Project No.: **NMP3-CT-2006-032970**

Project acronym: **HYCONES**

Project full title: **Hydrogen Storage in Carbon Cones**

Instrument: STREP

Thematic Priority: Nanotechnologies and nano-sciences, knowledge-based multifunctional materials and new production processes and devices

Publishable Final Activity Report

Start date of project:	01/11/2006
Duration:	36 months
Project coordinator name	Theodore Steriotis National Centre for Scientific Research “Demokritos”
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Date of preparation:	15/01/2010

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1. PROJECT EXECUTION

1.1 HYCONES objectives

Background

Efficient storage and delivery of H_2 are key elements of the H_2 economy. Generic use of H_2 as an energy carrier requires a means to store excess product for later use, to transport stored H_2 from the point of production to the point of use, and to charge and discharge H_2 to and from the storage container according to need. Two kinds of storage functions with very different requirements are needed for the H_2 economy. Systems used for stationary applications can occupy a large area, employ multi-step chemical charging/recharging cycles, operate at high temperature and pressure, and balance slow kinetics with capacity. On the other hand, H_2 storage for transportation, must operate within minimum volume and weight specifications, supply enough H_2 to enable a ~500 km driving range, charge/recharge near ambient temperature, and provide H_2 at rates fast enough for fuel cell locomotion of vehicles. The H_2 storage requirements for transportation applications are thus far more stringent and difficult to achieve than those for stationary applications.
The operating requirements for efficient on board H_2 storage include appropriate thermodynamics (favorable sorption-desorption enthalpies), fast kinetics (quick uptake-release), high storage capacity, effective heat transfer, high gravimetric and volumetric densities (light in weight and conservative in space), long cycle lifetime, high mechanical strength and durability, safety during use and acceptable risk under abnormal conditions. The use of tanks in which H_2 is stored as compressed gas or cryogenic liquid, fall far short of the mobile targets due to the required tank volume, safety reasons and energy intensity. Solid storage (in metal hydrides, chemical storage materials and nanostructured materials), holds considerable promise for meeting the targets, but fully satisfactory materials have not been identified yet.

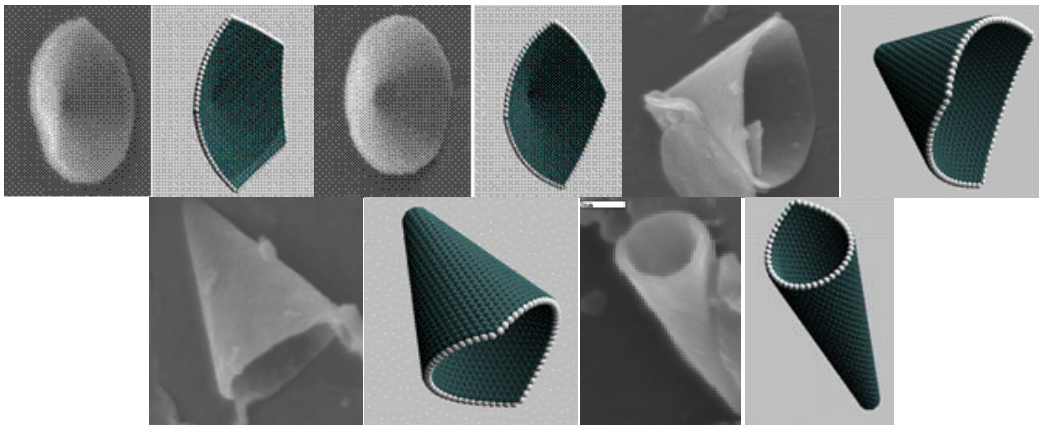
S&T Objectives

Responding to the technological needs described above, HYCONES has investigated the use of a radically new material, namely carbon cones (CCs), as a practical, inexpensive, lightweight, high capacity H_2 storage material capable of storing/releasing H_2 in a temperature window well suited for mobile applications. Carbon cones comprise a new form of carbon, fundamentally different from all the so far known carbon structures, which has been produced in industrial quantities during the so-called Kværner Carbon Black & H_2 Process[1] and is composed of carbon microstructures, which are flat discs and cones (appr. 20%). The CCs consist of curved graphite sheets, while five different cone angles have been observed, in accordance with the incurrence of one to five pentagons at the cone tips. Preliminary experiments performed before the start of the project had clearly demonstrated unprecedented uptake-release of H_2 unlike those for any other carbon material[2], as well as a new form of interaction between carbon and H_2 (in contrast to conventional physi- and chemi-sorption), capable of releasing H_2 at room temperature. This unique behavior was explained after ad-hoc computational calculations, which indicated that due to the special topology of CCs, the

