

SOLAR ENERGY AND ELECTRICAL MOBILITY BETWEEN UNIVERSITY, SCHOOL AND APPRENTICESHIP- 10 YEARS OF HESSEN SOLAR CUP

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1. Introduction



Fig. 1: Participant evaluating the solar condition

The core activity of the “Hessen SolarCup” project is the annual contest on solar mobility and education at Königsplatz in the city centre of Kassel. This event motivates hundreds of young people to actively engage themselves in the development of technical solutions and their documentation. At the same time the thus acquired knowledge is integrated in their living environment and social context.

From the beginning the Hessen SolarCup has been a project of the University of Kassel. It can be seen as a link between science and technology on one hand and school and education on the other hand. Its focus lies on the renewable energies, in particular photovoltaic use of solar energy and the conservative utilisation of the material. The target of the project is to intelligently combine energy, material, and human creative power. Another important role of the Hessen SolarCup lies in its interdisciplinary combination of technical, social and artistic disciplines. Certainly those aspects have an important impact on the evaluation. The teams of experts mainly consist of engineers, teachers, designers, civil servants and apprentices who intensively discuss with the participants their documentation, ideas and solutions. After all, the Hessen SolarCup serves as a link between the different age groups and proficiency levels.

However, the Hessen SolarCup is not limited to the contest. In order to accelerate the transfer process of scientific knowledge into the schools advanced training courses for teachers, pupils, students and interested people are offered as well. The big advantage of the Hessen SolarCup is its close relationship to experts of the University of Kassel (from the Faculties of Electrical Engineering / Information Technology, Mechanical Engineering and the School of Art and Design of Kassel), the Fraunhofer Institute for Wind Energy and Energy System Technology IWES and the Center for Environmental Systems Research (CESR). One goal of the workshops is to closely combine theory and practice by using innovative methods and to activate independent research and development. Therefore, special educational tools are designed to help people to understand complex concepts.

The Hessen SolarCup is finally very closely linked to the professional education system and the respective local energy companies functioning as a direct point of contact for the development of high-tech products and the motivation for the technical and scientific education.

2. Goals

At the Hessen SolarCup contest the fastest may not be necessarily the winner. The race serves rather to awaken enthusiasm among the youth. One goal is to practice important skills and talents such as craftsmanship, project management, goal-oriented working, co-operative teamwork, systematic reasoning and acting, technical relationship between different electrical and mechanical subsystems, development of intelligent control systems, reflection, and documentation of the construction, developments and ideas in a clearly defined small technical project. The overall aim is to sensitize the youth especially on the use of energy and materials, to encourage them to joined-up thinking and to apply the results in their daily life. The Hessen SolarCup intends to stimulate the children, teenagers and teachers to transmit the acquired knowledge into their social environment and thus take part actively in the development of solution models for the future use of energy and material.



Fig. 2: Fine tuning of the remote controlled solar vehicles

have our complete energy supply exclusively based on renewable energy systems which includes the central promotion of energy saving and energy efficiency.

With its workshops and seminars for pupils, teachers, apprentices and students, the Hessen SolarCup also aims to foster the knowledge transfer on renewable energies and mobility particularly into the school. Pedagogically this shall be achieved in the form of experience-oriented learning: experience of the energy!

The overall values the Hessen SolarCup is committed to, are teamwork, appreciation of fellow mankind, the natural environment, including the economical and considerate use of the resources. It targets to

3. The history of the Hessen SolarCups



Fig. 3: ... friendly vehicle

The history of the Hessen SolarCup began in 1985. Engineer and senior teacher Heino Kirchhof had the idea of participating together with his vocational students in a solar rally called "Tour de Sol" in the mountains of Switzerland. At this event competitors from automotive companies, research institutes, and creative business ventures met and brought more than 100 futuristic solar vehicles they had constructed. Their common goal was to combine mobility with environmental protection. The Kassel team totally unexpectedly won this contest.

The first Hessen SolarCup contest which took place on 24th May, 2002 in Kassel was expectedly a result of this victory. Therefore, the Hessen SolarCup is one of the oldest school challenge SolarCups in Germany and has since then inspired a series of other similar initiatives in the country. On the 10th June, 2011 Hessen SolarCup took place again at Königsplatz.

