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in Zusammenarbeit mit dem Kompetenzzentrum Energie und Mobilität (CCEM)
en collaboration avec le Centre de Compétence Energie et Mobilité (CCEM)

Book of Abstracts

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Paul Scherrer Institut, Villigen PSI, Schweiz / Suisse

Lösungsansätze zum Schutz des globalen Klimas

Die Schweiz und die internationale Staatengemeinschaft setzen sich ambitiöse Ziele zur Absenkung der Treibhausgasemissionen. Technische und gesellschaftliche Innovationen sind erforderlich, um diese Ziele zu erreichen. An der Energietagung des Paul Scherrer Instituts zeigen international anerkannte Experten einige vielversprechende Lösungsansätze zum Schutz des globalen Klimas auf. Möglichkeiten der Herstellung von Energieträgern aus Biomasse und Solarenergie, der CO_2-armen Elektrizitätserzeugung mit Kernenergie und der Effizienzsteigerung im Güterverkehr werden vorgestellt. Das Kompetenzzentrum Energie und Mobilität (CCEM), welches diesen Zielen verpflichtet ist, stellt seine Resultate vor.

Auf dem Podium diskutieren hochrangige Vertreter der Politik, der Energie-, Elektrizitäts- und Finanzwirtschaft und der Forschung ihren Einsatz zur Umsetzung der Klimaschutzziele. Das PSI und das CCEM laden zur Tagung und zur Besichtigung von Forschungseinrichtungen auf dem Themengebiet ein.

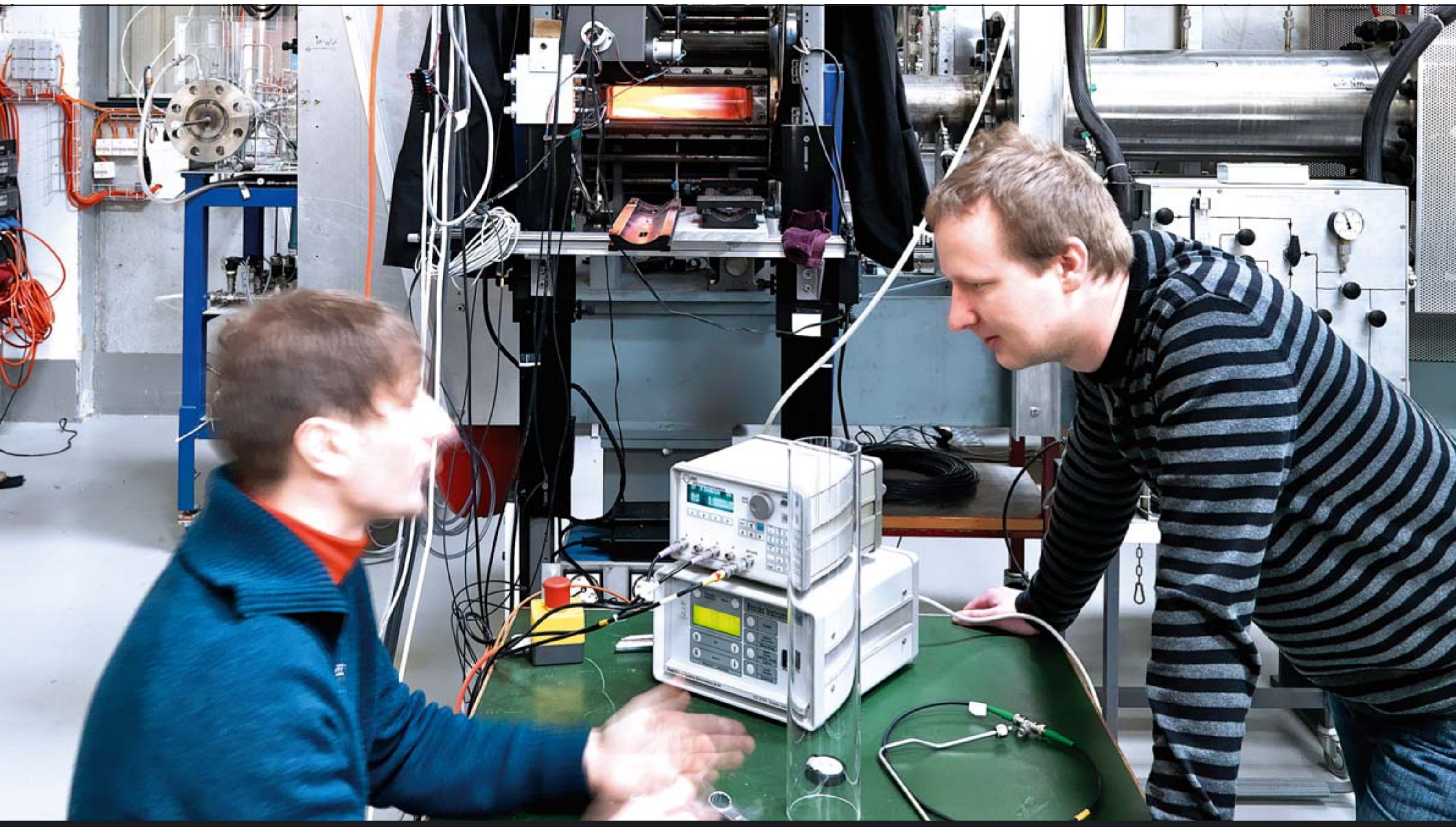
Zielpublikum sind Entscheidungsträger aus Wirtschaft und Politik sowie Wissenschaftler und interessierte Personen, die sich über Lösungsansätze informieren möchten und diese als langfristige Chancen für den Werkplatz Schweiz erkennen.

Quelques solutions dans la lutte contre le réchauffement climatique

La Suisse et la communauté internationale se fixent des objectifs ambitieux pour réduire les émissions de gaz à effet de serre. La réalisation de ces objectifs exige obligatoirement des innovations technologiques et sociales. Dans le cadre de la conférence sur l'énergie, qui se tient à l'Institut Paul Scherrer, des experts de renommée internationale présentent quelques solutions prometteuses en faveur de la protection climatique globale. Ils proposent des moyens pour produire des vecteurs énergétiques à partir de la biomasse et de l'énergie solaire, de l'électricité pauvre en CO_2 à partir de l'énergie nucléaire et l'augmentation de l'efficacité des transports de marchandises. Le centre de compétence Énergie et Mobilité (CCEM), qui se consacre à ces objectifs, présente ses résultats.

Des représentants de haut rang de la politique, de l'industrie énergétique et électrique, des finances et de la recherche, discutent de leurs contributions pour la mise en œuvre des objectifs fixés dans le cadre de la protection climatique. Le PSI et le CCEM invitent à la conférence et à la visite des installations de recherche dédiées à ces différentes thématiques.

Le public visé est composé de décideurs du domaine de l'économie et de la politique, ainsi que de scientifiques et de personnes intéressées, qui souhaitent s'informer sur les éventuelles solutions et qui les reconnaissent comme des occasions de longue durée pour la place industrielle suisse.



Teilnehmende der Podiumsdiskussion
Personnes participant à la table ronde

Philipp Dietrich	Geschäftsführer CCEM Managing Director CCEM
Michael Hölz	Direktor Nachhaltigkeit, Deutsche Bank Directeur du développement durable, Deutsche Bank
Tony Kaiser	Alstom, Vorsitzender der Eidgenössischen Energieforschungskommission CORE Alstom, président de la commission fédérale pour la recherche énergétique CORE
Philippe Méan	Chef de recherche, Alpiq Fachgruppe Elektromobilität, swisselectric research Groupe spécialisé mobilité électrique, swisselectric research
Ursula Renold	Direktorin BBT Directrice BBT
Ellinor von Kauffungen	Moderation Modération

Programm / Programme

Einführung / Introduction

09:00 – 09:05	Begrüssung am PSI	*J. Mesot (PSI)*
09:05 – 09:15	Lösungsansätze zum Schutz des globalen Klimas – Überblick	*A. Wokaun (PSI)*

Biomasse – Strom und Treibstoffe aus Holz / Biomasse – produire de l'électricité et des carburants à partir du bois

09:15 – 09:35	Einspeisung von Bioerdgas – die Sicht eines europäischen Gasversorgers	*M. Adelt (E.ON Ruhrgas)*
09:35 – 09:55	Bois: une source intéressante pour la production de bioélectricité et de bio méthane	*S. Biollaz (PSI)*

Verbrennungsmotoren – weniger Verbrauch und weniger Emissionen / Moteurs à combustion – moins de consommation et moins d'émissions

10:00 – 10:20	Hocheffiziente PW-Gasmotoren	*Ch. Bach (Empa)*
10:20 – 10:40	Lkw-Diesel – umweltfreundlich und effizient	*M. Signer (IVECO)*

Postersession / Séance de posters

10:45 – 11:15 Kaffee und Posters mit Ergebnissen der CCEM-Projekte / Pause-café et séance de posters avec les résultats du projet CCEM

Kernenergie für die CO_2-arme Stromversorgung / L'énergie nucléaire pour un approvisionnement électrique pauvre en CO_2

11:15 – 11:35	Le nucléaire: une énergie durable?	*J.-G. Devezeaux (CEA)*
11:35 – 11:55	Perspektiven neuer Technologien für Kernkraftwerke	*H.-M. Prasser (ETHZ und PSI)*

Solarenergie zur Produktion von Energieträgern / L'énergie solaire pour la production de vecteurs énergétiques

12:00 – 12:20	Electricité photovoltaïque à bas coût: le potentiel des couches minces et du silicium cristallin	*Ch. Ballif (EPFL)*
12:20 – 12:40	Konzentrierende Solarsysteme: Strom und Brennstoffe für oder aus dem Sonnengürtel?	*R. Pitz-Paal (DLR)*

Postersession / Séance de posters

12:45 – 14:30 Lunch und Posters mit Ergebnissen der CCEM-Projekte / Déjeuner et séance de posters avec les résultats du projet CCEM

Podiumsdiskussion / Table ronde

14:30 – 15:30 Stakeholders diskutieren zum Tagungsthema / Les parties prenantes discutent du thème de la conférence

Besichtigung von Forschungsstationen / Visite des centres de recherche

15:30 – 17:00 Möglichkeit zur Besichtigung von zwei ausgewählten Forschungsstationen / Possibilité de visiter deux centres de recherche au choix

Referate / Exposés

Einspeisung von Bioerdgas – die Sicht eines europäischen Gasversorgers

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Die Aufbereitung von Biogas und Einspeisung in Erdgasnetze ist in Deutschland bereits im industriellen Maßstab etabliert, wobei E.ON mehrere Biogasanlagen mit einer Einspeisekapazität von 200 – 1.700 m³/h betreibt. Weitere Anlagen befinden sich im Bau bzw. in Planung. Ziel der Bundesregierung ist ein Anteil von 6 Mrd. m³/a Biogas (Anm.: aufbereitet auf Erdgasqualität) im Erdgasnetz bis 2020, so dass ein starker Ausbau der Produktionskapazitäten notwendig ist. Bisherige Produktion von Biogas basiert überwiegend auf Energiemais und verschiedenen Zwischenfrüchten sowie anlagenabhängig unterschiedlichem Anteil von Bio-Reststoffen. Das Biogas wird auf Erdgasqualität aufbereitet und als Biomethan (E.ON: Bioerdgas) ins Gasnetz eingespeist. Für die Erfüllung der ambitionierten Ziele ist jedoch die Erschließung der bisher ungenutzten Holzpotenziale für die Vergasung und anschließende Methanisierung zu Bio-SNG erforderlich. E.ON AG engagiert sich auch für die Entwicklung und Einführung dieser Technologie.

