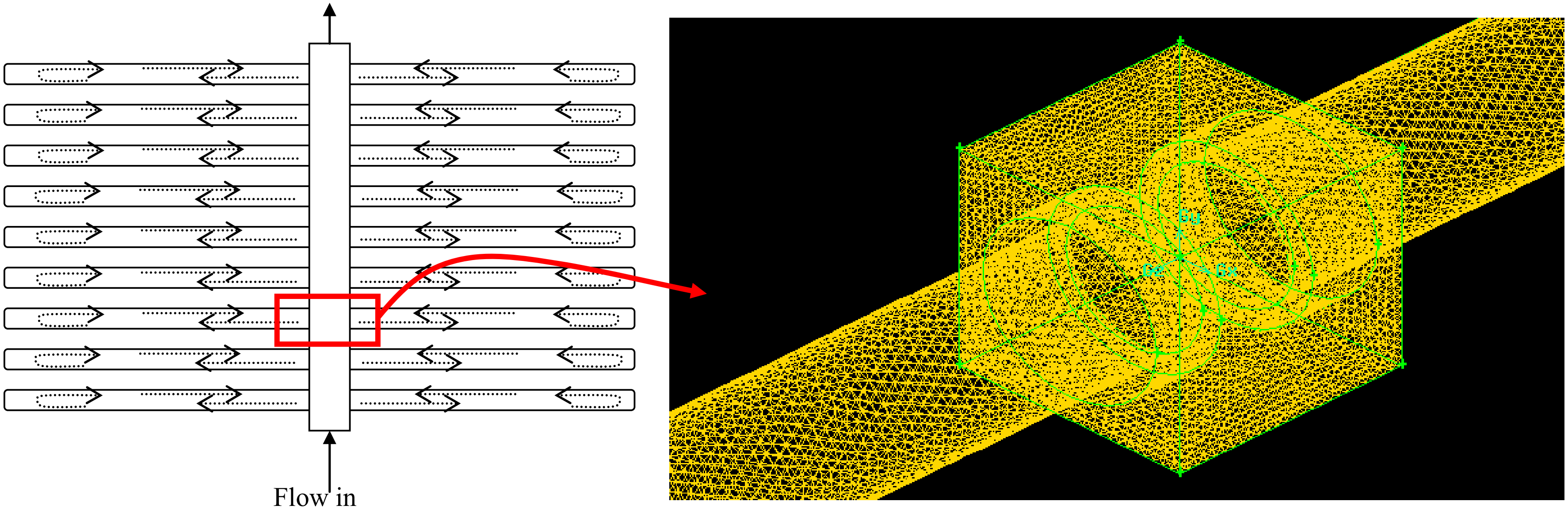


Computational Fluid Dynamics (CFD)

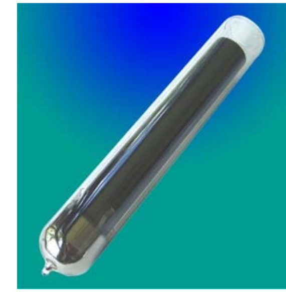


- With CFD temperatures and flow patterns are determined
- A grid is made of the geometry and governing equations of fluid flow are solved numerically



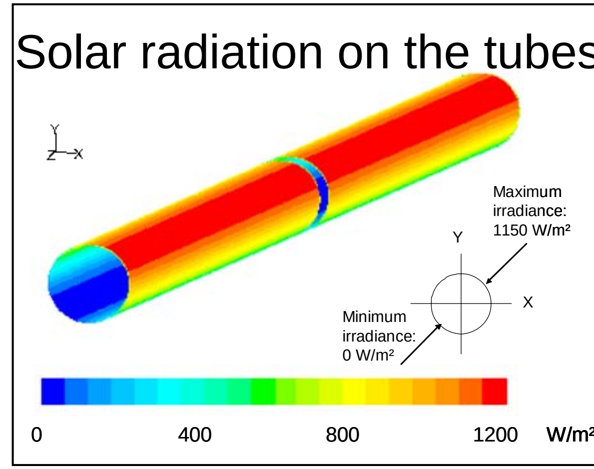


CFD investigations



Calculations:

- 5 different inlet flow rates:
  - 0.05 kg/min – 10 kg/min.
- Inlet temperature: 60 °C
- Typical solar radiation



Results:

- Flow structures
- Influence on collector efficiency

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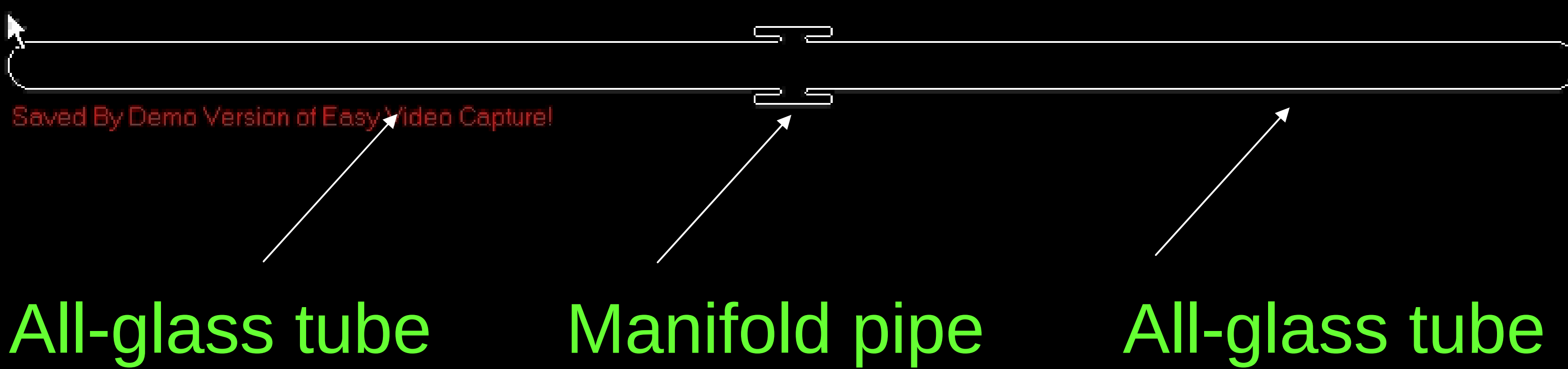
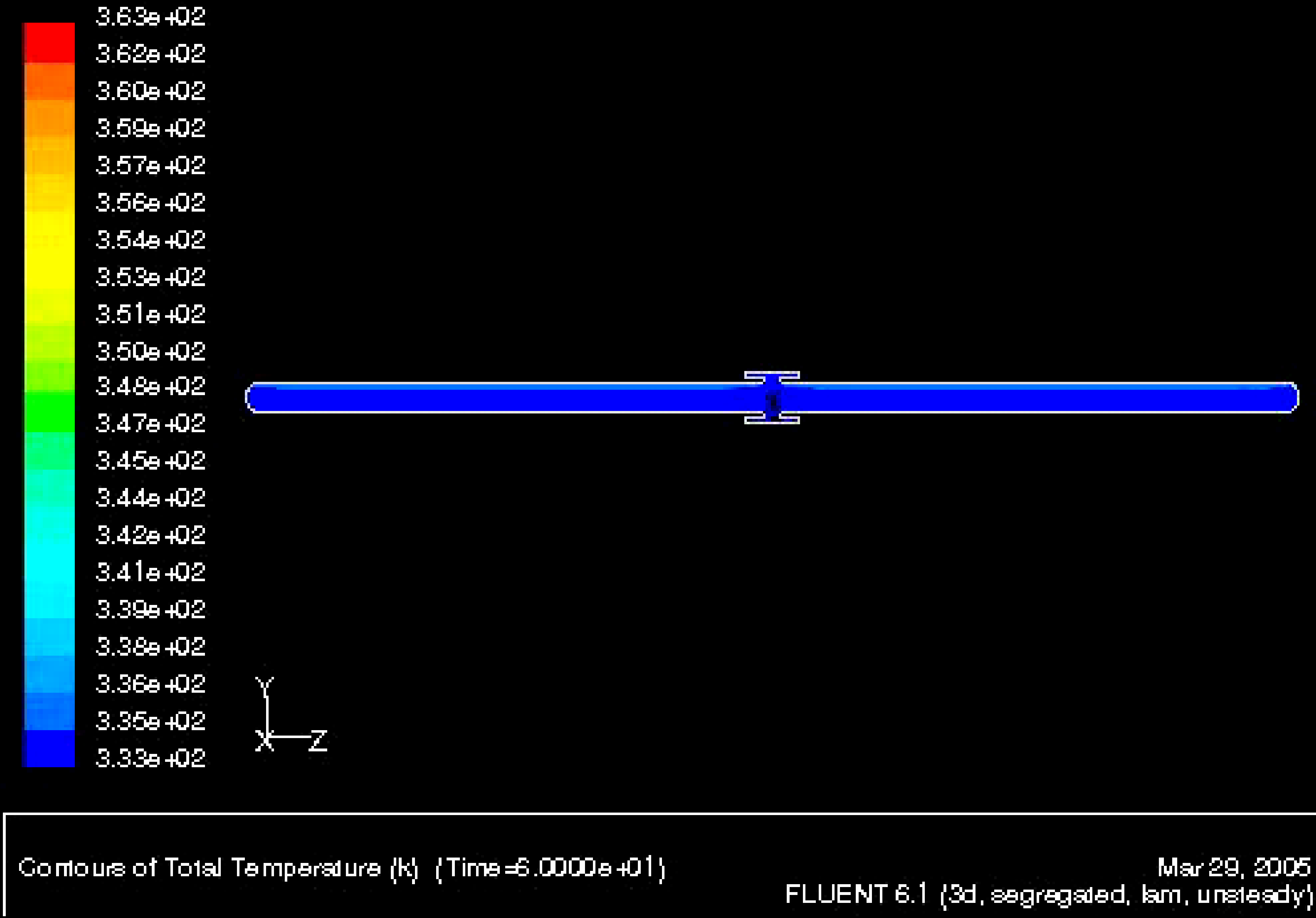
Flow inside the All-glass tube