In its early stages, trainees presented their remote-controlled solar vehicles, but soon solar boats, designed and built by primary school pupils, came along. In 2005 an additional discipline, the

Ultra-Light Solar Mobile, was introduced and in 2008 came yet another discipline, the SolaRobots. The invitations to participate in the once in a year event now goes to all age groups in the special schools, primary schools, secondary schools and vocational schools.

In Autumn 2009 talks between various national solar and educational initiatives were organized at the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung – BMBF) to clarify whether a nationwide and thus supra-regional SolarCup event could be realized. Fundamental parts of the regulations and the concept of the Hessen Solar-Cup and the Ultra-Light Solar Mobile discipline were adopted. In 2010 the first German SolarMobil ((SMD (2010)) national contest took place at Potsdamer Platz in Berlin where the winners of the local initiatives were invited. The second “SolarMobil” Germany event will be hosted on 30th September, 2011 as part of the Fair on Future Technologies “Clean Tech World” (CTW (2011)) at the Berlin-Tempelhof airport.

4. Pedagogic concept

Several publications did emphasis the interdisciplinary approach and the integration of the HSC in school education and vocational training [Kirchhof (2010); Wenzel (2006)]. The Hessen SolarCup motivates the pupils, students and apprentices by setting a task which can be solved partly playfully, by researching and experimenting and inspires them to participate in a very exciting major contest. Theory and practice is combined and the direct transformation into activities is promoted. The trail of brainstorming, realization and documentation are quite naturally already practiced at an early stage. This often leads to problems which are anyway part of the curriculum.



sufficient knowledge to the pupils, students and apprentices and at the same time leave them enough room for their own ideas and conceptualisation. Ideally, a dynamic interaction emerges in which both parties benefit.



Fig. 4: Enthusiastic and concentrated Teamwork

The autonomous teamwork plays a crucial role in the pedagogic concept of the Hessen SolarCup. The tutors have the difficult task of providing sufficient knowledge to the pupils, students and apprentices and at the same time leave them enough room for their own ideas and conceptualisation. Ideally, a dynamic interaction emerges in which both parties benefit. On the day of the contest all age groups and disciplines gather at Königsplatz. This offers the participants the opportunity to interact with each other. The younger pupils can learn about the possible opportunities for development of their projects and the older participants can be inspired by the creativity of the younger ones. Therefore, even on the day of the contest a learning process can be initiated and the strong experiences and impressions can have an enduring effect.

5. Financing

The financing of the project has been from the beginning a major challenge. There is a general consensus over the fact that a new thinking and action regarding the economical and intelligent energy use and the decentralized adoption of renewable energies will only develop if this complex subject has already been introduced in educational training. Nevertheless, this is not automatically connected with a basic funding for projects, which exactly deal with this range of topics.

In order to attract funding for the Hessen SolarCup at the University of Kassel, local sponsors were needed, but who first had to be impressed by this idea. Here should be mentioned the SMA Solar Technology AG, the municipal energy supplier “Städtischen Werke AG” Kassel, the savings bank “Kasseler Sparkasse”, the municipal environment and gardening office “Umwelt- und Gartenamt der Stadt Kassel” and numerous other local sponsors. The University of Kassel provides the

facilities, the Hessen SolarCup's offices, and the equipment free of charge. However, essential for the success of the project is above all the voluntary work of many enthusiastic people in the expert teams organizing the contest, the seminars and the workshops and designing and developing the advanced training material.

6. Disciplines

The Hessen SolarCup offers for each educational age group a challenging task. The spectrum ranges from the elementary school pupils with their solar boats over to the students of the middle school and senior classes with their ultra-light solar vehicles up to the trainees and students with their remote-controlled solar vehicles and solar robots.

All classes have a common requirement that all vehicles which constructed are run by photovoltaic energy. Therefore the point is to combine components namely; solar modules, storage batteries, driving and swimming constructions and intelligent control and regulation in one system.

The construction is documented in each case in the form of a poster. In addition, another poster based on a wider theme is provided which illustrates the connection to the social context (e. g. "How do we imagine the mobility in the year 2020?" or "Energy turnaround now!"). The evaluation of the posters is based on categories such as functional and artistic design and independent working.