Nachfolgend wird daher ein Überblick hinsichtlich folgender Aspekte der Bio-SNG-Erzeugung und -Nutzung gegeben:

- Nutzungspfade von Biomethan/Bio-SNG (Wärme, Kraftstoff, KWK)
- Holzpotenziale für Bio-SNG-Erzeugung,
- Technologiebewertung der Bio-SNG-Erzeugung
- Aktuelle E.ON-Aktivitäten und -Projekte.

Bois: une source intéressante pour la production de bioélectricité et de bio méthane

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La bioénergie est une ressource renouvelable. Le bois, le biogaz ou le bioéthanol sont tous des exemples de bioénergie bien connus qui peuvent être utilisés par les consommateurs directement. La production de chaleur à partir de bois est aujourd'hui l'application la plus importante dans le domaine de la bioénergie. La technologie pour la combustion est à un haut niveau. Néanmoins, à long terme une valorisation de la bioénergie sous forme de bioélectricité ou de biocarburant doit être envisagé à condition que le besoin pour le chauffage renouvelable va diminuer respectivement peut être couvert avec d'autres formes d'énergie renouvelable. Récemment la discussion en Suisse, mais également a l'étranger, a été intensifiée concernant l'application de la biomasse sous forme de biocarburant («food vs. Fuel»). Comme le potentiel de biomasse à l'échelle locale, régionale ou globale est limité, il est très important d'avoir cette discussion et d'identifier les différentes options prometteuses.

Dans cette présentation quelques exemples de ces options sont montrés et comment la contribution de la bioénergie peut être augmentée à l'avenir. Les points communs de ces exemples sont la compatibilité avec le potentiel local de la biomasse (quantité, qualité), la compatibilité avec l'infrastructure existante (production, distribution) et l'agenda politique. Toutes ces technologies basent sur la transformation de la biomasse en gaz de synthèse avec des procédés thermochimiques. Pour maximiser l'utilisation de la biomasse l'intégration optimale des procédés de conversion de la biomasse à l'énergie secondaire est décisive. Cela demande une bonne compréhension des processus.

Le bois sera une des sources les plus intéressantes pour la production de bioélectricité et de bio méthane. D'autres formes de biomasse sèche comme la paille ou le foin peuvent devenir important à l'avenir. A long terme même des biomasses comme le purin ou d'autres biomasses très humides peuvent être transformées en bioélectricité et en bio méthane par des procédés thermochimiques.

La demande des biocarburants liquides va augmenter à l'avenir. Néanmoins, aujourd'hui il n'existe pas de technologies qui sont compatibles avec l'infrastructure de production existante en Suisse ou en Europe. Le développement ou l'adaptation de ces technologies prendra quelque temps.

L'approvisionnement de biomasse pour les installations the conversion, soit pour les biocarburants liquides ou gazeux, soit pour la production de bioélectricité, reste un point très important et peut être décisif pour le succès d'une technologie.

Hocheffiziente PW-Gasmotoren

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Ausgangslage

Erdgas/Biogasfahrzeuge finden in letzter Zeit zwar einerseits vermehrt das Interesse der Automobilindustrie, weil die kurz- und mittelfristigen Anforderungen hinsichtlich Abgas- und insbesondere CO_2-Emissionen für Personenwagen doch wesentlich einfacher einzuhalten sind, als bei Benzin- oder Dieselfahrzeugen. Auf der anderen Seite wird das rein elektrische Fahren, selbst wenn die CO_2-Emissionen von Elektrofahrzeugen kaum niedriger, die technischen Herausforderungen und die Kosten aber deutlich höher sind, in der Bevölkerung doch als wesentlich zukunftsgerichteter gesehen, als ein Erdgas-/Biogasfahrzeug.

Weshalb also nicht das gute Umweltverhalten von Erdgas-/Biogasfahrzeugen bei niedrigen Kosten und das für den End-User faszinierende rein elektrische Fahren in einem Erdgas-/Biogas-Hybridantrieb kombinieren?

Projekt CLEVER (http://clever.empa.ch)

Die Empa und die ETH Zürich arbeiten gemeinsam mit Volkswagen und Bosch an einem solchen Erdgas/Biogas-Hybrid-Konzept. Dabei werden die Potentiale neuer Brennverfahren (z.B. Erdgas-/Biogas-Direkteinspritzung), die Optimierung des thermodynamischen Kreisprozesses (z.B. Miller-Zyklus mit frühem Einlassventil-Schliessen) untersucht und ein Laborprototyp aufgebaut. Parallel dazu wurde im Rahmen einer Dissertation im Institut für dynamische Systeme und Regelungstechnik die optimale Auslegung, Struktur und Regelung des parallelen Vollhybridantriebs aufgezeigt. In einer laufenden Dissertation am Laboratorium für Aerothermochemie und Verbrennungssysteme der ETH wird die Strömung, Gemischbildung und Verbrennung der Erdgas/Biogas-Direkteinblasung in Computersimulationen optimiert.

Um die Umsetzungspotentiale zu untersuchen, wurden Abschätzungen zu den CO_2-Emissionen und den Kosten gemacht. Diese Auswertungen werden im Referat anhand eines möglichen Einsatzfalls aufgezeigt. Dabei wird ersichtlich, dass Erdgas/ Hybrid-Mittelklassefahrzeuge bereits heute den geplanten CO_2-Grenzwerten der EU für 2020 (95 g/km) unterschreiten können und mit einer Biogasbeimischung von 20% (entspricht dem aktuellen Stand) insgesamt im untersuchten Fallbeispiel rund 50% niedrigere CO_2-Emissionen aufweisen, als ein modernes Benzinfahrzeug. Bei geeigneter, kostengünstig realisierbarer Abgasnachbehandlung weist ein solches Fahrzeug zudem nahezu keine Luftbelastung mit toxischen oder reaktiven Schadstoffen mehr auf.

Ein weiteres, für die Umsetzung wichtiges Merkmal sind die Kosten, die bei zukünftigen Antriebskonzepten aus gutem Grund oftmals nur im Hintergrund diskutiert werden. Basierend auf der aktuellen Kostenstruktur der Treibstoffe kann gezeigt werden, dass die höheren Anschaffungskosten des Erdgas-Hybridfahrzeuges, die für die Erreichung der o.g. CO_2-Reduktion natürlich nicht unerheblich sind, während der Lebensdauer des Fahrzeuges (Annahme: 12 Jahre, 180'000 km) vollständig amortisiert werden. Das bedeutet, dass die CO_2-Reduktion um 50% zu keinen Mehrkosten führt! Es gibt kein anderes Antriebskonzept für Mittelklassefahrzeuge, das diesem Anspruch genügt.

Zukunftsvision

Der Einsatz gasförmiger Treibstoffe eröffnet ein breites Feld von möglichen Zukunftsszenarien, das von heutigen erdgas/biogasbetriebenen Fahrzeugen über mit Erdgas/Biogas-Wasserstoffgemischen und/oder Erdgas/Biogas-Elektrofahrzeugen (im Fall von Plugin-Hybridkonzepten) und reinen Wasserstoffantrieben führt. Für die Schweiz hat dieser Treibstoffpfad neben der immer wichtiger werdenden Diversifizierung eine grosse Bedeutung, weil uns die Flächen für den Anbau von (sauberen) Energiepflanzen fehlen, demgegenüber aber ein zwar auch limitiertes, aber für effiziente Antriebe doch auch relevantes Biogaspotential in Form von Grüngutabfällen, Gülle, Klärgas und Altholz vorliegt.

Lkw-Diesel – umweltfreundlich und effizient

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Nutzfahrzeuge stellen das Rückgrat unserer Versorgung des täglichen Lebens und der Wirtschaft dar. Deren Wirtschaftlichkeit und Umweltverträglichkeit muss der entsprechende Stellenwert zugeordnet werden.

Das wohl signifikanteste Emissionsregelwerk Euro VI steht kurz vor der Einführung. Im Vergleich zu der Zeit vor der Emissionsgesetzgebung werden die NOx- und PM-Emissionen um mehr als 98% reduziert. Ein PM-Anzahlgrenzwert macht einen Filter mit mehr als 99% Wirkungsgrad notwendig. Die Emissions-Dauerhaltbarkeit ist spezifiziert und wird durch zwingende Messungen im praktischen Einsatz des Fahrzeuges überprüft. So wird sichergestellt werden, dass unter allen normalen Einsatzbedingungen eines Lkw's die Grenzwerte eingehalten werden.

Zur Erreichung dieser umfänglichen Forderungen mit tiefen Grenzwerten müssen alle bisherigen Techniken eingesetzt werden, optimierte Verbrennung mit Hochdruckeinspritzung basieren auf Common-Rail, gekühlte Abgasrückführung, aufladetechnische Massnahmen, Partikelfilter und SCR-Abgasnachbehandlung. Die Kombination dieser Technologien wird derart sein, dass Kosten einerseits und Treibstoffverbrauch, d.h. Betriebskosten andererseits für den Fahrzeugbetreiber möglichst tief sind.

Aus der Sicht der Nutzfahrzeug-Industrie stellt Euro VI die letzte Emissions-reduktionsstufe dar. In der Zukunft wird sich die Entwicklung auf die weitere Verbesserung des Treibstoffverbrauches und somit der CO_2-Emission konzentrieren. Der Wettbewerb unter den Herstellern hat bisher dafür gesorgt, dass die Wirtschaftlichkeit von Nutzfahrzeugen stets verbessert wurde. Der Verbrauch eines vollbeladenen 40-Tonnen Zuges hat sich so in den letzten 20 Jahren um 20% oder mehr gesenkt und liegt heute bei gut 32 l/100km (Langstreckenverkehr). Beim Nutzfahrzeug wird es wesentlich sein, die CO_2-Emission in Gramm pro Tonne Transportmasse und 100km zu bestimmen. Nur so kann die Vielzahl der Fahrzeugvarianten und –anwendungen berücksichtigt werden. Innerhalb der EU sind erste Programme zur Bestimmung der CO_2-Emission von Nutzfahrzeugen angelaufen.

