Contract No. 212206

Cost-Effective

Resource- and Cost-effective integration of renewables in existing high-rise buildings

SEVENTH FRAMEWORK PROGRAMME
COOPERATION - THEME 4
NMP-2007-4.0-5 Resource efficient and clean buildings
Grant Agreement for: Collaborative Project
(ii) Large-scale integrating project

D3.2.2 Prototype of an air heating vacuum tube collector for façade integration.

Due date of deliverable: month 30

Actual submission date: 18/10/2011

Start date of project: 01/10/2008 Duration: 48 months

Organisation name of lead contractor for this deliverable: Kollektorfabrik GmbH & Co. KG

Revision [1] - 18.10.11

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)

Dissemination Level		
PU	Public	√
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (incl. the Commission Services)	
CO	Confidential, only for members of the consortium (incl. the Commission Services)	

Content

1. Introduction

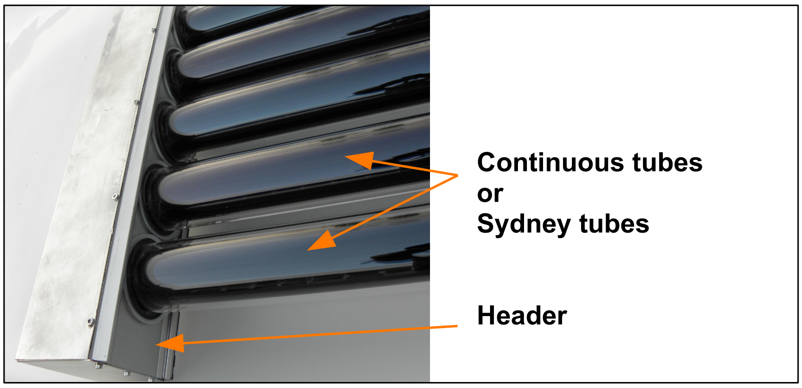
The Kollektorfabrik developed a new vacuum tube solar air collector for façade integration in high rise buildings. It bases on many advantages of the heat transfer medium air like in common rooftop installations. The vacuum insulation of the tubes is responsible for a good thermal efficiency at high operating temperatures and low irradiation. The heat transfer medium air has an intrinsic fail-safe behaviour in stagnation states. This is profitable for small and especially for large collector fields bigger than 1000 m².

Therefore the new vacuum tube solar air collector is particularly suitable for the special requirements of façade integration and the different interests in the high-rise building market, where the absence of technical risks is an important factor for the investing parties.

Low secondary costs e.g. maintenance and running costs and an additional benefit of shading (passive solar cooling) lead to a cost effective solution, which is the essence of this research project.

Two types of cost effective tubes were proposed during this project. The first type is a "Sydney tube" or "Dewar Tube" and has a closed end on one side. The other tube is called "continuous tube" and is open ended on both sides. Each tube has its own benefits in certain applications.

Picture 1 shows the main components of a vacuum tube solar air collector. The so called header distributes the heat transfer medium air to the vacuum tubes, where it is heated up. The hot air is extracted either on the same side “Sydney tube” or in case of the “continuous tube” on the opposite end.



Picture 1: Main components of newly developed vacuum tube solar air collector

There are two major integration possibilities for both types of vacuum tubes:

- Single façade element

  Every façade element consists of several vacuum tubes and at least one header.

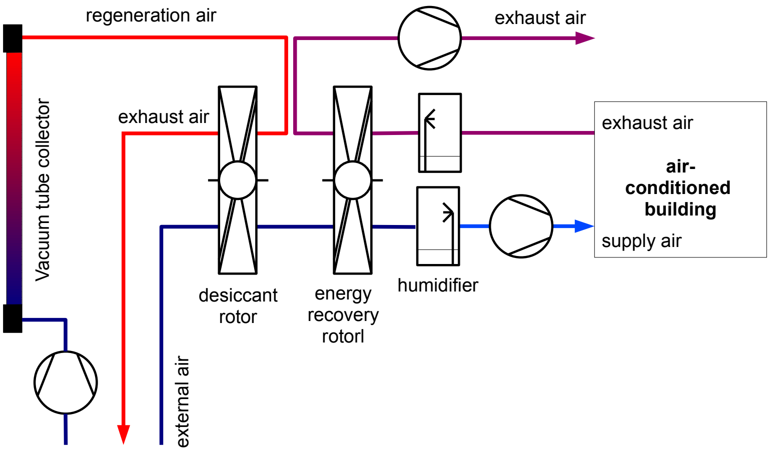
- Connected façade element

  The collector is extended along a certain distance sticking single tubes together to a serial connected unit. This long narrow stripe of a collector unit fits perfectly into the opaque or semi transparent areas of a storey.

Both types of the collector can be installed in front of a façade or behind protecting glass plates. The protecting glass plates are a security measure against falling pieces of broken glass tubes caused by e.g. strong hail stones.

2. Results

The different applications of the new vacuum tube solar air collector for façade integration in a high rise building were determined during this project. The most promising application includes heat supply of the building as well as the possibility of solar cooling in the summer with the hot and dry air of the vacuum tube solar air collector. Picture 2 illustrates an example for solar cooling. A desiccant and evaporative cooling system using hot air to dry a desiccant rotor (hot solar air for regeneration).