The evaluation categories should promote the co-operative, independent work of the group, the development of intelligent solution methods, the economical and considerate use of energy and matter, craftsmanship, and aesthetics as well as the comprehensive familiarity with multidisciplinary technical and social problem areas.

A key element of the concept is that evaluation teams consisting of scientists, technicians, teachers, and artists evaluate the posters according to the given categories. Each team has an interview in which the development and ideas are analysed, discussed and encouraged. In the following the specific characteristics of each class are presented.

Finally, numerous prizes are awarded. Naturally there are material and cash prizes, but also special prizes as for instance for the most creative and innovative vehicle. In the run-up to the Hessen SolarCup specific workshops and seminars for preparation of teachers are offered.

6.1 Solar boats



Fig. 5: Focussed primary-school child before the start of the solar boats

The contest of the solar boats addresses to the youngest participants from elementary school and special school classes. The solar module and an engine with fan are the basic requirements. The task of the teams is to construct a solar boat out of them. Above all the design of the hull poses hereby a major challenge. The boat is constructed according to their own ideas. Thereby, the main focus is to build the most environmentally friendly boat possible. Preferably only waste, recycling products or natural building material should be used. The development and construction process has to be documented and displayed on a poster. A second poster is dedicated to an annually changing theme within the context of the Hessen SolarCup (e. g. "Sun is life!")

At the contest at Königsplatz the teams compete against each other with their boats in a big water basin, which is set up by the fire-brigade of Kassel. At the same time the posters are displayed. The evaluation of the races, the construction of the boats and the posters are done. There are awards for the teams with the most points and special prizes for outstanding performances, for instance, the creativity award. The event has

been accomplished in the past in co-operation with the "Wassererlebnishaus Fuldata".

6.2 The ultra-light solar vehicles



Fig. 6: Last check of the vehicle before starting the Ultra-Light vehicle race



Fig. 7: Selfmade vehicle with a lot of recycling material, e.g. wheels from CD's

a large extend to the opposite direction. At the contact with the stop tape the electrical motor should be switched to the opposite direction as well. Thereby, the chassis should remain stable on the course and if possible not stray. The solution to this task could be on a more or less conscious level, for example to study the topic areas: springs, drive dynamics and stability and electromechanical change over switch. A further big challenge is the fact that only a small capacitor may be used as energy storage. The vehicles should be able to cope with all weather conditions, even cloudy sky.

Pupils of the junior high school up to the sixth grade have the task to construct a light-weight solar vehicle, which is powered by a solar module. The only restriction is that the surface of the solar module is limited. A capacitor of up to 1 Farrad as energy storing unit is allowed. The rest is up to the pupils and their technical skills and ideas.

The designed vehicle has to tackle the following task: it has to drive as often as possible in a given time on a 9 m long straight-line course, which is fitted with guide rails. At the end of the course there is a stop tape, on which the vehicle should, with the aid of a switch, change direction automatically. In the middle of the course there is an about 100 cm long tunnel where the boats must pass. The running mode is a double KO system, so that each team competes at least twice. In the final rounds the vehicles drive in the mode of a world championship, with eighth, quarter, semi-finals and final.

There are different technical challenges in this discipline to the teams. For instance the switch-over at the end of the course is such a complex task. Depending on the irradiation and thus changing speed the vehicles reach the final stop. The kinetic energy should be converted to

7.3 The remote-controlled solar vehicles



Fig. 8: Remote-controlled solar vehicle under heavy rainy conditions

The set of solar module and electric motor is provided. The rest is left to the technical designers to decide. The vehicles have to drive the most rounds possible and preferably, without touching the opponents or taking the right of way. The vehicles are to be designed by the students or the trainees according to their own designs and attempts. These scooters require a quite diversified comprehension of engineering, energy efficiency and construction background. The remote-controlled solar vehicles reach a maximum speed of more than 30 km/h.

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To be able to achieve these speeds and at the same time being able to negotiate corners, the vehicle needs a solid chassis and a good steering unit. The realization of the remote control means a special challenge to the participating teams as well. At Königsplatz there are many interfering frequencies. In this contest the skillfulness of the driver is particularly demanded. Collisions are not uncommon.