Die technischen Massnahmen zur weiteren Optimierung von Verbrauch und CO_2 sind Verbesserungen des Transportkonzeptes (Masse und Gewichte), Fahrzeugtechnik (Reduzierung der Widerstände) und Antriebstechnik. Bezogen auf die transportierte Masse ist dem Transportkonzept grosse Beachtung zu schenken. Schon geringe Anpassungen von Massen und Gewichten und optimierte Fahrzeugauslegung können den Verbrauch um mehr als 20% senken. Beim Antriebsstrang werden Verlustleistungs-reduzierung beim Motor, Hybridisierung und Wärmerückgewinnung aus dem Abgas Themen sein. Je nach Fahrzeugtyp und Einsatz sind die Gewinne stark unterschiedlich, aber dennoch immer signifikant.

Die Nutzfahrzeugindustrie hat bereits vor mehr als einem Jahr angeboten, Verbrauch und CO_2 – gemessen in g/Tonne*100km – bis ins Jahr 2020 um 20% zu reduzieren. Dies bedingt aber auch eine gewisse Flexibilität seitens des Gesetzgebers. Ausser Zweifel steht aber die Bedeutung des Lkw-Dieselmotors auch in der Zukunft.

Le nucléaire: une énergie durable?

Par Jean-Guy Devezeaux de Lavergne
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La durabilité du nucléaire est liée à divers aspects, tels que notamment:

1. la ressource en uranium
2. la compétitivité
3. la capacité du nucléaire à sortir de son usage électrogène „standard"
4. les risques et l'acceptabilité

Ce papier proposera quelques éclairages sur ces différents points, en privilégiant les aspects liés à la ressource en uranium.

La dépendance du nucléaire actuel à la disponibilité en uranium peut-être qualifiée de faible. D'une part, les coûts de cette ressource sont modestes au regard du coût de production de l'électricité, d'autre part, des stocks stratégiques existent et, enfin, les ressources sont importantes. En effet, la connaissance actuelle des ressources en uranium et les perspectives de développement du nucléaire montrent que les seules ressources formellement identifiées (raisonnablement assurées) permettent près d'une centaine d'années de fonctionnement du parc à son niveau actuel, ce qui est une bonne performance par rapport à d'autres énergies.

Le nucléaire est toutefois appelé à se développer fortement. A l'horizon de quelques dizaines d'années, les améliorations de la gestion de l'uranium en réacteurs à eau pourraient ainsi permettre de faire gagner encore plusieurs dizaines de pourcents en ce domaine. Mais il faudra faire plus.

Au-delà, il faudra faire mieux que ne consommer que moins de 1% de l'uranium naturel extrait. Il faudra donc faire évoluer le parc et remplacer les REL par des réacteurs utilisant beaucoup mieux l'uranium naturel comme les réacteurs à neutrons rapides (RNR) qui peuvent produire de l'ordre de 100 fois plus d'énergie avec la même quantité d'uranium naturel. Les défis à relever par ces RNR sont principalement ceux de la sûreté et de l'économie. Notons que si leur coût d'investissement apparaît aujourd'hui plus élevé que celui des REL, c'est justement un prix de l'uranium naturel suffisamment haut qui les rendra compétitifs… prix qui sera atteint avec la raréfaction graduelle des ressources naturelles. Un développement important de ces réacteurs est prévu vers la moitié de ce siècle. Nous montrerons ce qu'on peut en attendre du point de vue des ressources pour le 21ème siècle.

Concernant les autres points, nous passerons rapidement sur les aspects économiques (compétitivité), pour introduire l'intérêt du nucléaire (énergie bas carbone) comme composante de systèmes associant des énergies nouvelles.

Puis, nous évoquerons les questions de risques et d'acceptabilité, en illustrant notamment la démarche française quant à la gestion de la toxicité des déchets.

Perspektiven neuer Technologien für Kernkraftwerke

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Hauptziele der international im GIF (Generation IV International Forum) koordinierten Aktivitäten zur Entwicklung von Reaktoren der Generation IV sind die weitere Verbesserung der Kernbrennstoffauslastung, die Reduktion der Mengen an langlebigem radioaktivem Abfall, die Bereitstellung von Prozesswärme auf hohem Temperaturniveau, die weitere Erhöhung der Sicherheit sowie die Verstärkung inhärenter Eigenschaften, die die Proliferation erschweren. Durch Reaktoren mit schnellen Neutronen kann die Brennstoffeffizienz signifikant angehoben werden und gleichzeitig die Umwandlung langlebiger Aktinide in Spaltprodukte kürzerer Halbwertszeit erfolgen. Die Erhöhung der Arbeitstemperatur durch geeignete Brennstoffe und Kühlmittel schafft Möglichkeiten zur Erhöhung der thermischen Effizienz und zur Auskopplung von Wärmeenergie auf einem Temperaturniveau, das für interessante chemisch-verfahrenstechnische und metallurgische Prozesse ausreicht, z.B. für die Erzeugung von Wasserstoff und anderen synthetischen Treibstoffen.

Einige dieser Ziele, so die Erhöhung von Sicherheit und Effizienz sowie die Verbesserung der wirtschaftlichen Konkurrenzfähigkeit gegenüber den fossilen Energieträgern, waren ebenfalls Gegenstände der Entwicklung der Generation III, die im wesentlichen auf den Erfahrungen heute betriebener Leichtwasserreaktoren aufgebaut hat. Als drittes Element kommen die unterkritischen, beschleunigergetriebenen Systeme dazu, die vorrangig zur Reduzierung der notwendigen Einschlusszeiten des hochaktiven Abfalls dienen sollen.

Bei der Vielfalt der verfolgten Lösungsansätze weisen stets mehrere Systeme die Potenz auf, eine bestimmte Zielvorgabe zu erreichen. So kann z.B. Wasserstoff sowohl durch Hochtemperaturprozesse, gekoppelt mit Hochtemperaturreaktoren, aber auch unter Nutzung von Elektrizität aus Reaktoren, die auf mit moderatem Temperaturniveau laufen, erzeugt werden. Die Kernbrennstoffauslastung kann durch die Erhöhung von Konversionsraten, aber auch durch eine Wirkungsgradsteigerung verbessert werden. Für die Steigerung der Konversionsraten stehen unterschiedliche Kühlmittel für Reaktoren mit schnellen Neutronen zur Verfügung, aber auch wasser- und schwerwassergekühlte Reaktoren haben noch Potenzen, die Konversion von Brutstoff in Spaltstoff zu steigern.

Ein wichtiges Element der Nachhaltigkeit ist die Brennstoffeffizienz. Im Beitrag werden die einzelnen Lösungsmöglichkeiten unter dem Blickwinkel des spezifischen Verbrauchs an primärem energetischem Rohstoff gegenübergestellt. Es zeigt sich, dass der anstehende Ausbau der Kernenergie durch Reaktoren der Generation III in Verbindung mit dem Übergang zu hocheffizienten Verfahren zur Urananreicherung bereits eine signifikante Steigerung der Brennstoffeffizienz nach sich zieht, die durch eine weitere Optimierung, insbesondere von Siedewasserreaktoren, noch gesteigert werden kann. Die Ressourcennutzung durch die kommende Generation neuer Leichtwasserreaktoren führt nicht zu einer Einschränkung der Möglichkeiten für eine spätere serienmässige Einführung von Reaktoren mit schnellen Neutronen und entsprechend optimierten Brennstoffkreisläufen.

Electricité photovoltaïque à bas coût: le potentiel des couches minces et du silicium cristallin

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En 2009 plus de 12 GWp de cellules solaires cristallines et de modules en couches minces ont été produits à travers le monde*. Dans la première partie de cette présentation, la situation du marché du photovoltaïque ainsi que l'abaissement spectaculaire du prix des modules seront abordés. L'impact pour une production à bas coût de l'électricité solaire sera discuté. De fait, dans les régions ensoleillées, la partie du module dans le coût de l'électricité pourrait atteindre à très court terme quelques centimes d'euro. Les progrès en matière de coût, ainsi que les soutiens aux développements vont également amener dans certaines parties de l'Allemagne le PV à bientôt dépasser le 5% de la production totale d'électricité. La question de l'intégration du photovoltaïque au réseau va donc devenir un thème de première importance.

Dans la deuxième partie les derniers résultats de recherche obtenus par plusieurs groupe de recherche en Suisse ainsi que les transferts et développements technologiques en cours seront présentés. Les derniers résultats du développement d'une technologie combinant le silicium amorphe et le silicium cristallin (hétérojonction) entre l'IMT et la compagnie Roth and Rau montreront une manière simple de fabriquer des cellules solaires à 20% et plus de rendement avec des procédés «basses températures».

* Source Photon International, March 2010

Konzentrierende Solarsysteme: Strom und Brennstoffe für oder aus dem Sonnengürtel?

Robert Pitz-Paal
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Parabolrinnenkollektoren, die mittels Hochtemperaturwärme in einem konventionellen Kraftwerk Strom erzeugen, stehen seit mehr als 20 Jahren in der kalifornischen Mojawe Wüste. Lange fand ihre Erfolgsgeschichte keine Nachahmer. Doch die globale Herausforderung durch Klimawandel und Ölpreisschock haben die Vorteile dieser Technik wieder wachgerufen und führten seit einigen Jahren zu einem regelrechten Bauboom, zunächst angeregt durch ein entsprechendes Stromeinspeisegesetz in Spanien. Inzwischen wird jedoch im gesamten Sonnengürtel der Welt gebaut.