1. Kværner's patent no PCT/NO98/00093 for production of micro domain particles by use of a plasma process.
2. Norwegian patent No. 307986 in 2000, US patent No. 6,290,753 in 2001, EPO Patent No. 1051530 in 2004 ("Hydrogen storage in carbon material"). (A.T. Skjeltorp and A.Maeland)

system is characterized by unique electronic properties distinctively different from any other form of activated or nanostructured carbon).
HYCONES targets have been pursued through a coherent work plan built around the following R&D objectives:

- Material development including purification (in terms of improving the carbon cones content of the as produced mixed material).
- Material decoration with metallic nanoparticles that can lead to enhanced hydrogen sorption.
- Use advanced experimental techniques to characterize the material, study the interaction of CCs (or metal doped CCs) with H_2 on an atomic/molecular scale and thus gain fundamental understanding of the store-release process.
- Measure accurately H_2 sorption/release capacities, kinetics and cycle-lifetime after following standardized protocols.
- Use experimental data and advanced ab-initio and semi-empirical computational calculations to (a) establish the cone structures and resolve the mechanisms of H_2 uptake and release, including kinetics, and (b) understand the fundamentals of H_2 interaction with cones and metal doped analoques and fine tune the sample synthesis process.
- Use mesoscopic simulation tools, based on molecular level modelling, to develop a multi-scale predictive simulation tool, which can describe the H_2-cones system from atomic to bed scale.



SEM images of the five different cones and their "reconstructed" analogues

1.2 Partnership

HYCONES partnership has embraced key players and worldwide leaders in the areas of H_2 technology, i.e. well-established academic groups working intensively on the development and assessment of materials for H_2 storage as well as active industrial representation (the only producer of the actual carbon cone material is member of the HYCONES team). More specifically, HYCONES consortium consists of 5 independent participants from 4 European countries: National Centre for Scientific Research "Demokritos" (Greece), Institute for Energy Technology (Norway), University of Nottingham (UK), Institute of Nuclear Physics – Polish Academy of Sciences (Poland), Scatec AS (Norway).

1.3 Main achievements

The HYCONES workplan involved six technical workpackages (WPs) reflecting both basic (characterization, functionalization and modelling of innovative nano-structured materials such as CCs) and applied (by exploring the possible use of CCs for H_2 storage) research aspects. WP1 focused on down-scaling the CB&H process in order to enable the reproduction of carbon cones. WP2 addressed the purification of the as produced sample aiming to remove the carbon discs and soot and thus improve the carbon cone content. Additionally, WP2 has been aiming at the functionalization of the CC samples via doping with metallic nanoparticles in an attempt to enhance hydrogen sorption capacity. WP3 activities focused on the use of advanced experimental techniques in order to investigate the CCs morphology, the CC structures in an atomistic level and the interactions between H_2 and CCs (or metal doped CCs). The fundamental understanding of H_2 storage in CCs was assisted by WP4, which focused on the development of multi-scale advanced computational methods with clear predictive power. The H_2 sorption/desorption capacities of WP1 and WP2 samples, the pertinent kinetics and cycle-life were determined within the framework of WP5 by using different techniques. Additionally, a lab-scale CC (100 g carbon or doped carbon material) H_2 storage system was developed for testing the performance of the optimised material under realistic conditions.
The intense S&T work within the lifetime of the project has generated significant results, has verified that carbon cones comprise materials with exceptional properties and most interestingly has revealed new directions for advancing their hydrogen storage potential. The main activities and the associated results achieved so far are summarized below.