Picture 2: Example for a DEC cooling system driven by vacuum tube solar air collectors

One goal of the solar air collector development was to achieve high air temperatures for the special situation of lower irradiation on the vertical façade. A high-performance collector was requested with the ability to deliver heat at 80 °C with good thermal efficiency.

Sample collectors based on Sydney tubes were manufactured and can be reproduced in different dimensions for further investigations. One sample of such a new vacuum tube solar air collector from Kollektorfabrik is shown in Picture 3.

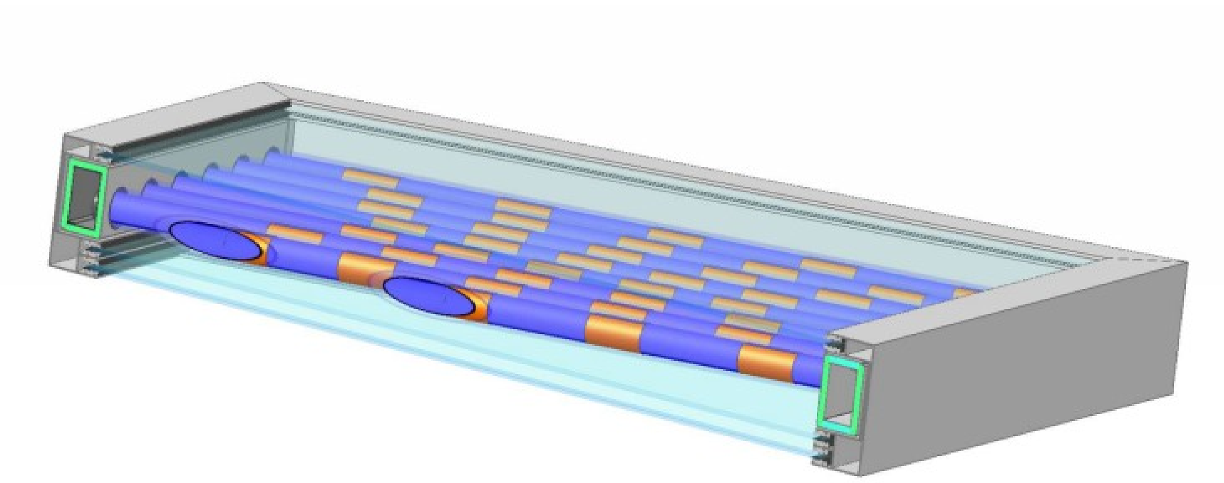
Additionally a solar air collector with the continuous tube was developed and will be fully available as soon as all issues of manufacturing of the vacuum tube are solved.

Picture 3: New Cost-Effective collector prototype mounted at the windows of our Kollektorfabrik storehouse

2.1. Housing and air ducts

Besides the vacuum tubes, the air ducts and the headers are further important components of a vacuum tube solar air collector. The headers distribute the air into the tubes.

For a good thermal efficiency of a vacuum tube solar air collector a minimum flow rate has to be guaranteed, but the available space inside a façade cavity is often limited. The inner size of an air duct and the collector header determine the maximum allowed airflow and therefore the maximum size of the collector within a given area.



Picture 4: Sectional drawing of the new Cost-Effective air collectorshowing headers and continuous tubes

To increase the small size of the air ducts a new microporous thermal insulation with a thermal conductivity = 0,020 W/(m*K) at a temperature = 200 °C is used. Thus, a favourable relation between pressure drop depending on the air flow in the system and the heat losses of the header surface can be achieved. The microporous thermal insulation resists high temperatures, but it is easily affected by humidity and condensing occurrences. Processing a temperature resistant and tight coverage of the insulation during the manufacturing process is an important precondition to achieve the target requirements.

Furthermore the junction of a vacuum tube and the header impacts the assignment of the air flow to each tube. To achieve an equal volume flow in every tube, the geometry of the header and the size and length of the tubes have to fit to each other.

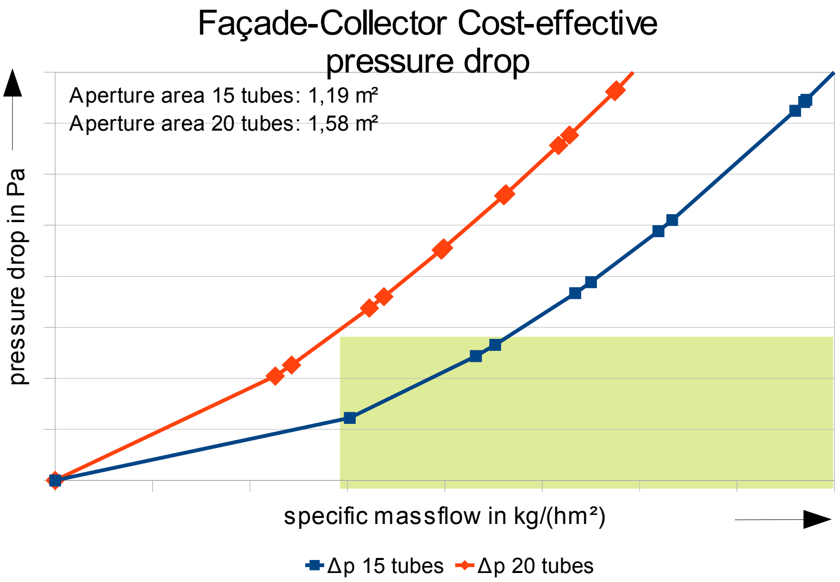
To come up with a suitable configuration for each possible façade element, basic estimations have been made and are going to be elaborated in the on-going project.