Lots of programming, soldering, screwing, gluing and experimenting has to be done. Some pieces are separately machined (CAD). Therefore, this task is a perfect candidate for teamwork and is best done in

Fig. 9: Remote-controlled solar vehicles right before the start

close collaboration with different technical specializations. This complexity ensures that the most diverse group of technical experts work together in a project, for example technical draftsmen and mechatronics engineers. This project enables the schools and companies to link in a multidisciplinary, theoretical as well as practical project, different recognized trades. Some big local companies have therefore integrated the Hessen SolarCup contest as one of the key events in their training schedules.

6.4 The SolaRobots



Fig. 80: SolaRobots following the line conducted by a micro-controller

The SolaRobot should be able to retrace autonomously a black line in form of a lying eight. At the same time the SolaRobots have to obey priority rules at the intersection point. The design of the construction and the selection of the components are arbitrary and only the solar cell surface and the driving motor are prescribed. If a complete new construction is too demanding to the team, SolaRobots can also be built up on the basis of prefabricated kits, which then have to be enhanced with the photovoltaic modules. The vehicles do not have any backup batteries.

On a large board, the racecourse is stuck as a black line tape on white background. The racecourse takes the form of a triple 8, in which the three lanes cross. Three solar robots compete at a time in one race and all races last 10 min. In each run the number of rounds made and fouls by each robot is determined for each robot. The race is run according to the KO-system.

It is important for the race that the SolaRobots can autonomously recognize the track as well as possible even with changing lighting conditions and that they could drive along that track as energy-efficiently as possible. A gap of 3 cm on the track in a straight stretch should be bridged and at the central crossing another solar robot



Fig. 91: SolaRobots following the line

should possibly be recognized and thus a collision avoided (right-of-way rule: right before left).

In case a robot loses orientation, it is repositioned on the track by a referee and fined. If it knocks another solar robot a fine is paid which is credited to the victim robot.

In case of bad weather, the race management decides on the day of the contest itself about the use of the bad weather batteries which have to be brought along loaded by the teams. These are labeled and sealed in the robot by the race management for the entire duration of the race.

For the evaluation the results of the races, the construction of the solar robots and the poster are scored and the violations counted. Referees at the side of the racecourse evaluate and score for the construction and the poster by interviewing the team members as well.

7. Summary

In the ten years of its existence, the Hessen SolarCup has developed to a very broadly diversified project which offers not only a solar educational contest for all school classes and for trainees, but as well as advanced educational courses and the development of teaching and learning material. Thanks to the numerous contributors the Hessen SolarCup is closely integrated in the public life of Kassel. The supporters range from pupils and students, apprentices, teachers and the evaluation teams to the supporting establishments, the city of Kassel and the organizers up to the many volunteers. The Hessen SolarCup is not only fostering the intense occupation with the topic of the solar and electrical mobility, but also the occupation with relevant societal issues such as the future energy supply.

The Hessen SolarCup plays a crucial role as a link between science and school, between the different technical disciplines and between the diverse age groups and experts. By its playful and experimental approach, it inspires year in year out many young people to be interested in renewable energies and the solar technology and sensitizes them for a sustainable coexistence with the environment.

8. Outlook and vision

For the future more workshops and seminars in the framework of the Hessen SolarCup should be offered to the target groups. Therefore besides technical and constructional topics, comprehensive fields of interest should be brought into focus. The interdisciplinary approach should be further intensified and lecturers from various other fields at the University of Kassel and the research institutes should be incorporated.

For learning support, teaching and learning material should be developed. Thus complex connections could be made plausible and intuitively tangible. This is a key future task for the Hessen SolarCup.

The disciplines of the Hessen SolarCup could again be adjusted and revised and the adventurous character of the event and the race could be enhanced. It would be an advantage, if driving skills and the momentary concentration would play a role in all disciplines. In particular, progressing back to the roots would certainly be an exciting project: Racing for solar-driven hybrid vehicles for passenger transportation.

It is a great desire that through the Hessen SolarCup Project a completely new consciousness in the youthful new generation grows, and that a new thinking in regard to the use of energy and of its intelligent application and, regarding decentralized, renewable electrical energy be created.

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