Operational bench-scale CC production unit. A bench-scale rig for the production of fresh carbon cone samples has been set-up and the proper adjustment of the reaction conditions led to materials with a progressively improved morphology, i.e. from spherical carbon particles to flat and conical structures. The key parameters controlling the growth of such structures are now well understood and as a result large stacks of (clearly visible individual) disks but also (perfectly shaped) cones have been produced in a systematic manner. The production capacity is currently limited however the large-scale re-production of cones/disks mixtures is considered feasible in the long term.

Purification of the raw CC material. Since graphite sheets and amorphous carbon are considered impurities interfering with most of the CCs properties and thus affect the H_2 storage capacity and/or kinetics, purification of the raw samples has been a central activity. In this respect, various methods, both physical and chemical, have been explored for the modification/purification of the raw carbon cone samples received from the available inventory and quite encouraging results have been obtained with respect to the improvement of the respective cone content (gram quantities of highly purified material have been generated). Seeking to harmonize with the international developments in the area of hydrogen solid storage, the modification of the raw carbon cone material towards metal-doped derivatives with enhanced performance has been also considered.

Experimental verification of the unique CC properties. An impressively wide range of state-of-the-art and sophisticated methods have been employed for the study of the morphology and the structure of the materials (SEM including statistical analysis of volume distributions, TEM, AFM, FFEM, ELDIF, STM, TGA/DSC, FT-IR, RAMAN, XRD, SANS, Neutron Diffraction, Synchrotron SAXS-WAXS, ESR, etc.), as well as for the elucidation of their

interaction with H_2 (Calorimetry, Inelastic Neutron Scattering, X-ray Photoelectron Spectroscopy, Neutron diffraction with in-situ H_2 sorption, Temperature Programmed Desorption, etc.).

Functional numerical codes. The fundamentals of the associated H_2 storage mechanisms have been investigated systematically by intense modelling work on the atomistic-molecular mesoscopic scale which has led to significant conclusions about the properties and the performance of CCs. The atomistic-molecular simulations have resulted in the construction module of the HYCONES code, the only currently available routine that generates reliably multilayered cones and disks of any size with correct bonding topology. A number of theoretical studies on different cone systems have led to significant conclusions on their properties as well as the associated H_2 storage mechanisms. It has been shown that the hydrogen released at normal temperatures cannot be covalently bonded to the cones leading to the conclusion than H_2 sorption is non-dissociative. Moreover it has been shown that there are many parameters affecting the H_2 storage capacity of cones, such as apex angle, cone size, and position of reactive sites. For example, the reactivity of the cones tip has been studied extensively, as it is a property that can be connected with both the spillover and the purification potential. On the other hand, significant work has been also made on molecular - mesoscopic simulations based on Grand Canonical Monte Carlo (GCMC) calculations. A dedicated GCMC code for the prediction of H_2 sorption isotherms of single angle CCs for different P-T conditions has been developed for this purpose. Carbon cones have been shown to exhibit superior performance compared to other geometries such as single wall carbon nanotubes and slits; this can be attributed to the cone tip area but also to the unique combination of local curvature and confinement offered by the cone geometry.

Proven H_2 release at room temperature. The capability of carbon cones to release hydrogen at near room temperature has been verified experimentally by independent methods, implying a certain potential for use in H_2 storage applications. The most interesting results were obtained from the measurement of the metal doped CC samples which showed enhanced hydrogen uptake as high as 4.3 %wt at 25 ^{o}C and 20 bar. Similar uptake values (3.5 - 3.8 %wt at 25 ^{o}C and relatively low pressures, ca. 10 bar) were recorded during systematic serial charging-discharging experiments on a specially designed lab-scale storage system containing 100 g of alloy doped cyclone purified CC sample. The respective measurements also demonstrated the stability of the material upon cycling.