Zwei unterschiedliche Systeme zur großtechnischen solarthermischen Stromerzeugung in sonnenreichen Ländern sind heute verfügbar. Zum einen linienfokussierende Systeme, die die konzentrierte Strahlung in ihrer Brennlinie auf ein selektiv beschichtetes Absorberrohr richten und damit Temperaturen bis zu 400°C im dort zirkulierenden Wärmeträger erzielen. Zum anderen Punkt-fokussierende Systeme, bei denen dreidimensional gekrümmte, der Sonne nachgeführten Einzelspiegeln (Heliostaten) die Solarstrahlung auf einen Wärmetauscher (Receiver) ausrichten, der sich auf der Spitze eines Turms befindet. Dabei können höhere Temperaturen als in den linienfokussierenden Systemen erzielt werden. Beide Techniken zielen darauf ab, die in konventionellen Kraftwerken durch fossile Energieträger erzeugte Wärme ganz oder teilweise zu ersetzen. Ihr Charme besteht darin, dass sich die erzeugte Hochtemperaturwärme (im Vergleich zum Strom) sehr kostengünstig und effizient zwischenspeichern lässt, um damit den Betrieb bei Wolkendurchgängen oder nach Sonnenuntergang fortzusetzen. Sind geringe Mengen (‹15%) an fossiler Zufeuerung im Kraftwerk möglich, lässt sich mit diesem Konzept Strom nach Bedarf mit hoher Zuverlässigkeit bereitstellen, um damit fossile Kraftwerkskapazitäten vollständig zu ersetzen.

Da die Stromerzeugungskosten stark von den verfügbaren Strahlungsressourcen abhängen wurde unter anderem unter dem Stichwort DESERTEC vorgeschlagen, die Kraftwerke selbst in der Wüste Nordafrikas zu errichten und den Strom relativ verlustarm mittels Hochspannungsgleichstromübertragung in die Ballungszentren nach Europa zu übertragen. In der öffentlichen Diskussion wird oft nicht deutlich welche Anteile der Energie hierbei sinnvollerweise tatsächlich exportiert werden sollten und welche für die lokale Versorgung und für die lokale Bereitstellung von Trinkwasser, durch die Entsalzung von Meerwasser in den Ländern Nordafrikas benötigt werden. Dieser Frage wird in diesem Beitrag nachgegangen. Darüber hinaus wird dargestellt, welchen wesentlichen Strategien zur Kostensenkung hier verfolgt werden

Posters / Abstracts

Mobility	**Klaus Hoyer**	LERF – Large Engine Research Facility
	O. Kröcher / U. Baltensperger	NEADS – Next Generation Exhaust Aftertreatment for Diesel Propulsion Systems
	Lino Guzzella	Cohyb – Customized Hybrid Powertrains
	Patrik Soltic	TransEngTesting – New Heavy Duty Engine Research Facility
	Christian Bach	Hy.muve – Hydrogen driven municipal vehicle
	Silvia Ulli-Beer	Hy-Change – Transition to Hydrogen Based Transportation
	Nikos Prasianakis	CEMTEC – Computational Engineering of Multiscale Transport in Small-scale Surface Based Energy Conversion
	Pascal Wilhelm	CELaDE – Clean and Efficient Large Diesel Engines
	Stefan Hirschberg	THELMA – Technology-centered Electric Mobility Assessment
Electricity	**Manuel Pouchon**	PINE – Platform for Innovative Nuclear FuEls
	Mohamed Fahrat	HydroNet – Modern Methodologies for Design, Manufacturing and Operation of Pumped Storage Power Plants
	Christian Bauer	CARMA – Carbon Dioxide Management in Swiss Power Generation
	Ioannis Mantzaras	GTCO2 – Technologies for Gas Turbine Power Generation with CO_2 Mitigation
	René Tölke	ONEBAT - Battery Replacement using Miniaturized Solid Oxide Fuel Cell
	Frank Nüesch	ThinPV – Cost Efficient Thin Film Photovoltaics for Future Electricity Generation
	Wolfgang Hoffelner	PHiTEM – Platform for High Temperature Materials
Heat & Buildings	**Mark Zimmermann**	ccem-retrofit - Advanced energy efficient renovation of buildings
	Mark Zimmermann	House2000 – Innovative Building Technologies for the 2000 Watt Society
	Severin Zimmermann	AQUASAR – Direct Re-Use of Waste Heat from Liquid-Cooled Supercomputers
	Jan Carmeliet	SuRHiB – Sustainable Renovation of Historical Buildings
Fuels	**Samuel Stucki**	2nd Generation Biogas – New Pathways to Efficient Use of Biomass for Power and Transportation
	Jan van Herle	WOODGAS-SOFC – Integrated Biomass – Solid Oxide Fuel Cell Cogeneration
	Serge Biollaz	ARRMAT – Attrition Resistant Reactive Bed Materials in Fluidised Beds

Large Engine Research Facility – Research for cleaner, more efficient diesel combustion technologies

P. Dietrich, K. Hoyer; M. Hottiger
K. Boulouchos, P. Obrecht, P Kyrtatos

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After engine/facility commissioning and measurement chain validation by May 2009, the facility has been in full operation for one year. The basic engine configuration having single stage TC with standard valve timing, has since been modified to a serial 2-stage TC system in combination with Miller timing of the intake valves.
This approach allows transferring part of the in-cylinder compression work to the external TC-system where the charge air is subject to inter- and after-cooling. The filling at higher boost pressure is limited by the shorter valve timing to yield the same charge air mass as in the conventional engine. This results in colder initial conditions before fuel injection and is therefore reduces thermal NOx formation.
The obtained data comprise time averaged values for all energy flows (e.g. fuel, shaft power, waste heat from cooling water and exhaust gas stream) plus exhaust gas composition, and also detailed transient measurements of the in-cylinder and gas exchange pressures together with an instrumented and calibrated fuel injector. The injection parameters such as CR-fuel pressure and SOI-timing are accessible and can be varied on the fly.
The facility allows variable speed operation of the engine while maintaining a grid-synchronous feed of the generated electric power via a 3-phase converter and 400V/16kV transformer.
The obtained time-averaged data is analysed in a global sense to estimate engine overall efficiency and sensitivity with respect to exhaust gas composition and fuel consumption. The transient data allow estimating not only the work supplied to the piston, but also the heat release rate during combustion, which is of prime interest for combustion modelling. The difference in shaft power versus the indicated power on the cylinder surface allows estimating also the internal losses due to friction and gas exchange.
In addition, the entire dataset is also used to calibrate and validate a GT-Power simulation to predict NOx and soot formation under various boundary conditions.

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Large Engine Research Facility

P. Dietrich, K. Hoyer, M. Hottiger; PSI - ENE

K. Boulouchos, P. Obrecht, P. Kyrtatos; MAVT ETHZ

Research for cleaner, more efficient diesel combustion technologies

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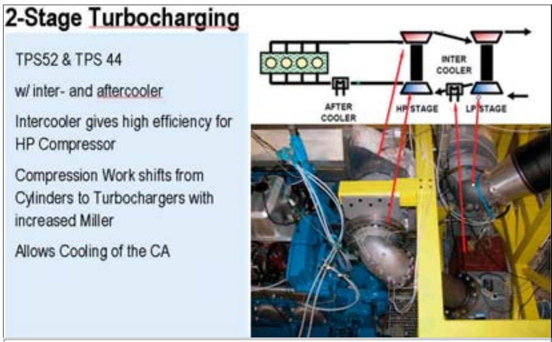

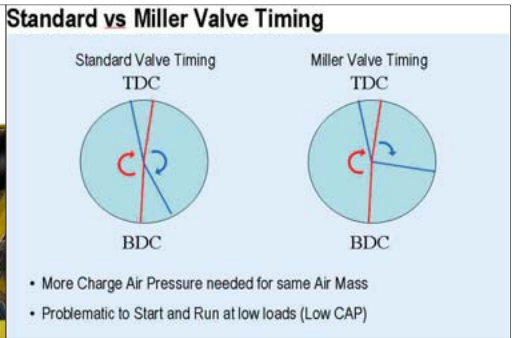

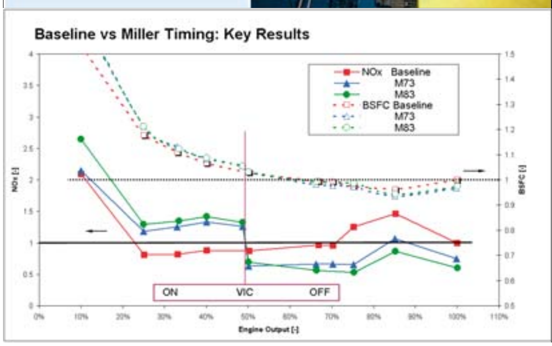

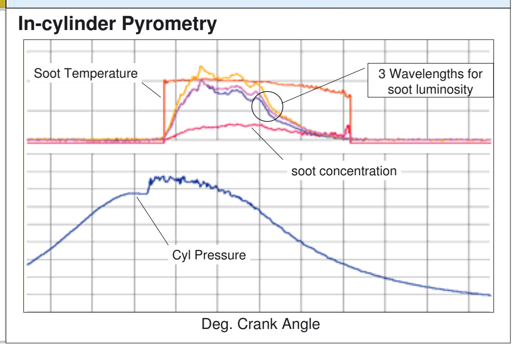

NEADS (Next Generation Exhaust Aftertreatment for Diesel Propulsion Systems)

Panayotis Dimopoulos Eggenschwiler, Oliver Kröcher, Konstantinos Boulouchos, Markus Ammann, Heinz Burtscher, Yuri Wright, Urs Baltensperger

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Main aim of the project is research and development, application and prototyping of next generation exhaust after treatment for diesel propulsion systems, leading to drastic reduction of NOx and particulates, without sacrificing the high efficiency of the diesel engines or prohibitively increasing the system costs.

- Zeolithe based Selective Catalytic Reduction (SCR)
- Ceramic based catalysts
- Soot emissions in transients

Meeting those targets involved development of high precision analytics:

- Advanced Particle Characterization
- Numerical simulation
- Assessment of atmospheric impact

Some achievements from each project part are summarized below:

New generation of zeolite SCR catalysts for passenger cars: Our results suggest that the SCR of NO by NH3 is catalyzed by different active sites and that their activation energies are dependent upon the reaction temperature. Isolated species are responsible for the SCR activity up to 300°C, but, with increasing temperature, dimeric and oligomeric species, and even Fe2O3 particles, become active. The temperature at which the species become active increases with increasing nuclearity.

Ceramic Foam based catalysts: The main aspect in the flow field investigations was the effect of the catalyst substrate on the flow uniformity. It could be shown that the flow downstream of honeycombs becomes less uniform with increasing mean flow, while this is not the case with ceramic foam substrates, where flow uniformity is not thereby. Further activities have focussed in investigating soot and ash accumulation and regeneration phenomena in Diesel Particulate Filters.

Soot emissions in transients: Focus on further development and validation of the MVSM program for transient engine operation. Importance of temperature estimation in the intake manifold on predicted engine-out soot emissions was identified. Use of the MVSM to synthetic diesel fuel with low aromatic content and lower cetane number accomplished.