The connection to the building has to be done with flexible connectors. For low mass flows like in element-based collectors corrugated pipes can be used. There are several kinds of flexible ducts available on the market for larger collector fields which fulfil the requirements of the building regulations.

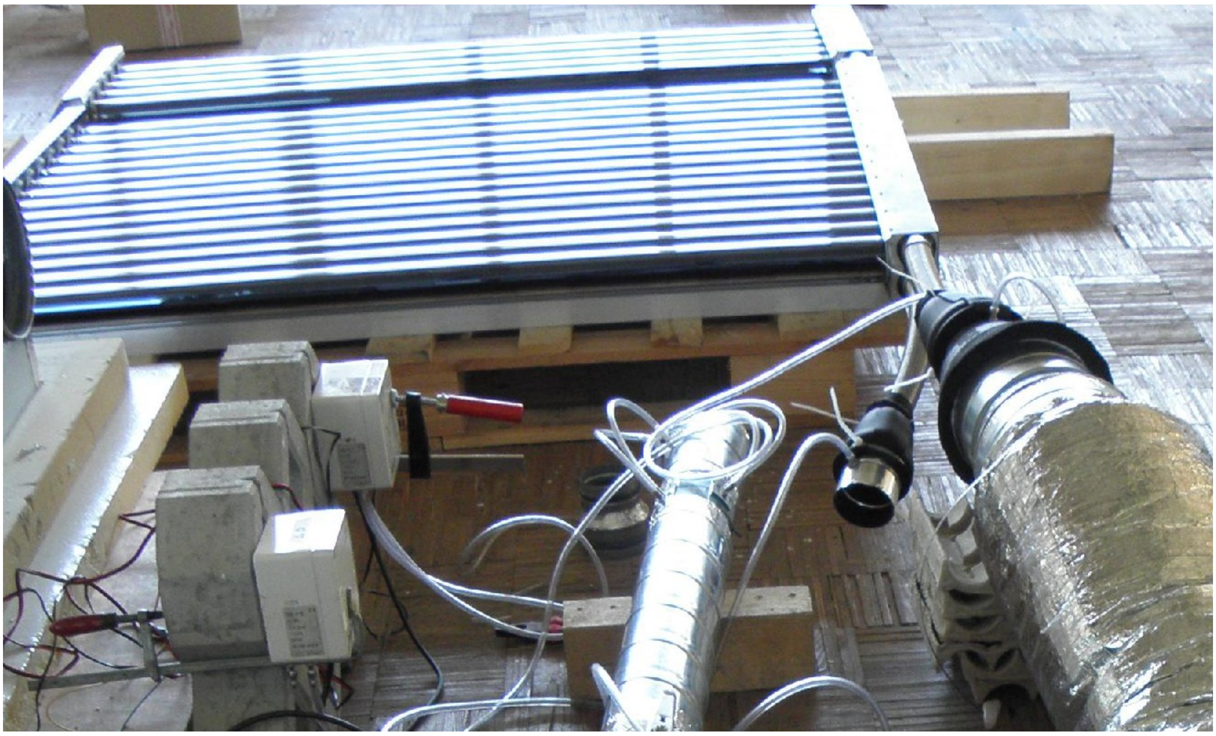
2.2. *Tube construction*

For the solar application of air collectors within the façade of high rise buildings, Sydney tubes can be used for collectors inside a single façade element. Due to pressure drop issues, the size of such an air collector is limited depending on the available size for air ducts and headers to an aperture area of 1 m² – 4 m².

Picture 5 shows the pressure drop curve of a vacuum tube solar air collector element-included field with 15 and with 20 tubes and the area of acceptable boundary conditions in green. The limiting factor is the possible header size of only 8 cm x 12 cm which makes this configuration interesting only for fields up to 15 tubes.



Picture 5: Pressure drop curve of the new Cost-Effective air collector



Picture 6: Kollektorfabrik test facility for pressure drop measurements of air collectors

For solar air collectors covering a larger area a new tube with openings on both sides is developed. The tubes can be used inside a single element or can be extended over a longer distance by connecting each other in series. Improved pressure drop behaviour and less space for air ducts are the benefit of this kind of tube.