1.4 Contact details

More information about the project can be found on its dedicated website: http://www.hycones.eu. Alternatively, the contact details of the Coordinator are as follows:

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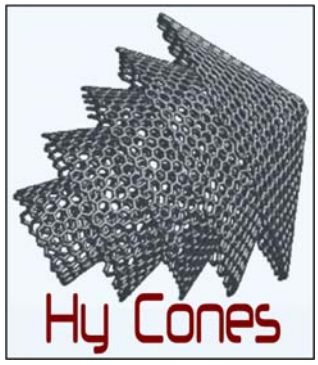
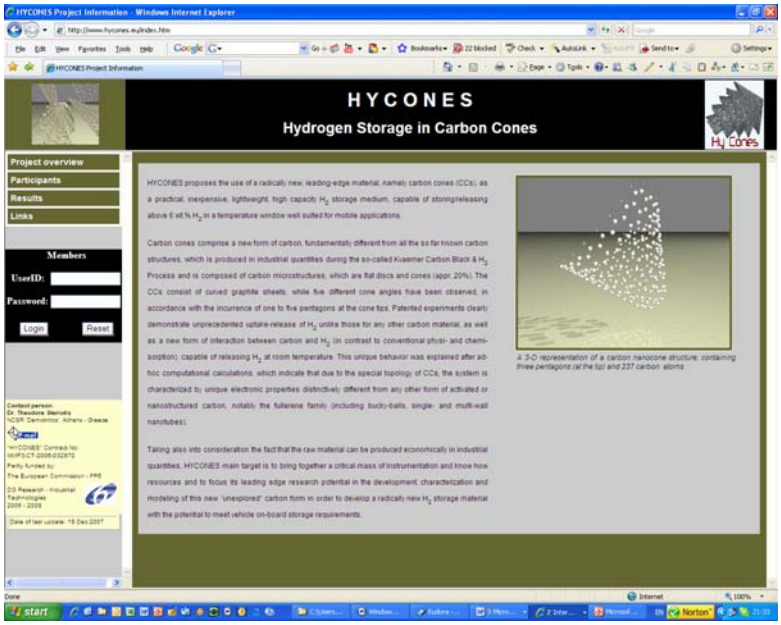


2. DISSEMINATION AND USE OF RESULTS

The results obtained during the course of the HYCONES project have received much attention not only from the scientific community but also industries and relevant stakeholders, as also reflected by the extended dissemination activities, summarized below. HYCONES consortium has established active links and cooperation with several other running European and international projects and hydrogen storage programs (including DoE activities). Moreover, the project partners disseminated widely their results through appropriate channels. A noticeable number of publications and presentations (40 in total) have been realised by the partners. They include refereed journal articles, conference papers, workshop/seminar presentations as well as invited lectures, presentations at industry forums and EC events, press releases, etc. In addition HYCONES established close collaboration with other FP6 and FP7 Hydrogen solid storage projects and had the initiative of co-organising a dedicated hydrogen storage workshop. All these activities have provided important external advice and feedback towards the identification of industrially relevant areas and porential applications for the carbon cones material.

2.1 HYCONES website

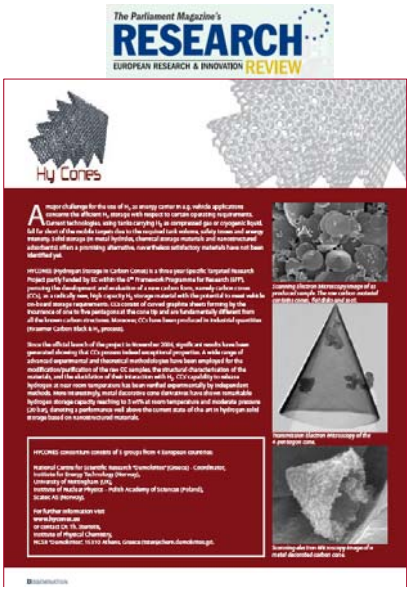
A dedicated HYCONES website (www.hycones.eu) has been developed. The public area of the HYCONES website refers to a summary of non-confidential project information, such as main objectives and expected outcome, description of partnership, publishable information, as well as H_2 related events and links.