We see two horizontal All-glass tubes connected to the manifold pipe in the centre



Temperatures inside the All-glass tube



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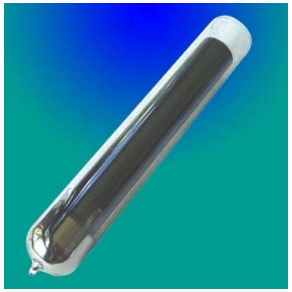
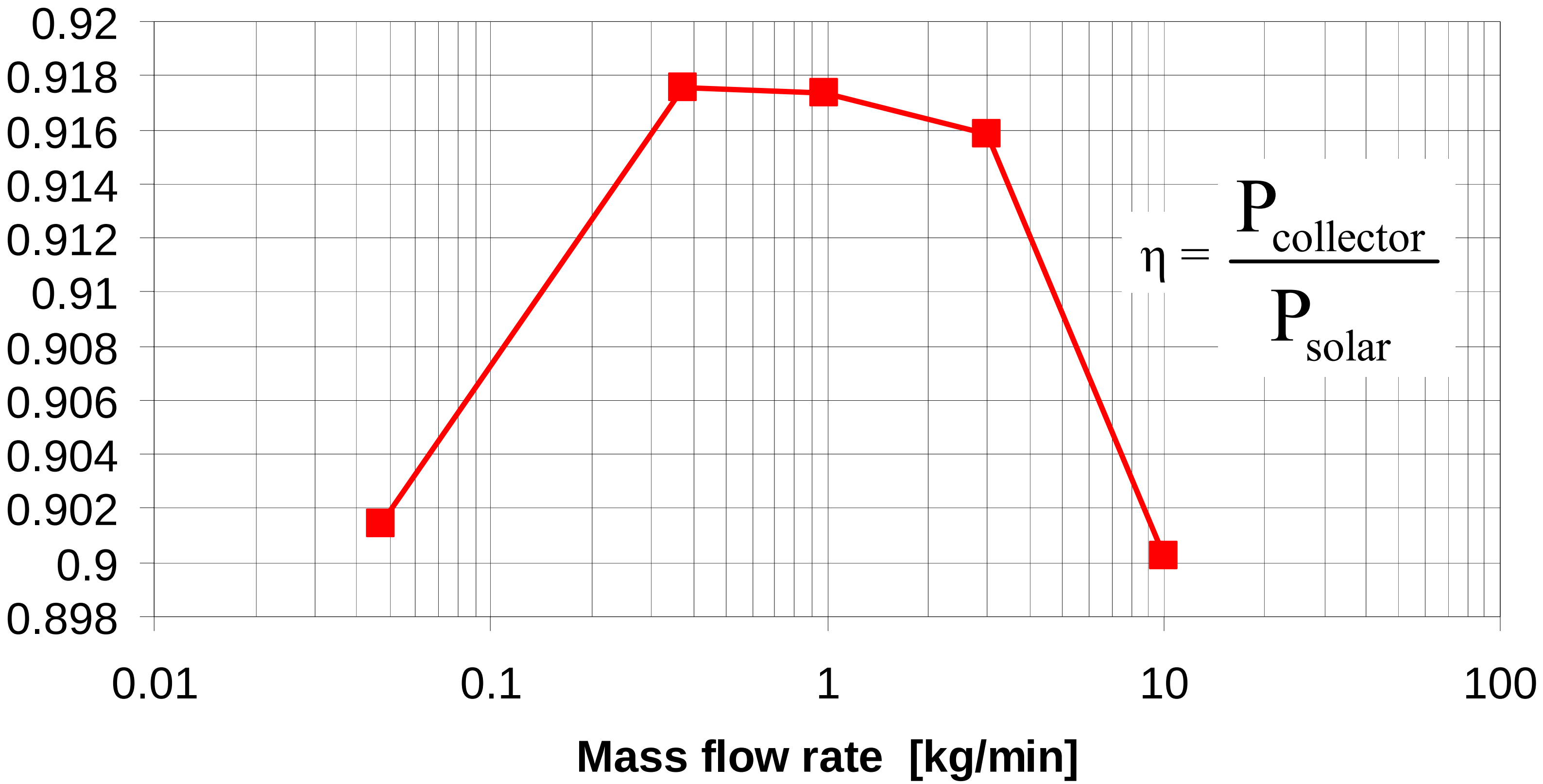
Calculated efficiency based on CFD calculations





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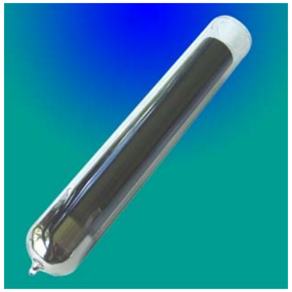
Results for different inlet flow rates