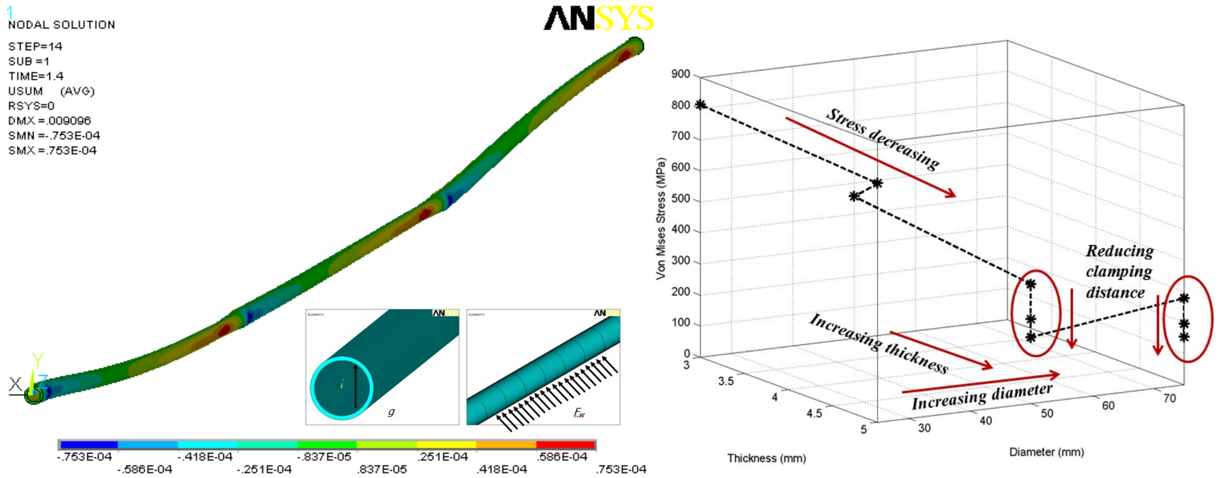
The width of the extended collector shown in Picture 7 is reached by two tubes in each line.

Picture 7: Continuous tube collector prototype developed in the Cost-Effective project

The structural strength of a continuous tube is analysed by D´Appolonia. A FEM model was used which integrates the oscillating vortex shattering of the tubes at high wind speed which can activate a resonant vibration of the tubes which can lead to very high dynamic loads. While accounting for this wind effects a dependency between the calculated stress inside the tube, its external diameter, its thickness and the clamping distance could be highlighted. This is also explained in Picture 8.

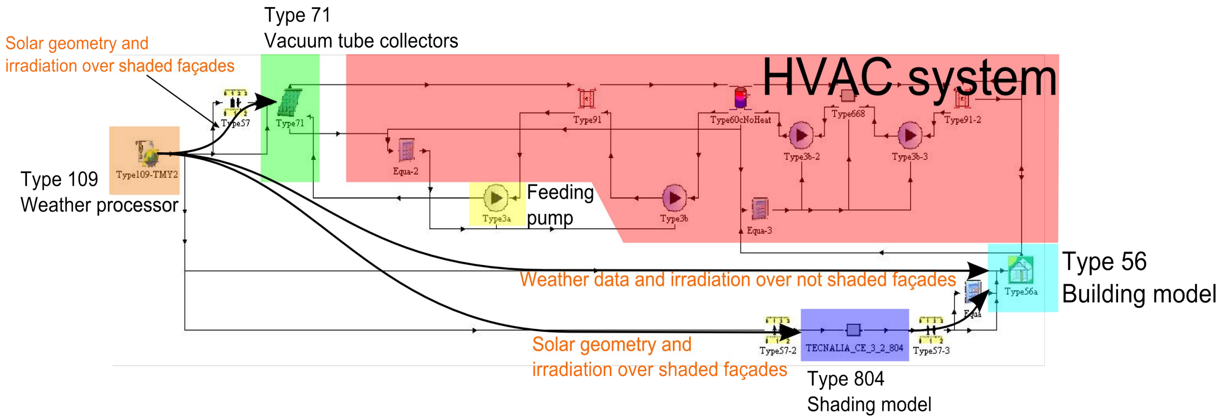
These calculations emphasize, that a usage without protecting window requires a strong and high resistant tube.

Further development of the FEM simulation regarding variants of damping and an experimental setup were specified to continue this research.