HYCONES website

2.2 Representation of HYCONES to international events

The Coordinator has received invitations for presenting HYCONES results in several international events and even in press as outlined below:



- Hydrogen and Fuel Cell Review Days 2007 (Brussels, 10-11 October 2007).
- DoE 2008 Hydrogen Program Annual Review, June 2008, Arlington – Washington DC, USA.
- 17th World Hydrogen Energy Conference - WHEC2008 (Brisbane – Australia, 15-19 June 2008) - Presentation by B. Hauback.
- HyForum - International Hydrogen Forum 2008 (Changsha - China, 3-6 August 2008) - Presentation by P. Millet.
- 1st Stakeholders' General Assembly of the Fuel Cells and Hydrogen Joint Undertaking (Brussels, 14-15 October, 2008.
- Dedicated article in The Parliament's Magazine: Research Review, 22nd September 2008.
- SSH-IP (Solid Storage of Hydrogen – International Perspectives) workshop (Crete-Greece, 10-11 June, 2009).

2.3 Co-organisation of dedicated workshop

HYCONES had the initiative of co-organising a dedicated hydrogen storage workshop together with other FP6 and FP7 Hydrogen solid storage projects (NESSHY, NANOHY). The SSH-IP (Solid Storage of Hydrogen – International Perspectives) workshop took place in Crete on June 10-11, 2009 (the program is attached below). The event was quite successful (an audience of more than 85 participants, invited speakers on the key topics addressed by each project from US and Japan including car industry (Toyota), updates on JTI and IEA-HIA initiatives), while future directions and industrial perspectives were discussed.

Workshop on
Solid Storage of Hydrogen - International Perspectives
co-organized by NESSHY, HYCONES, and NANOHY EC projects
Fodele Beach Hotel – Crete, Greece
10 - 11 June 2009

Wednesday, June 10

09:15-09:30	Welcome - Introduction	NESSHY, HYCONES, NANOHY Coordinators
09:30-10:00	Novel Efficient Solid Storage for Hydrogen – the NESSHY Project	Thanos Stubos NCSR "Demokritos"
10:00-10:30	Hydrogen Storage in Carbon Cones – the HYCONES Project	Theodore Steriotis NCSR "Demokritos"
10:30-11:00	Embedding Hydrides in Nanoscale Matrices – the NANOHY Project	Max Fichtner FZK
11:00-11:15	*Coffee break*	
11:15-11:45	Metal-Organic Frameworks for Hydrogen Storage	Jeffrey Long U. Berkeley
11:45-12:15	SW Carbon Nanohorns for Hydrogen Storage	David Geohegan ORNL
12:15-12:45	On Nanoscaffolding and Nanostructures Impact on Metal Hydride Materials Performance: On-going Efforts in USA	Ewa Rönnebro PNNL
12:45-14:00	*Lunch break*	
14:00-14:30	Developments on Nanostructured Materials / Carbons	Gavin Walker U. Nottingham
14:30-15:00	Novel Functionalized Metal-Organic Frameworks and High Surface Area Carbon-based Materials for Hydrogen Storage	Pantelis Trikalitis U. Crete
15:00-15:30	Complex Hydrides for Hydrogen Storage	Max Fichtner FZK
15:30-16:00	Borohydrides for Hydrogen Storage	Andreas Züttel EMPA
16:00-16:20	*Coffee break*	
16:20-16:50	Improving Hydrogen Storage Properties of Mg-based Hydrides by Limiting Metal Atom Diffusion	Dag Noreus U. Stockholm
16:50-17:20	Tanks for Complex Hydrides	Jose Bellosta von Colbe GKSS
17:20-17:40	JTI Prospects/Opportunities for Hydrogen Storage	Marcello Baricco U. Torino
17:40-18:00	Discussion – Closing of Day I	ALL
18:00 -19:00	Poster session	

Thursday, June 11

09:30-10:00	From Optimised MgH_2 based Composites to Efficient Storage Tanks	Patricia de Rango CNRS
10:00-10:30	Design of Nanoporous Materials for Hydrogen Storage	George Froudakis U. Crete
10:30-11:00	Computer Modelling of Release Temperature in Hydrogen Storage Materials	Ian Morisson U. Salford
11:00-11:20	*Coffee break*	
11:20-11:50	Hydrogen Storage: Car Industry Perspective	Katsuhiko Hirose Toyota
11:50-12:10	IEA – HIA Task 22 Activities	Bjorn Hauback IFE
12:10-13:00	Discussion - Closing Remarks	ALL
13:00	End of Workshop	