Advanced Particle Characterization: Samples from the smog chamber have been taken. Spectral features at the carbon edge have been examined using the upgraded POLLUX beamline. The results show that chemical functional group composition of soot as well as its evolution with photochemical processing is depending on catalyst technology.
The MiniDiSC has been developed, which is small enough to be used as personal monitor for ambient air measurements.

Numerical Simulation: Development of a model for catalytic channels. Parameterisation of the model by employing genetic algorithm based optimisation using a data-set from a Zeolite catalyst. Successful application to different operating conditions. First simulations of catalyst upstream processes, including urea spray and mixture formation.

Atmospheric Impact: The results were obtained from Euro 3 vehicles. Fresh aerosols consisted mainly of black carbon (BC) with a low fraction of organic matter, in line with the experiments at the test bench in Ispra. Depending on the efficiency of the oxidation catalyst, the relative importance of SOA varies considerably.

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NEADS (Next Generation Exhaust Aftertreatment for Diesel Propulsion Systems)

O. Kröcher PSI/EGT, P. Dimopoulos Eggenschwiler Empa, Prof. K. Boulouchos ETHZ IET/LAV,
M. Ammann PSI/LRC, Prof. H. Burtscher FHNW, Y. Wright ETHZ IET/LAV, U. Baltensperger PSI/LAC

Project Scope and Goals

Main aim of the project is research and development, application and prototyping of next generation exhaust after treatment for diesel propulsion systems, leading to drastic reduction of NOx and particulates, without sacrificing the high efficiency of the diesel en-gines or prohibitively increasing the overall system costs.

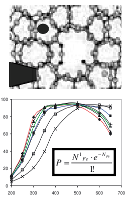
- Zeolithe based Selective Catalytic Reduction (SCR) systems for low tempera-ture applications
- Ceramic based microreactors enhancing the aftertreatment system performance
- Understanding Combustion-Aftertreatment Interface

Meeting those targets involved development of high precision analytics:

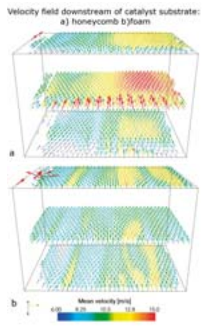
- Fast particle sizers, synchrotron based spectroscopy and time of flight aerosol mass spectroscopy (ToF AMS)
- Numerical simulation
- Assessment of the atmospheric and environmental impact

Zeolithe Screening for SCR

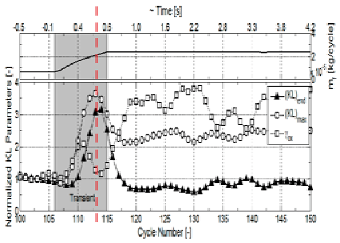
Temperature	Isolated species	Dimeric species	Oligomeric species Fe_xO_y	Particles Fe_2O_3
200-300 °C	Active TOF ≈ 14 s^{-1} (250 °C)	-	-	-
≈ 350 °C	Active TOF ≈ 46 s^{-1} (350 °C)	Active TOF ≈ 120 s^{-1} (350 °C)	-	-
≈ 400 °C	Active TOF ≈ 100 s^{-1} (400 °C)	Active TOF ≈ 170 s^{-1} (400 °C)	Active	-
≥ 500 °C	Active	Active	Active	Active



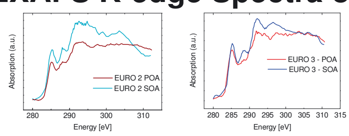
Ceramic Foam based Catalysts



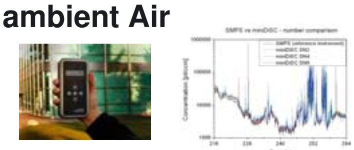
Understanding Soot Emissions in transients



NEXAFS K-edge Spectra of Soot



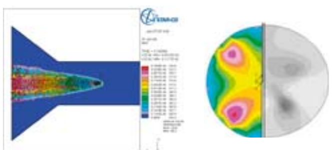
MiniDiSC: Particle Measurements in ambient Air



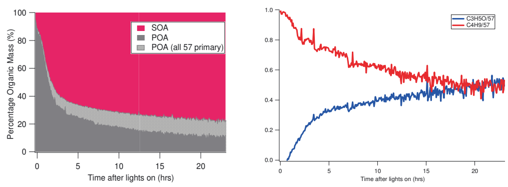
Partners

PSI: EGT, LAC, LRC
ETHZ: IET/LAV
Empa: ICEL
FHNW: IAST

Numerical Simulation of SCR Sprays



Diesel Soot Potential for Primary and Secondary organic Aerosols



Industrial partners

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ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
n|w Fachhochschule Nordwestschweiz Hochschule für Technik
EMPA Materials Science & Technology

Cohyb – Customized Hybrid Powertrains

Prof. Dr. Lino Guzzella, Dr. Chris Onder, Dr. Alois Amstutz, Tobias Ott
Prof. Dr. Konstantinos Boulouchos, Karel Steurs
Dr. Patric Soltic
Prof. Dr. Anke Weidenkaff, Oliver Brunko, Sascha Populo
Dr. Urs Sennhauser, Dr. Veronica Berdinas, Marcel Held

Institute for Dynamic Systems and Control, ETH Zürich
Aerothermochemistry and Combustion Systems Laboratory, ETH Zürich
Internal Combustion Engines Laboratory, EMPA Dübendorf
Solid State Chemistry Laboratory, EMPA Dübendorf
Electronics / Metrology / Reliability Laboratory, EMPA Dübendorf

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Hybrid electric vehicles will play an important role in the mobility of the next twenty years. They combine the excellent efficiency of electrical powertrains with the advantages of liquid or gaseous fuel combustion engines which allow excellent travelling ranges and easy and fast refueling.
For historical reasons the components which build a hybrid powertrain are chosen with a focus on availability and not with a previous optimization. This leads to vehicles which do not fully exploit the potential of a hybridization and therefore do not reach the lowest possible CO_2 emissions. The Cohyb project aims at closing this gap by investigating the following aspects:

Optimal Configuration and Control
A methodology will be developed which allows to select the optimal hybrid configuration, as well as the optimal component size for a specific customer demand. Control algorithms will be derived, which ensure that the maximum potential of the chosen configuration is exploited.

Adapted Internal Combustion Engine
Compared to conventional vehicles, the requirements for the internal combustion engine are different in hybrid electric vehicles. Transient operation of the internal combustion engine is less important, such that the engine can be optimized for maximum efficiency and low pollutant emissions. Different possible fuels, both liquid or gaseous, may offer advantages and will therefore be investigated.

Thermoelectric Converters
In an internal combustion engine, one third of the chemical energy of the fuel leaves the engine as hot exhaust gas. Thermoelectric converters which are based on the Seebeck-effect, allow to convert a part of the exhaust enthalpy directly to electric power, which can be used to recharge the battery.

Reliability, Availability Maintainability Safety
Hybrid electric vehicles pose completely new problems concerning safety and reliability. The combination of combustion engines with strong electric motors and large batteries will be investigated in depth. Insights for the choice of components from this point of view will be generated and suggestions for system design will be made.

All project participants have a high level of expertise in their corresponding field. The goal of the project is to fuse this knowledge to make a major contribution to customized hybrid powertrains. In the second part of the project a joint hybrid powertrain will be built based on the previous findings. The energy saving potential of this powertrain will then be demonstrated on a highly dynamic test bench.

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Cohyb

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Customized Hybrid Powertrains (2010 – 2013)

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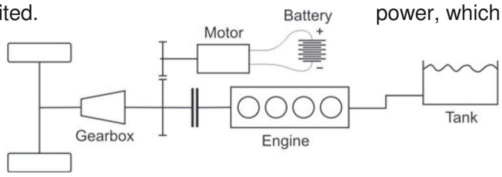

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New Heavy Duty Engine Research Facility at Empa (TransEngTesting)

Patrik Soltic, Internal Combustion Engines Laboratory, Empa Dübendorf (patrik.soltic@empa.ch)

Motivation

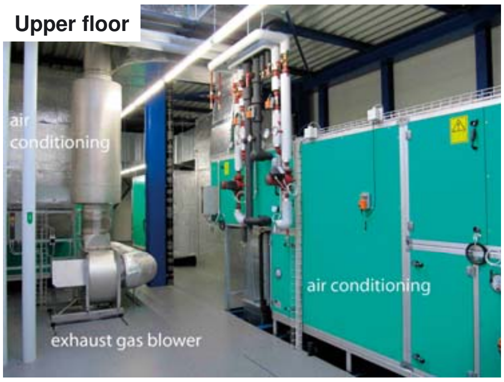
Modern truck engines in the 300 to 400 kW class with displacements of around two liters per cylinder achieve efficiencies of more than 45%. Such engines have to fulfill more and more stringent exhaust gas emission limits which lead to complex exhaust gas treatment system, the CCEM project "NEADS" performs research on this topic. Additionally, clean and efficient combustion has to be implemented which includes research on boosting, mixture formation , low-NO_x and low-particle strategies, injection and so on. The CCEM Project "CELaDE" focuses on these aspects.

Modern engines in the class mentioned above achieve higher and higher peak torque values due to progress in boosting and combustion technology. Empa was able to perform R&D on such engines with a transient engine test stand which could carry engines with peak torques up to 2'400 Nm. In the last years when modern heavy duty engines exceeded such peak torques by far, no test stand was available within the ETH domain to continue research at full engine load. This was the motivation to install a new transient engine test stand at Empa with a co-financing of about 20% from CCEM. The new test stand, which was inaugurated in 2009, is now able to carry engines with peak torques up to nearly 4'000 Nm and is used in the projects CELaDE and NEADS.