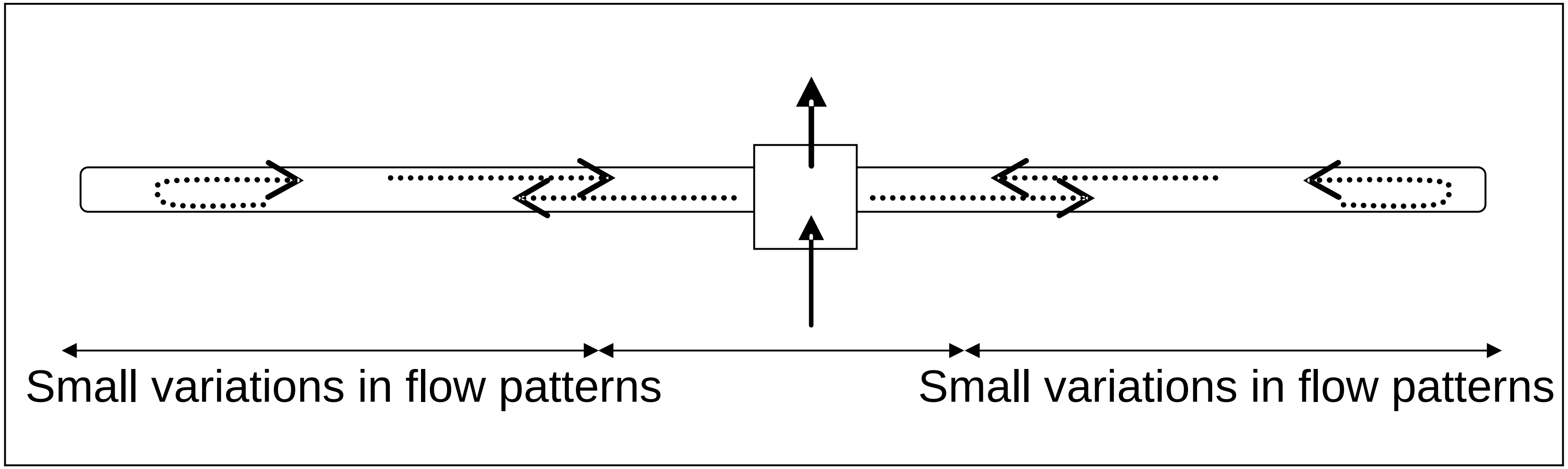


Observation:

- The manifold inlet flow rate has only small (<2%) influence on collector efficiency

Explanation:

- Small variations in the flow patterns in the glass tubes
- Self adjusting flow in glass tubes



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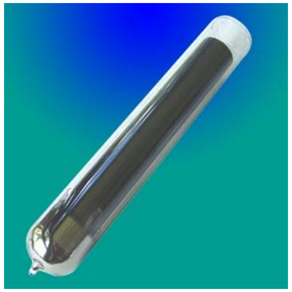
Summary



- Example of how Computational Fluid Dynamics gives detailed useful results

- Optimal manifold inlet flow rate is around 0.4-1 kg/min.

- Flow structures in the glass tubes were relatively uninfluenced by the manifold inlet flow rate

- This indicates that the collector design is well working for most operating conditions.

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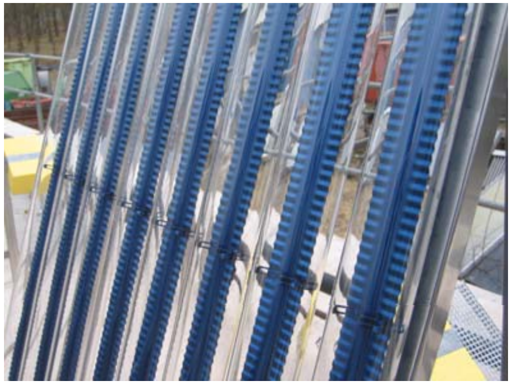
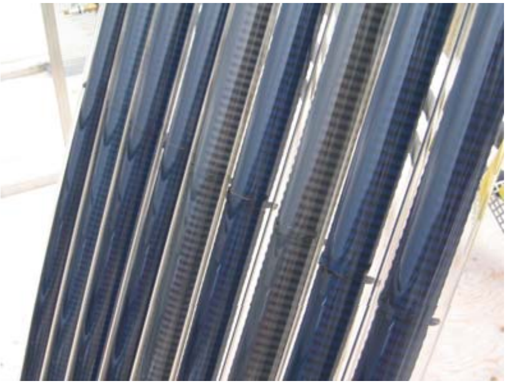
Further work