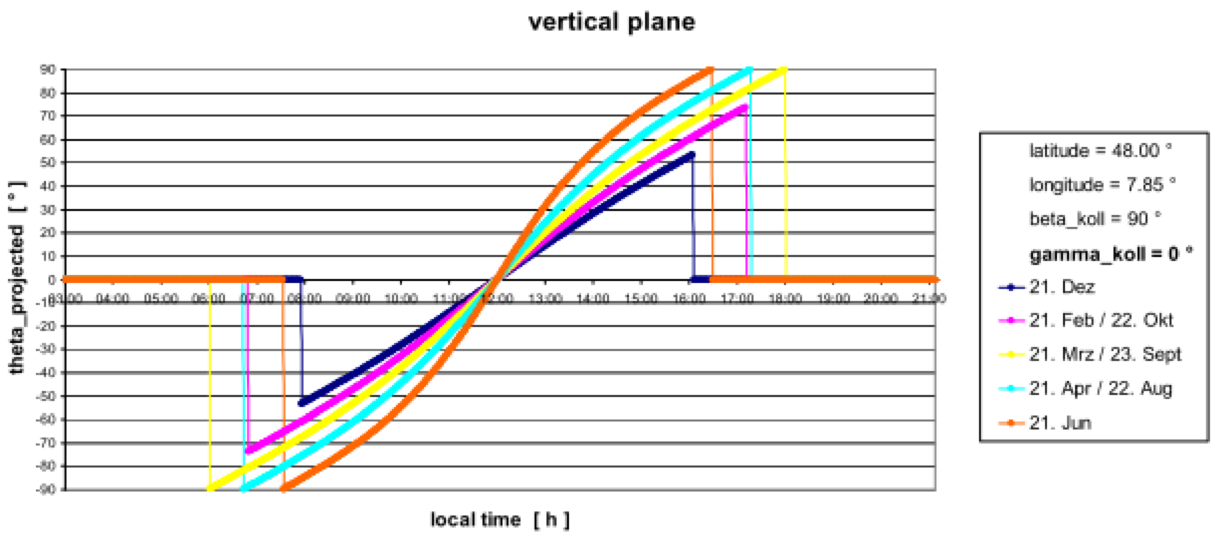


Picture 8: Pictures according to D'Appolonia's FEM simulation

As a façade integrated element, vacuum tubes have a shading function, too. Labein created a simulation model with a suitable vacuum tube solar air collector model in combination with an optical model for façade shading. It was built up for implementation in TRNSYS – a simulation software. Therefore tube models with horizontally, vertically or at an angle mounted tubes were contemplated to create a certain algorithm. The final simulation model can be coupled to any HVAC system.

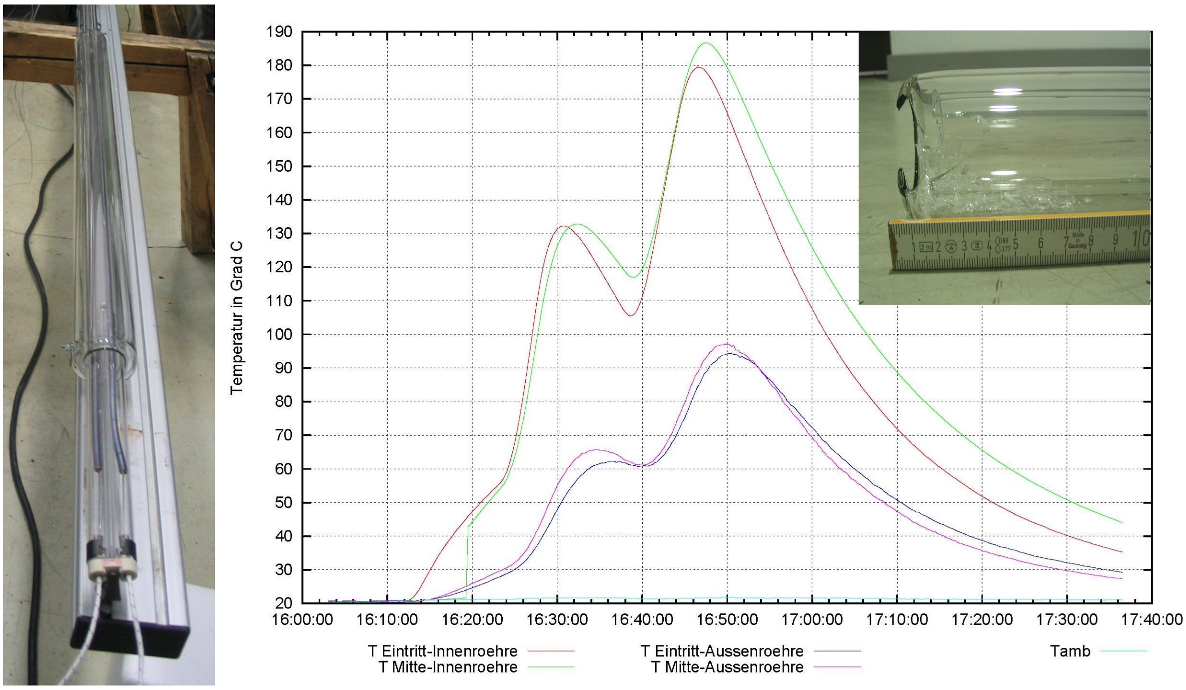


Picture 9: Model of a vacuum tube solar air collector for both HVAC and shading performance analysis