2.4 Detailed list of dissemination activities

No	WP	Dates	Type	Full Reference(s)	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
1	2	2007	Conference	G S Walker, Modification and Purification of Carbon Nanomaterials, Invited presentation, The NANOMAT Conference 2007, Bergen-Norway	Research	Norway	150	UNOTT
2	2	2008	Conference	G.S. Walker, Characterisation of porous materials for hydrogen storage, IEA Task 22 Experts Workshop, March 2008, Sacacomie-Canada	Research	International	150	UNOTT
3	2	2008	Conference	G.S. Walker, Recent advances in metal-carbon materials for hydrogen storage, IEA Task 22 Experts Workshop, October 2008, Rome-Italy	Research	International	150	UNOTT
4	2	2009	Publication	P. Matelloni, D.M. Grant, G.S. Walker, Supporting metal catalysts on modified carbon nanocones to optimize dispersion and particle size, "Hydrogen Storage Materials" (Mater. Res. Soc. Symp. Proc. Volume 1216E), eds E. Akiba, W. Tumas, P. Chen, M. Fichtner, S. Zhang, Paper: 1216-W02-02, DOI: 10.1557/PROC-1216-W02-02	Research	International	Worldwide	UNOTT
5	2	2009	Conference	G.S. Walker, Spillover effect in metal-carbon hydrogen storage materials, IEA Task 22 Experts Workshop, April 2009, Jeju-Korea	Research	International	150	UNOTT
6	2	2009	Conference	G.S. Walker, Porous carbons as hydrogen storage materials, Solid Storage of Hydrogen – International Perspectives (SSH-IP workshop), June 2009, Crete - Greece	Research	International	100	UNOTT
7	2	2009	Conference	G.S. Walker, Effect of N-doping on the hydrogen uptake of templated carbons, IEA Task 22 Experts Workshop, October 2009, Paris-France	Research	International	150	UNOTT
8	2	2009	Conference	G.S. Walker, Hydrogen storage materials and hydrogen applications, UK-France Hydrogen Workshop, 2009, French Embassy, London-UK	Research	UK, France	100	UNOTT

No	WP	Dates	Type	Full Reference(s)	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
9	2	2010	Conference	G.S. Walker, Neutron scattering investigations of Hydrogen Storage Materials, CIMTEC 2010, 12th International Ceramics Conference, June 2010, Italy	Research	International	300	UNOTT
10	3	2007	Publication	E. Svåsand, G. Helgesen, and A.T. Skjeltorp, Chain formation in a complex fluid containing carbon cones and disks in silicon oil, *Colloids and Surfaces A*, 308 (2007) 67	Research	International	Worldwide	IFE
11	3	2007	Conference	I. Natkaniec, J. Krawczyk, M. Nowina Konopka, K. Hołderna-Natkaniec, A. Skjeltorp, J.P. Pinheiro, Inelastic neutron scattering study of hydrogen adsorbed on carbon nano-particles containing cones and discs, 4th European Conference on Neutron Scattering, Lund-Sweden	Research	International	400	IFJ PAN
12	3	2008	Publication	T. Garberg, S.N. Naess, G. Helgesen, K.D. Knudsen, G. Kopstad, and A. Elgsaeter, A transmission electron microscope and electron diffraction study of carbon nanodisks, *Carbon*, 46 (2008) 1535	Research	International	Worldwide	IFE
13	3	2008	Publication	X. Yu, M. Tverdal, S. Raaen, G. Helgesen, and K.D. Knudsen, Hydrogen adsorption on carbon nanocones studied by thermal desorption and photoemission, *Appl. Surf. Sci.*, 255 (2008) 1906-1910	Research	International	Worldwide	IFE
14	3	2008	Conference	G. Helgesen, K.D. Knudsen, J. P. Pinheiro, A.T. Skjeltorp, H.F. Cuesta, A. Elgsaeter, T. Garberg, and S.N. Naess, The Structure of Carbon Cones and Disks, Materials Research Society (MRS) Fall Meeting, Dec 1-5, 2008, Boston-USA	Research	International	400	IFE
15	3	2009	Publication	S.N. Naess, A. Elgsaeter, G. Helgesen, K.D. Knudsen, Carbon nanocones: wall structure and morphology, Sci. and Tech. of Adv. Mater., 10 (2009) 65002	Research	International	Worldwide	IFE
16	3	2009	Conference	A. E. Gunnæs, Ø. Prytz, A. Olsen, G. Helgesen, K. D. Knudsen, Structural study of C-cones and discs by	Research	International	150	IFE