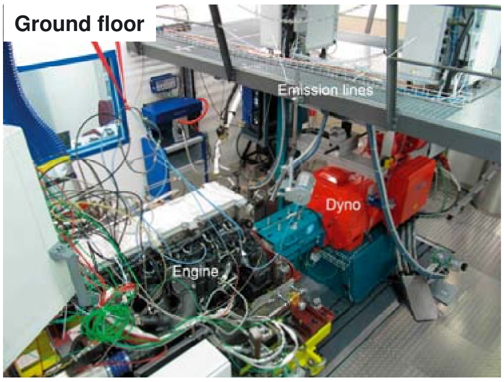
Technical Characteristics

- Rated power 600 kW, rated torque 3'957 Nm
- Combustion air conditioned (choice between 20…30 C and 30%...65% relative humidity)
- Controlled engine cooling system
- Water flowing to the Intercooler controlled to 20…30 °C
- Emission bench Horiba 7500 DEGR, 2 lines for CO, CO2, NO_x, THC, CH_4, O_2 measurement plus 1 EGR line
- Automatic fuelling infrastructure
- Fuel mass flow measurement and conditioning system
- Combustion air flow measurement
- Particle partial dilution system
- Opacimeter and smokemeter
- Blow-by meter
- Indication system

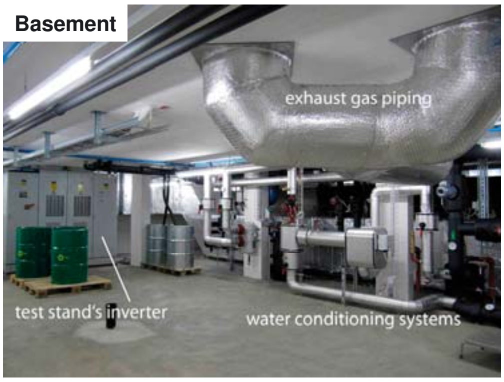
Upper floor



Ground floor



Basement



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Hydrogen driven municipal vehicle

Christian Bach (Empa), Peter Schlienger (Empa), Felix Büchi (PSI), Silvia Ulli-Beer (PSI), Stephan Walter (PSI).
Internet: www.empa.ch/hy.muve

Targets of the project

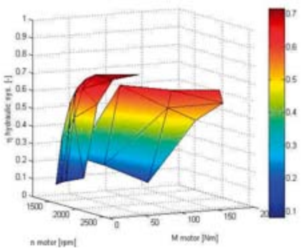
Development of a short term marketable hydrogen driven vehicle and real world testing in 3 swiss pilot regions.

Why a municipal vehicle?

Municipal vehicles are back-to-base-vehicles, which can be operated around one single hydrogen fueling station. Such vehicles are operated most of time in part load, where I.C. engines show a low, fuel cells a high energy efficiency.
The operation in public areas close to pedestrians offers a good platform for socio economic studies.

Analysis of power train efficiency

The efficiency of the diesel-hydraulic power train was determined experimentally in the two operating modes (dislocation ride and cleaning mode).



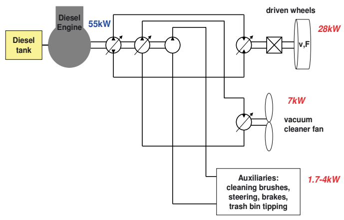
Efficiency map of hydraulic system

Project vehicle Bucher Schörling CityCat H_2

Longitudinal dynamics model

The typical operation, consisting of dislocation and cleaning phases, was simulated using a longitudinal dynamics model. The model was used for the design and the specification of the power train components.

From diesel-hydraulic to fuel cell/battery electric power train

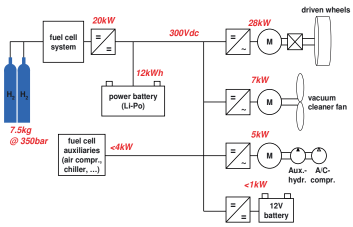


Diesel power train layout

Due to efficiency reasons, the 55 kW diesel engine and the hydraulic transmission have been replaced by a 20 kW fuel cell system combined with a 12 kWh LiPo battery, electric drives and a 7.5 kg hydrogren storage system.

Hybrid mode

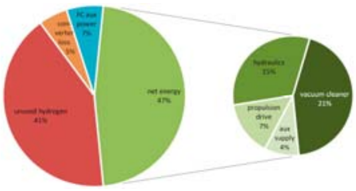
The fuel cell/battery hybrid mode allows a more stationary operation of the fuel cell than a fuel cell only concept, extending the fuel cell life time and enables energy recuperation.



hy.muve FC/battery hybrid power train concept

Energetic consumption

The predicted hydrogen consumption of 0.5 kg/h could be verified during a real-world test.



Typical energy balance of hy.muve

Compared to the specified diesel consumption of 5 l/h, a reduction of more than 70% of tank-to-wheel energy could be achieved in that particular situation.

Project partners:
BUCHER schörling, MESSER, BRUSA, Kanton Basel-Stadt, St. Gallen, novatlantis, energieschweiz, ccem.ch, PSI, EMPA

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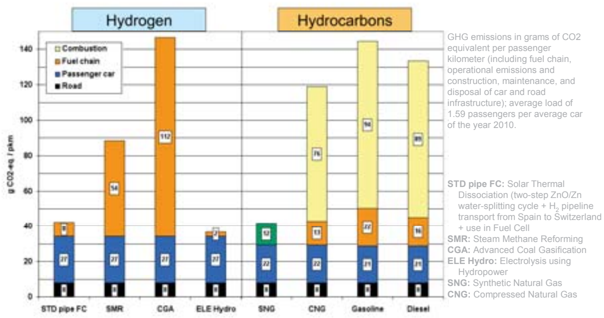
Energietagung 11. Juni 2010

Hy-Change: Transition to H_2- based Transportation

Opportunities and Challenges of Hydrogen as a Transportation Fuel

Alexander Wokaun with researchers from PSI, Empa, ETHZ: Warren Schenler, Erik Wilhelm, Hal Turton, Timor Gül, Ulli-Beer Silvia, Mathias Bosshardt, Manuel Bouza, Ramon Felder, Bauer Christian, Martin K. Vollmer, Steven Bond

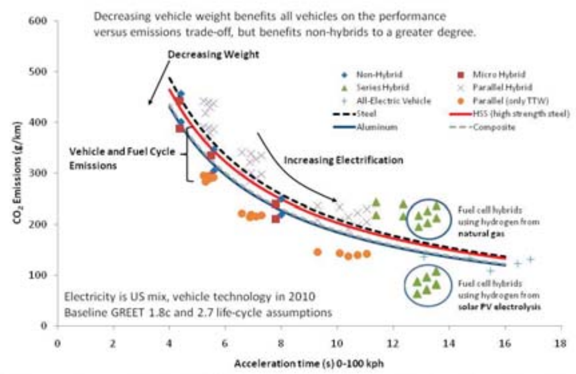
1. What is the life cycle impact of alternative and conventional fuels?



Hydrocarbons: With advanced internal combustion engines the CO2-equivalent emissions during the vehicle use phase strongly dominate. Methane from biomass (SNG) leads to a large reduction.

Hydrogen: For fuel cell vehicles propelled by hydrogen produced from fossil fuels(CGA & SMR), the fuel chain emissions dominate. Hydrogen fuel CO_2-equivalent emissions are significantly lower, if produced from renewable (ELE Hydro & STD pipe FC).

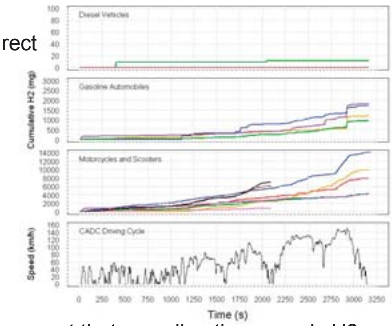
2. What are the performance characteristics of different drive-train concepts?



On a tank-to-wheel (TTW) basis, parallel hybrids dominate this trade-off. On a well-to-wheel (WTW) basis, micro-hybrids with start/stop technology tend to dominate present vehicle designs.

Using design heuristics a virtual fleet is modeled and simulated to evaluate present and future technical characteristics. Hybrids dominate the current performance versus emissions trade-off. Fuel cell vehicles (a subset of series hybrids) can be dominant technologies if hydrogen is produced renewably.

3. How crucial are H_2-emissions today and tomorrow?

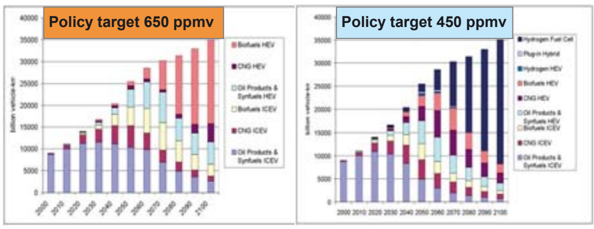


H_2 may act as an indirect greenhouse gas.

Today: Test results show, H_2-emissions over a driving cycle are much smaller for diesel cars than for gasoline cars. Motorcycles and scooters emit significantly higher quantities.

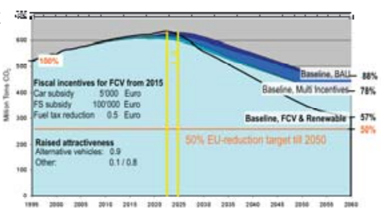
Tomorrow: Analyses suggest that overall anthropogenic H2 emissions to the atmosphere should remain within the realm of current estimates, should emissions from fuel cell vehicles and other well-to-wheel losses of H2 be minimized.

4. Under what climate policy targets are FCV competitive?



Global energy economic modeling shows that under a moderate climate policy target (650 ppmv) biofuels, and hybrid cars are competitive. Under a stringent climate policy target (450 ppmv) hydrogen becomes competitive. Further analysis shows: Battery electric vehicles could play a larger role if battery costs are substantially reduced.

5. How effective are transportation polices?



System dynamics fleet modeling shows that fiscal incentives alone are not very effective unless the attractiveness of alternative vehicles is raised (i.e. higher relative utility).

A 50% CO_2-emission reduction target for the EU passenger vehicle fleet could be reached with the early promotion of „near zero emission"-vehicles (e.g. fuel cell vehicle running on renewable hydrogen).

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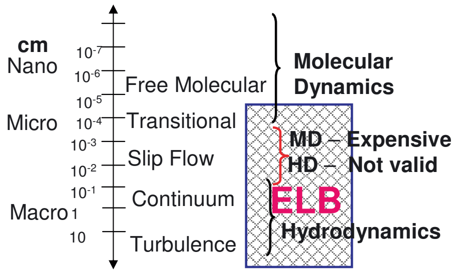
CEMTEC-CCEM

LAV-ETHZ, PSI, LTNT-ETHZ, EPFL

Computational Engineering of Multi-Scale Transport in Small-Scale Surface Based Energy Conversion



CEMTEC project developed a platform for multi-scale simulations of multi-component reacting flows in porous media with specific applications in solid oxide fuel cells (SOFC) and micro-reactors for portable power generation.

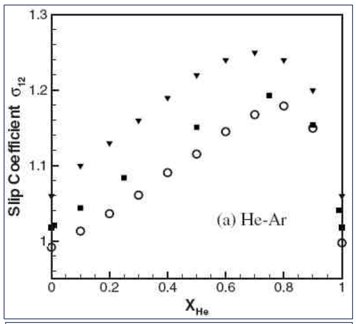
At the cornerstone is the novel **Entropic Lattice Boltzmann** method for fluid dynamics and micro-flows.
ELB models for chemically reactive flows, thermal flows, catalytic reactions and multi-phase flows were developed and numerically implemented in highly efficient parallelized codes.