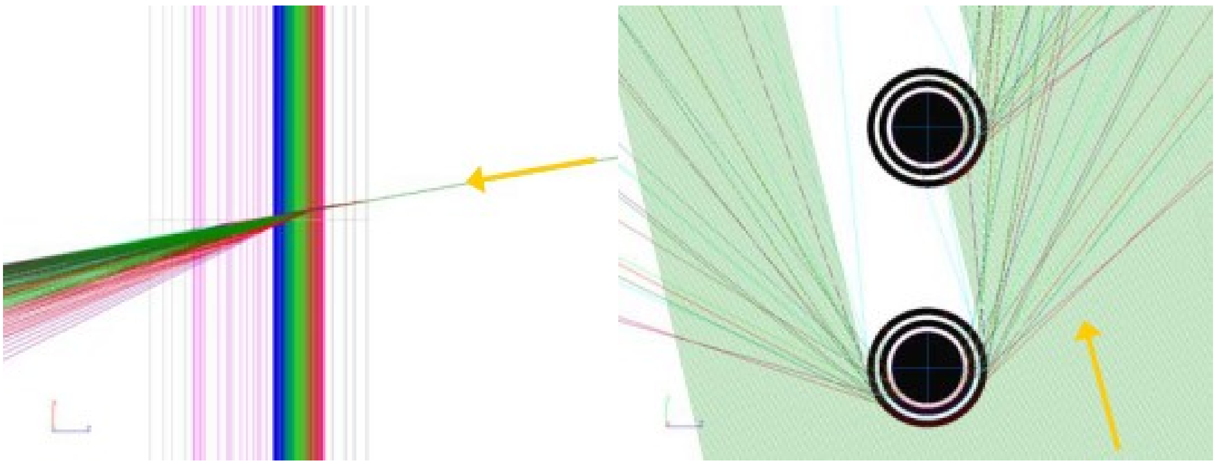
Picture 10: Incident angle of a vacuum tube solar air collector facing south

Different options of continuous tubes were examined and tested in the labs of Fraunhofer ISE to find the most promising solution (Picture 11).



Picture 11: Researches according to the fracture behaviour of glass tubes depending on thermal friction

To find an optimal geometry the effect of flat glass in front of the tubes and the distance between the tubes (Picture 12) regarding the incidence angles for horizontal or vertical installed solar air collectors facing in different directions from east to west was analysed. A big distance between each tube enables the incidence of light from wide angles. This leads to a maximum efficiency of a single tube. A low distance between the tubes lowers the efficiency of the single tube by shading each other at certain angles but it enlarges the utilisation of a given area. To find an optimum, a long term simulation over one year has to be done for each orientation and application.

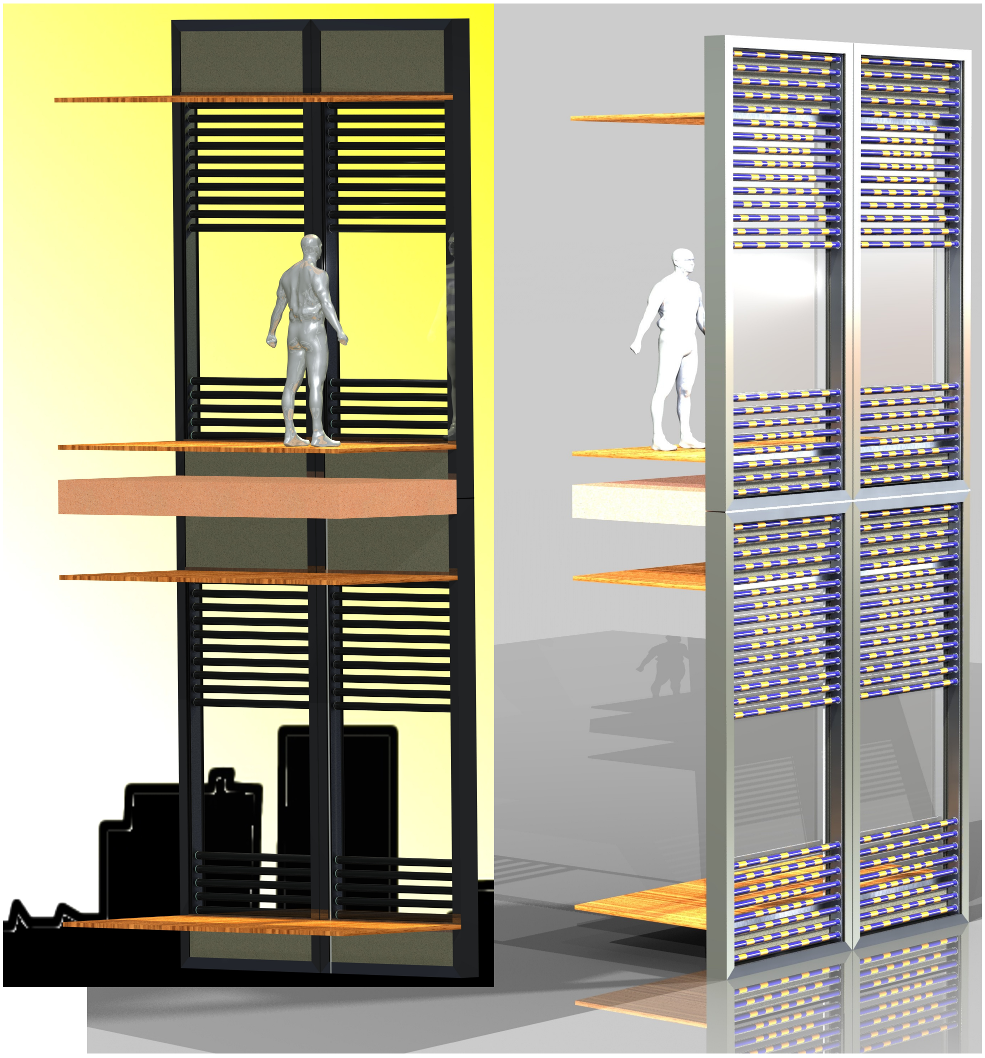


Picture 12: Simulating IAM - longitudinal (left) and transversal (right)

In the finalised tube a new method of laser welding is used to connect the glass tube to the elongation compensation units of the inner absorber tube. The method of laser welding was developed in the research project LafueSol "BMBF PO2140". It offers a faster and precisely controlled treatment of the glass tubes which is not available in common gas fired welding processes.