No	WP	Dates	Type	Full Reference(s)	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
				use of analytical TEM, SCANDEM 2009, June 8-10, 2009 Reykjavik-Iceland				
17	3	2009	Conference	G. Helgesen, K.D. Knudsen, A.T. Skjeltorp, M.Knaapila, J.P. Pinheiro, M. Bourgeaux, H. Heiberg-Andersen, A. E. Gunnaes, Ø. Prytz, The Structure and Properties of Carbon Cones, Materials Research Society (MRS) Fall Meeting, Nov 30 - Dec 4, 2009, Boston-USA	Research	International	400	IFE
18	3	2010	Publication	A. Budziak, J. Dryzek, J. Krawczyk, P.M. Zieliński, Calorimetric and Positron Lifetime Measurements of Hydrogenated Carbon Nanocones, *Acta Phys. Pol. A*, in press	Research	International	Worldwide	IFJPAN
19	4	2007	Publication	H.Heiberg-Andersen and A.T. Skjeltorp, Spectra of conic carbon radicals, *J. Math. Chem.*, **42** (2007) 707	Research	International	Worldwide	IFE
20	4	2007	Publication	H. Heiberg-Andersen, Chemical applications of the inverse adjacency matrix, accepted for publication in *J. Math. Chem.*	Research	International	Worldwide	IFE
21	4	2007	Conference	A. Gotzias, Th. Steriotis, M. Kainourgiakis, Comparison study of Hydrogen adsorption in isolated carbon nano-tubes and nano-cones, 3rd Pan-Hellenic Symposium of Porous Materials, October 2007, Thessaloniki-Greece	Research	Greece	150	NCSRD
22	4	2009	Conference	H. Heiberg-Andersen, Charge distributions of alternant carbon nanocones, 1st International Conference on Nanostructured Materials and Nanocomposites (ICNM-2009): April 6-8, 2009, Kottayam, Kerala, India	Research	International	200	IFE
23	4	2009	Conference	A. Gotzias, H. Heiberg-Andersen, M. Kainourgiakis, Th. Steriotis, Grand Canonical Monte Carlo Simulations of Hydrogen Adsorption in Carbon Cones, 7th International Symposium Surface Heterogeneity Effects in Adsorption and Catalysis	Research	International	150	NCSRD

No	WP	Dates	Type	Full Reference(s)	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
				(ISSHAC 7), July 2009, Kazimierz Dolny – Poland				
24	4	2009	Conference	A. Gotzias, Th. Steriotis, M. Kainourgiakis, Hydrogen sorption in carbon nanotubes and cones, 3rd Pan-Hellenic Symposium of Porous Materials, October 2009, Patra-Greece	Research	Greece	150	NCSRD
25	4	2010	Publication	A. Gotzias, H. Heiberg-Andersen, M. Kainourgiakis, Th. Steriotis, Grand Canonical Monte Carlo Simulations of Hydrogen Adsorption in Carbon Cones, *Appl. Surf. Sci.*, in press	Research	International	Worldwide	NCSRD
26	1-5	2007	Conference	E. Svåsand, H. Heiberg-Andersen, G. Helgesen, K.D. Knudsen, J.P. Pinheiro, A.T. Skjeltorp, Carbon nanocones, The NANOMAT Conference 2007, Bergen - Norway	Research	Norway	150	IFE
27	1-5	2007	Conference	H. Heiberg-Andersen, G. Helgesen, K.D. Knudsen, J. P. Pinheiro, A.T. Skjeltorp, E. Svåsand, A. Elgsæter, T. Garberg, S.N. Næss, S. Raaen, M.F. Tverdal, X. Yu, and T.B. Melø, Carbon cones – a structure with unique properties, Materials Research Society Fall Meeting 2007, Boston-USA	Research	International	300	IFE
28	1-5	2007	Publication	G. Helgesen, H. Heiberg-Andersen, K.D. Knudsen, J. P. Pinheiro, A.T. Skjeltorp, E. Svåsand, A. Elgsæter, T. Garberg, S.N. Næss, S. Raaen, M.F. Tverdal, X. Yu, and T.B. Melø, Carbon cones – a structure with unique properties, in Nanotubes and Related Nanostructures, edited by Yoke Khin Yap (Mater. Res. Soc. Symp. Proc. Volume 1057E, Warrendale, PA, 2007), 1057-II10-46	Research	International	Worldwide	IFE
29	1-5	2008	Publication	H. Heiberg-Andersen, A.T. Skjeltorp and K. Sattler, Carbon nanocones: A variety of non-crystalline graphite, Journal of Non-Crystalline Solids 354 (2008) 5247	Research	International	Worldwide	IFE
	1-5	2008	Conference	H. Heiberg-Andersen, A.T. Skjeltorp and K.	Research	International	300	IFE