- Measurements
  - New test facility
  - Test of 5 differently designed evacuated tubular collectors
  - Direct performance comparison
  - Final validation of theoretical models
- Optimization work
- Design
  - Based on the findings and on economy considerations, optimum designed evacuated tubular collectors for Arctic latitudes will be recommended





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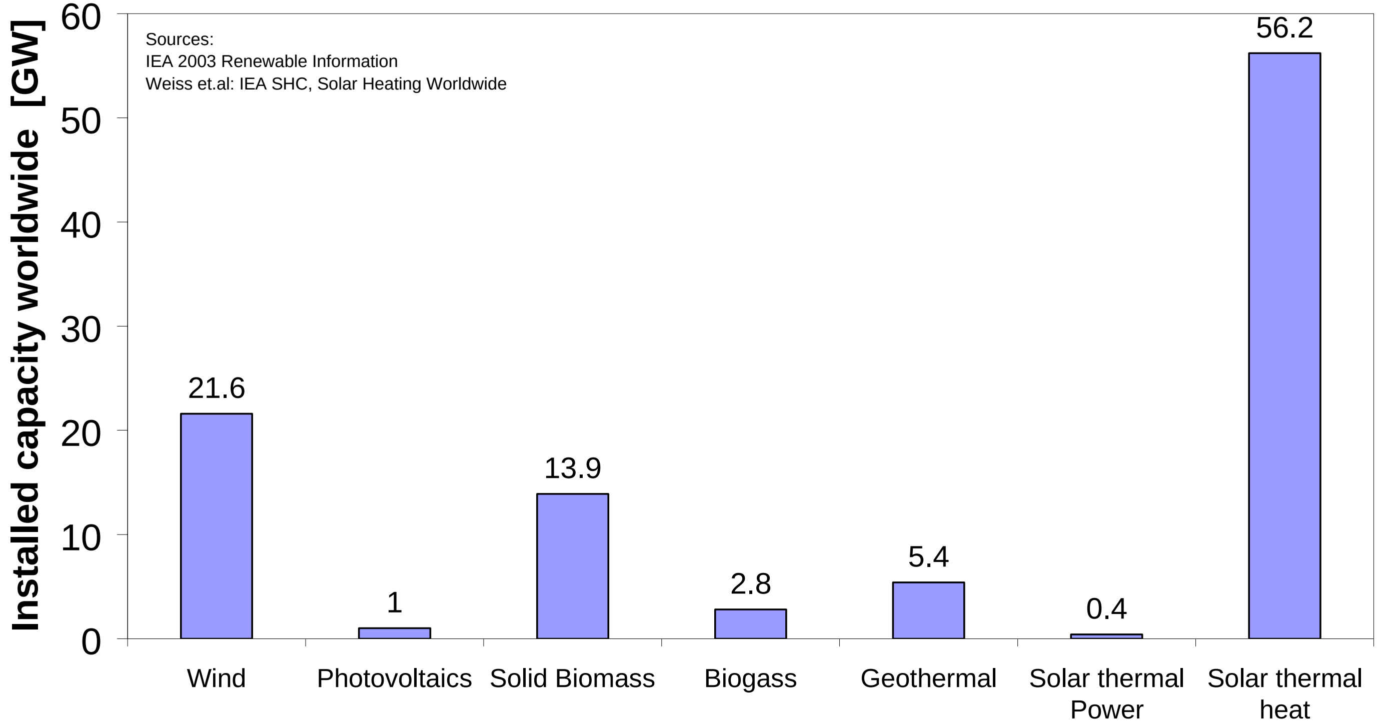
Outlook

- Today, solar heating is one of the largest renewable energy technologies



- Maybe, well designed cheap evacuated tubular collectors, will create a shining future for solar heating in Arctic regions

Thank you for your attention!