The absorber is clipped onto a stainless steel center tube. The air carrying center tube is connected to the outer glass tube by a longitudinal compensator which provides the vacuum tightness of the tube. In order to create some room for architectonic compositions, parts of the absorber surface can be modified (e.g. different colours) to affect the optical appearance from inside and outside the building. Picture 13 shows an example for an individually designed façade element with the "cost-effective" vacuum tube solar air collectors.

Although different tube diameters are possible, the manufacturing of a standard size will be established at first.



Picture 13: Drawing of a façade element with the new "Cost-Effective" vacuum tube solar air collectors.

Samples of these tubes, that are not evacuated, are used to investigate and assess the passive aspects of the tubes as a shading device and the possibilities to influence the optical and aesthetic appearance.

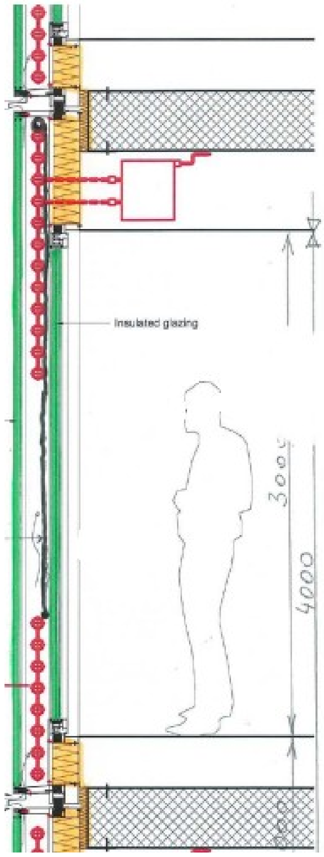
2.3. Integration

The distance between the tubes influences the throughput of light at a certain solar altitude, and the shading of the tubes from each other. For different locations of the building and every cardinal direction a unique distance leads to a maximum thermal performance. The tubes should not shade each other, but they also should take advantage of the given area.

In opaque areas the thermal performance is most important. Customer demands of visibility and comfort also affect the distance of the tubes, the size and position of complete transparent areas and so said semi-transparent areas with the visible part of the solar air collector.

Nevertheless the sizes of the façade cavity and the width of bars between the single façade elements, where the air ducts can be hidden are usually unique. This clarifies that the integration of the new vacuum tube solar air collector should be specifically customized for every façade.

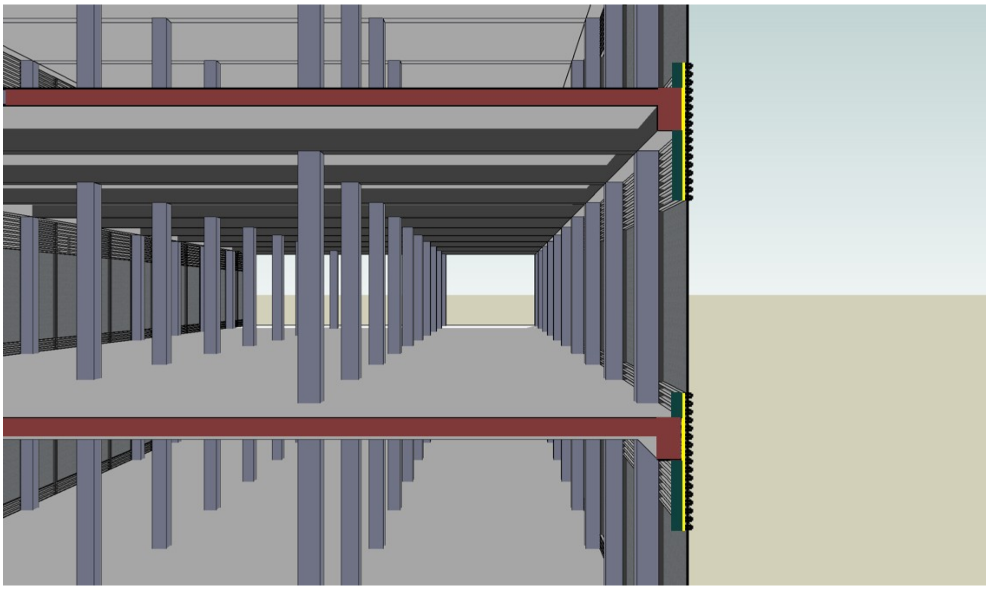
The following pictures (14 - 20)show different samples of the façade integration of the new "Cost-Effective" vacuum tube solar air collector.