A new, complete and systematic array of ELB models was created, implemented and tested with a specific focus on compressible flow simulation and simulation of micro-flows beyond continuum physics.

State-of-the-art high performance ELB code was developed and tested in a number of benchmark problems including high resolution simulation of turbulent flows.
A novel method to accurately reduce a mechanism of a complex chemical reaction was developed and was coupled to the ELB solver to implement reactive flow simulations.
A new ELB model for complex geometries, with appropriate boundary conditions, for realistic reactive multi-component mixtures, was built and further extended to include detailed catalytic reactions.
ELB model for mixtures was applied to simulate the flow in a realistic porous anode SOFC, and successfully compared with the conventional fluid dynamics simulations .

ELB – hydrodynamics simulation

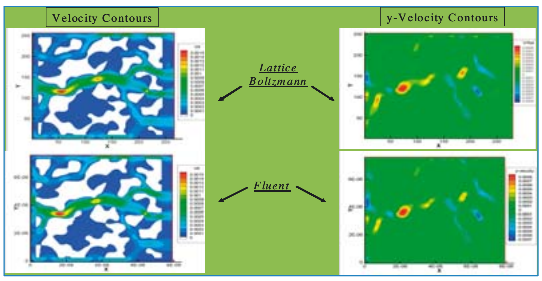
Vorticity iso-surface in ELB simulation of a turbulent wake behind a bluff body ("bridge").



ELB – microflow simulation

Slip coefficient in micro-Couette flow at Kn=0.2 in helium-argon mixture as a function of helium molar fraction

Circle: ELB for mixtures; Squares: Analytic solution of the Boltzmann equation; Triangles: Molecular Dynamics. Maximum of slip coefficient is well predicted by all three methods. Computational effort: ELB – few minutes; MD – few days



CH_4 and H_2O mixture flow in SOFC: LBE and conventional CFD simulation

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CELaDE Clean and Efficient Large Diesel Engines

Alexey Denisov, Klaus Hoyer, Peter Jahnson – PSI
Panagiotis Kyrtatos, Pascal Wilhelm – LAV, ETH Zurich
Patrik Soltic, - Empa, Internal Combustion Engines Laboratory

Introduction – Project Overview

The CELaDE project is geared towards the development of new technologies with the view of efficiency improvement and emission reduction in modern large diesel engines. This includes advances in engine modeling, model based control, measurement procedures and sensors.

• In-Cylinder Optical Measurements for Soot Model Calibration and Phenomenological Combustion Model Development (LAV/ETH)

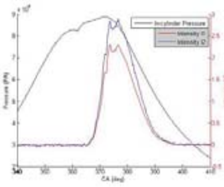
• *LERF:* The Large Engine Research Facility houses a Wärtsilä W20 6L Common Rail six-cylinder medium speed marine engine. The test rig is used for research into two-stage turbocharging and combustion concepts for future emission reduction and efficiency improvements. This test facility was partly financed by CCEM.

• *MTU:* The single-cylinder MTU-396 research engine is equipped with state-of-the-art measurement equipment and offers the possibility to study the combustion process isolated from environmental influences. This engine testbed was financed by CCEM.

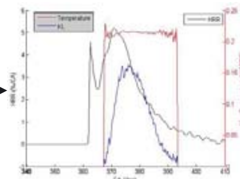
• *Phenomenological Models:* Phenomenological combustion and NO emission models have been developed and calibrated for specific use in modern medium-speed Diesel engine applications.

• *Optical Measurements:* Using three-color pyrometry, the in-cylinder soot concentration (KL-factor) and temperature can be measured. The miniaturized pyrometers, developed in conjunction with Kistler Instrumente, are mounted into the cylinder and are heated to avoid soot deposits on the sensor window. The light intensity recorded at three wavelengths is used to calculate the soot particle temperatures and in-cylinder KL-factor.

W20 LERF (Large Engine Research Facility) in PSI



Measured in-cylinder pressure and light intensity for two different wavelengths



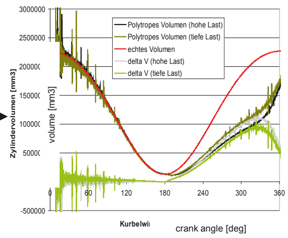
Calculated HRR from in-cylinder pressure and Temperature/KL-factor from light intensity

MTU Single cylinder test engine in ETH

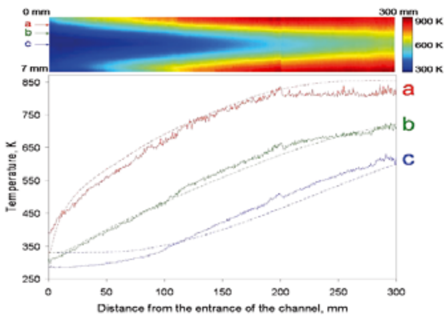
• Use of cylinder pressure signals (Empa)

Cylinder pressure measurement during gas exchange and combustion delivers important insight into the engine's thermodynamics cycle by cycle. Within the CELaDE project, a method was developed for a computationally cheap but robust detection of the start of combustion. This method proved to be robust to measurement uncertainties and was applied for a patent.

Experiments with a heavy duty diesel engine



Start of combustion detection using the polytropic approach



Top: two-dimensional temperature profile of air flowing through a heated channel reactor. Bottom: temperature profiles along the channel at 1(a), 2(b) and 3.5(c) mm from the wall, compared with the simulation (in-house CFD code, dashed line)

• NO LIF (PSI)

•A method of nonintrusive two-dimensional thermometry has been implemented that uses laser-induced fluorescence of seeded nitric oxide

•It has been tested on a laminar methane flame in a lab-scale burner at pressures up to 15 bar

•Results of temperature measurements in the channel reactor at 1 bar agree well with simulations (see figure left)

•Further measurements in the channel reactor at elevated pressures are planned to study the influence of radiative heat transfer on temperature profiles.

External Funding Sources and Industrial Partners

HERCULES-B
ABB
KISTLER measure. analyze. innovate.
WÄRTSILÄ
FVV
KTI/CTI DIE FÖRDERAGENTUR FÜR INNOVATION L'AGENCE POUR LA PROMOTION DE L'INNOVATION L'AGENZIA PER LA PROMOZIONE DELL'INNOVAZIONE THE INNOVATION PROMOTION AGENCY
BFE OFEN UFE SFOE

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THELMA Technology-centered Electric Mobility Assessment

An inter-disciplinary project examining road transport technologies in the context of climate friendly policies. A collaboration between six laboratories of the ETH-domain:

- Laboratory for Energy Systems Analysis (**PSI - LEA**),
- Life Cycle Assessment and Modelling group (**EMPA - LCAM**)
- Aerothermochemistry and Combustion Systems Laboratory (**ETHZ - LAV**)
- Ecological Systems Design (**ETHZ - ESD**);
- Institute for Transport Planning and Transport Systems (**ETHZ - IVT**);
- Power Systems Laboratory (**ETHZ - PSL**)

THELMA objectives

- Assess LCA-based environmental impacts of electric vehicle technologies: compare with combustion engines and range of fuels;
- Determine the potential role and requirements of the electric grid depending on the various electric mobility options;
- Conduct case studies on the environmental implications at regional or local levels, eg. centralised vs. decentralised energy supply;
- Assess aggregated environmental and economic vehicle technology attributes to enable cost-benefit analysis of mobility options;
- Evaluate the relative sustainability of the options by combining their multi-criteria performance with stakeholder preference profiles.

The structure and responsabilities within THELMA

THELMA is divided into five research work packages (WP):

WP1 Technology characterisation & Life Cycle Assessment (EMPA - LCAM; PSI - LEA)

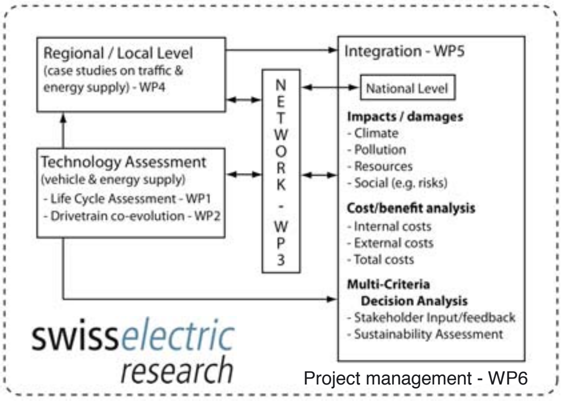
WP2 Vehicle simulation and powertrain assessment (ETHZ - LAV; PSI - LEA)

WP3 Power system modelling accounting for the presence of new charging loads from electric vehicles (ETHZ - PSL)

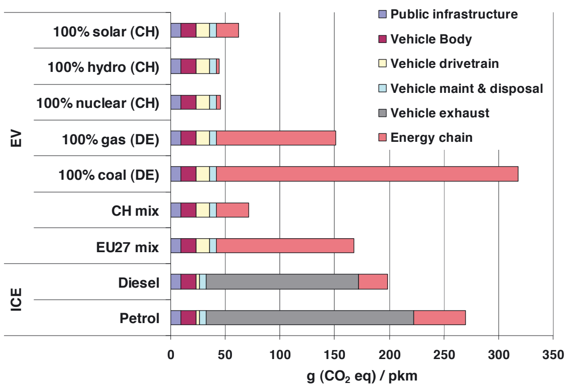
WP4 Case studies: Local/regional environmental implications of traffic patterns & energy supply (ETHZ - ESD; ETHZ - IVT)

WP5 Analysis integration and sustainablity assessment; total costs and multi-criteria decision analysis (MCDA) (PSI - LEA)

With a sixth work package covering project management (PSI - LEA)



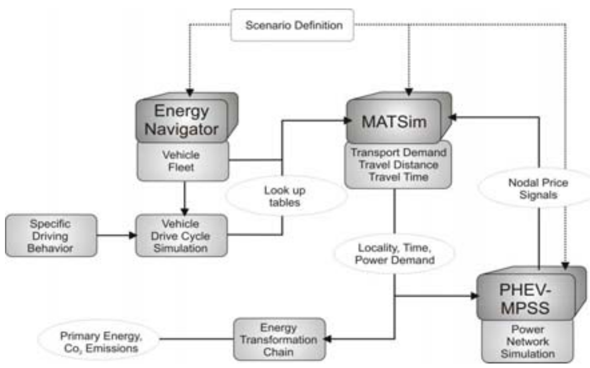
Initial results: GHG's of electric vehicles



Initial comparison of greenhouse gas (GHG) emissions from the complete life cycle of a small passenger car using either battery and electric motor (EV) or internal combustion engine (ICE). Results for various electricity supplies, including fuel production (energy chain).