No	WP	Dates	Type	Full Reference(s)	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
				Sattler,Carbon nanocones: A variety of non-crystalline graphite won prize for best poster at the 9th International Workshop on Non-Crystalline solids, Porto, April 27-30, 2008				
30	1-5	2008	Conference	J. Muller, A.T. Skjeltorp, G. Helgesen, K.D. Knudsen, H. Heiberg-Andersen, Carbon Discs and Carbon Cones, NATO Advanced Research Workshop "Silicon vs Carbon, June, 18 -20 2008, Saint-Petersburg-Russia	Research	International	250	IFE
31	1-5	2009	Chapter	H. Heiberg-Andersen, G. Walker, A.T Skjeltorp and S. Nalum Næss, Graphene Cones in *Handbook of Nanophysics*, ed. K. Sattler, Taylor & Francis, in press	Research	International	Worldwide	IFE
32	1-5	2009	Conference	J.Muller, A.T. Skjeltorp, Carbon Nano Discs and Carbon Cones, S3C Symposium on Size Selected Clusters 2009, March 2009, Brand-Austria,	Research	International	100	IFE
33	7	2006	Dedicated website	www.hycones.eu	Research	International	Worldwide	NCSRD
34	7	October 2007	EC/HFP event	Th. Steriotis, "HYCONES: Hydrogen Storage in Carbon Cones" European funded research on Fuel Cells and Hydrogen: review, assessment and future outlook, Conference Hydrogen and Fuel Cell Review Days – 2007, Bruxelles, 10- 11 October 2007	Research	EU	300	NCSRD
35	7	June 2008	DoE event	Presentation of HYCONES results at DoE 2008 Hydrogen Program Annual Review, June 2008, Arlington – Washington DC, USA	Research	International	Worldwide	NCSRD
36	7	June 2008	Conference	Presentation of HYCONES results at 17th World Hydrogen Energy Conference - WHEC2008 (Brisbane – Australia, 15-19 June 2008) - Presentation by B. Hauback	Research	International	Worldwide	NCSRD
37	7	August 2008	Conference	Presentation of HYCONES results at HyForum - International Hydrogen Forum 2008 (Changsha -	Research	International	Worldwide	EC (P. Millet)

No	WP	Dates	Type	Full Reference(s)	Type of audience	Countries addressed	Size of audience	Partner responsible /involved
				China, 3-6 August 2008)				
38	7	September 2008	Press	HYCONES dedicated article in The Parliament's Magazine: Research Review, 22nd September 2008	Research	EU	EU	NCSRD
39	7	October 2008	EC /JTI event	HYCONES poster presented at the 1st Stakeholders' General Assembly of the Fuel Cells and Hydrogen Joint Undertaking (Brussels, 14-15 October, 2008	Research	EU	300	NCSRD
40	7	June 2009	Workshop (co-organised by HYCONES project)	Th. Steriotis, Hydrogen storage in carbon cones – The HYCONES project, Solid Storage of Hydrogen – International Perspectives (SSH-IP workshop), June 2009, Crete - Greece	Research	International	100	NCSRD