Picture 14: Example for façade integration of tube collectors, Emmer Pfenninger Partner AG

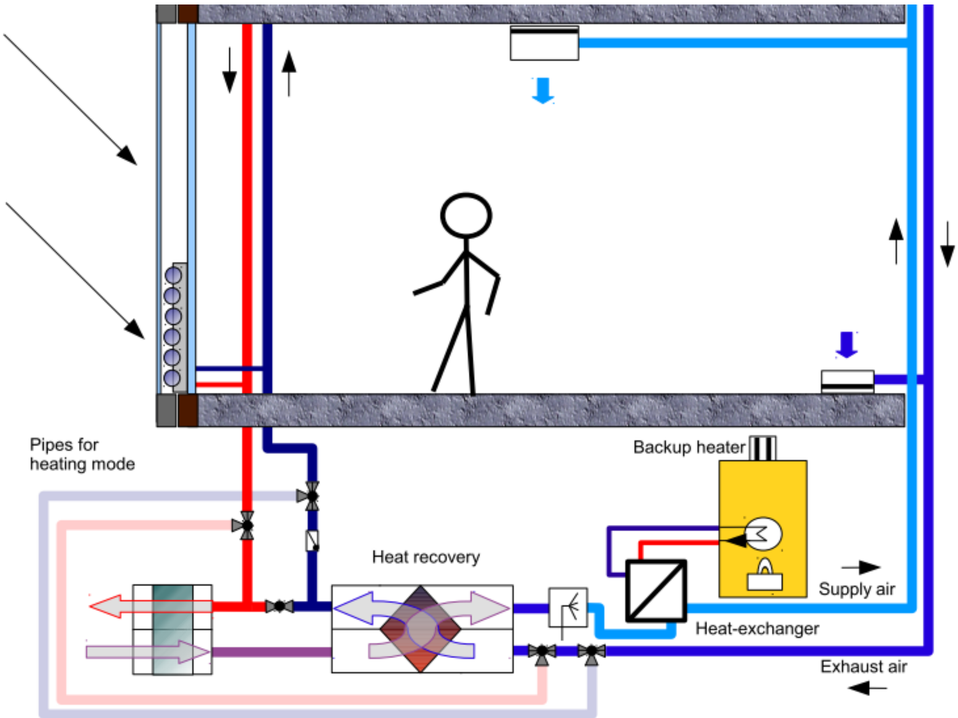
The task is to size the collector, the tubes, the covered area and the air duct to achieve maximal performance and to process the different parts of the collector individually.

Proposals of a façade integrated solar air collector were calculated by the Emmer Pfenninger Partner AG. For the long term laboratory test and for the whole system simulations, different proposals meeting the unique demands were used.



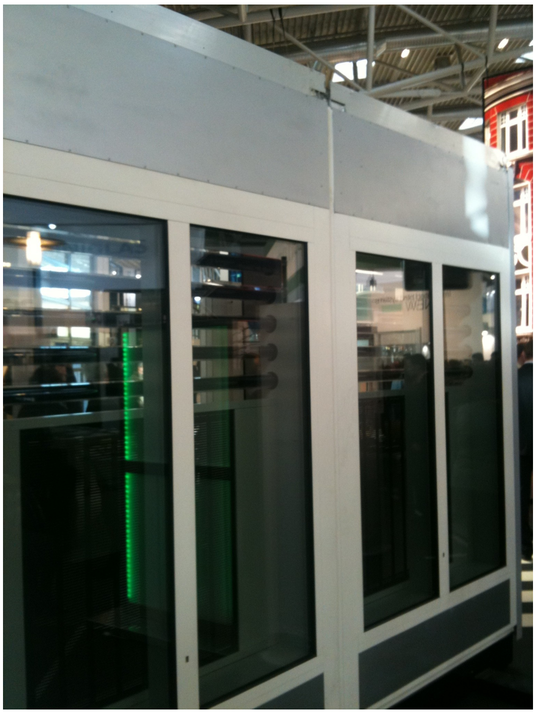
Picture 15: Example for façade integration of tube collectors,KOW Architectur B.V.

Picture 16: Façade Cost-Effective vacuum tube solar air collectors installed in the test facility from Fraunhofer ISE



Picture 17: Example for cooling system with vacuum tube solar façade air collectors, Kollektorfabrik

Picture 18: Small air ducts inside a façade element and the Cost-Effective vacuum tube solar air collector



Picture 19: Rear side of the façade element with Cost-Effective vacuum tube solar air collector at the fair Bau München 2010

Picture 20: Front side of the façade element with Cost-Effective vacuum tube solar air collector at the fair Bau München 2010

3. Conclusion and outlook

A vacuum tube solar air collector for façade integration was prototyped, and many issues arising from the thermal insulation, the heat transfer between the heat transfer medium air and the absorber, the pressure drop and the air distribution have been investigated and approaches to resolve these issues have been proposed in order to implement a flexible manufacturing of this kind of air collector.

A second type of a continuous tube is going to be manufactured in series with improved performance behaviour for larger collector fields.

The thermal performance of the façade integrated collector will be assessed at the laboratories of Fraunhofer ISE. The behaviour of installed prototypes will be assessed at the demo building in Ljubljana.

Improved heat transfer, glare protection and the serial production of the continuous tube are topics to work on to ensure the successful implementation of this technology in the demo building in Ljubljana until November 2012.