Source: Simons and Bauer, 2010 (PSI-LEA)

Methodology example: System Integration



- MATSim couples detailed information of transport networks with temporal and spatial modelling of user behaviour to provide mobility load forecasting.
- Smart charging then results in efficient management of electricity supply systems and avoidance of demand peaks and local system overloading.

Sources: Noembrini, 2009; Waraich et al., 2009 (ETHZ – LAV, IVT & PSL)

For further information please contact: Dr. Stefan Hirschberg, THELMA project leader, PSI stefan.hirschberg@psi.ch

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PINE – Platform for innovative nuclear fuel

Manuel A. Pouchon[1], Cédric Cozzo[1], Sébastien Vaucher[2], Kotaro Ishizaki[2], José M. Catalá Civera[3], Thomas Graule[4], Lorenz Holzer[4], Ines Günther-Leopold[1], Jiří Křepel[1], Konstantin Mikityuk[1]

[1] *Paul Scherrer Insitut, Villigen PSI, Switzerland*
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[3] *Universidad Politecnica de Valencia, Valencia, Spain*
[4] *EMPA, Dübendorf, Switzerland*

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Introduction
The PINE-project aims for the development of carbide sphere-pac nuclear fuel for fast reactors and addresses all aspects, from the production, the utilization, to the reprocessing. Sphere-pac is a concept which is advantageous for minor actinide containing fuel (high radiation levels), as the process is powder less, does imply less mechanical parts as presses or grinders, and therefore is ideal for remote operation. The concept has successfully been addressed and tested in the past. New insights are expected from an even more simplified production process, new neutronic considerations and a thermal treatment before chemical reprocessing.

Material production
The fuel spheres are produced by a sol-gel process, at PSI especially the internal gelation was applied in the past. The chemical process leading from a solution to a gel is triggered by temperature rise. Classically the heating is achieved by contact with hot silicon oil, whereas in the PINE project the energy is induced by a microwave field, where the drops are passing through in free fall. As the time for heating is very short, the microwave field has to be developed, researched and highly optimized. Thanks to an innovative design it could be achieved, that the energy transfer coefficient is highly increased compared to a classical design.
A further task is the development of a continuous sintering process by using a rotary kiln. This is more cost effective than a batch wise sintering, guarantees a more homogeneous processing temperature and opens the possibility to have varying processing gases.

Reprocessing aspect
In a closed fuel cycle, as it is implied by the usage of fast reactors, it must be assured that the fuel can be reprocessed for the next irradiation stage. In frame of the PINE project a pre-conditioning heat treatment is investigated, researching the release of fission products as a function of temperature by ICP-MS. Presently inactive tests up to 2300 °C can be performed with an inductive heating device.

Neutronics
The carbide fuel and the sphere-pac concept are studied towards their compatibility with fast reactors in the context of a fuel cycle in a park of GEN IV system. The most important performance and safety-related parameters (nominal reactivity, breeding gain, void reactivity and Doppler constant) should be evaluated and compared with classical MOX fuel. This comparison will be based on one of the SFR reference cores designed at CEA in France.

Conclusions
The first results are very promising. The difficult task of microwave gelation is on a good track to be resolved; the continuous thermal treatment for sintering can be performed today, only the parameters have to be optimized. The future will show how the carbide spheres are compatible with the foreseen fuel cycle, regarding reprocessing and the fissile component breeding behavior.

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Energietagung 11. Juni 2010

PINE - Platform for innovative nuclear fuel

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[*] Paul Scherrer Insitut, Villigen PSI, Switzerland
[‡] EMPA, Thun, Switzerland
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A further task is the development of a continuous sintering process by using a rotary kiln (picture on the right). This is more cost effective than a batch wise sintering, guarantees a more homogeneous processing temperature and opens the possibility to have varying processing gases.

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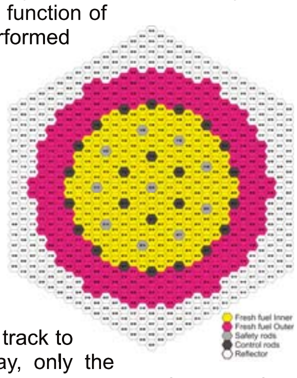

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HYDRONET

Mohamed Farhat

On behalf of HydroNet consortium: EPFL – Laboratory of Hydraulic Machines, EPFL – Laboratory of Hydraulic Construction, EPFL-Laboratory of Electric Machines, EPFL-Energy Center, EAWAG, EMPA, HTA Lucerne.

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Scope of the project

Pumped storage power plants are the key components for the development of new renewable CO_2-free primary energies and the security enhancement of electricity supply. Reversible pump-turbine technology enables to store large amount of extra electrical energy and quickly supply peak power by moving water back and forth between two reservoirs. However, the frequent switching between pumping and generating modes is posing new technical and scientific challenges related to the operation safety, the integrity of the mechanical and civil structures with unknown impact on the environment. The project aims to improve the design, manufacturing and operation of pumped storage power plants. Thank to its multidisciplinary consortium, the project involves hydrodynamic, electricity, civil engineering and environmental issues with a special focus on a joined monitoring strategy. A total of 8 PhD theses are planed within the project period (2007-2010)

Status of the project

In the hydrodynamic field, flow instabilities under off design operation are investigated with the help of a reduced scale model of a radial pump-turbine with state of the art instrumentation. The focus is put on the generating mode at runaway. We have clearly identified the occurrence and development of a flow recirculation in guide vane channels, which rotates at sub synchronous frequency and causes large flow induced vibration. Further investigations are underway to mitigate these effects. Numerical simulation of flow instabilities within a pump turbine during start-up is also carried out to propose new design rules for improved operation safety. The fluid structure interaction is an important issue which is addressed in the frame of two PhD works. The first one focuses on the effect of trailing edge geometry on the flow induced vibration on a hydrofoil while the second one deals with the mechanical response of a pump turbine under different operating conditions.

In the area of variable speed pump turbines, new control strategies for start-up procedure were developed and validated.

In civil engineering, two test rigs have been constructed to develop a monitoring procedure for shafts and tunnels, based on wave propagation, and to investigate long term sedimentation in pumped storage schemes with respect to their operation. The impact on the environment, due to pumping and generating activities, is being investigated through onsite monitoring of particle properties. Finally, the monitoring issue, which stands for the central task of the project involving all partners, is progressing well. A monitoring strategy has been already tested in laboratory and is being deployed at Grimsel 2 power plant with the participation of KWO personnel. We expect to achieve soon the integration of all measuring systems and the remote access to the pilot site.

The Hydronet project is jointly financed by CCEM (Competence Center for Energy and Mobility) and swisselectric research with the following industrial partners: Andritz (Switzerland), Alstom Hydro (France), Voith Hydro (Germany), KWO (Switzerland).

For more information, visit our web site: Hydronet.epfl.ch

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HYDRONET

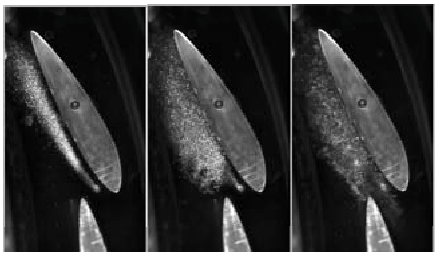
M. Farhat, EPFL, Lausanne, Switzerland
On behalf of HydroNet consortium

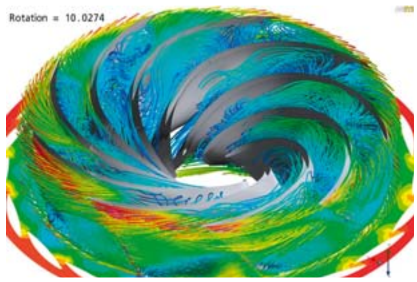
The Consortium

- **EPFL**:
  - LMH: Laboratory of Hydraulic Machines
  - LCH: Laboratory of Hydraulic Construction
  - LME: Laboratory of Electric Machines
  - Energy Center
- **EAWAG**: Swiss Federal Institute of Aquatic Science and Technology
- **EMPA**: Structural Engineering Research Laboratory
- **HTA Lucerne**: Fluid Mechanics and Hydromachines
- **Funding:** CCEM and swisselectric research
- **Industrial partners:** Andtritz (Switzerland), Alstom (France), Voith Hydro (Germany), KWO (Switzerland)
- **Period:** 2007-2010

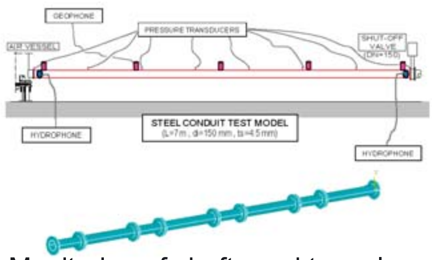
Objectives

improve the design, manufacturing and operation of pumped storage power plants. Thank to its multidisciplinary consortium, the project involves hydrodynamic instabilities, fluid structure interaction, variable speed turbines, civil engineering and environmental issues with a special focus on a joined strategy for non intrusive monitoring. A total of 8 PhD theses are planed within the project.


Visualization of rotating stall in a pump turbine distributor



Unsteady flow simulation



Monitoring of shafts and tunnels


Pilot site for non intrusive monitoring


Particle Sampling (Grimsel reservoir)

For more information: Hydronet.epfl.ch

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CARMA - Carbon management in power generation

Energietagung 11. Juni 2010

Carbon dioxide capture and storage (CCS)

- CCS is a set of technologies for the capture of CO_2 from its anthropogenic point sources, its transport to a storage location, and its isolation from the atmosphere.
- This is only one, though very important, option in a portfolio of actions to fight the increase of atmospheric CO_2 concentration, while at the same time allowing for the continued use of fossil fuels.
- Deployment of CCS technologies is expected to be limited in the next 5–10 years, but to contribute significantly to the reduction of CO_2 emissions 20 years from now.

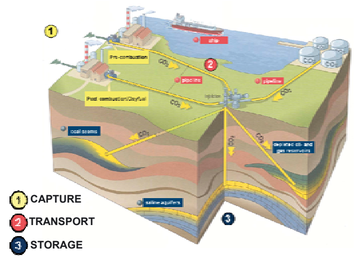


Figure: modified from Total AG

Motivation for CCS research in CH

- Fossil fuel based power generation is one of the candidate options in the Swiss energy roadmap.
- Reduction of CO_2 emissions is a global issue and requires concerted international action; new technology and know-how have global value.
- Despite significant additional cost and energy penalty, CCS is needed to bridge the time gap to CO_2-free/neutral energy technologies.

CARMA key questions

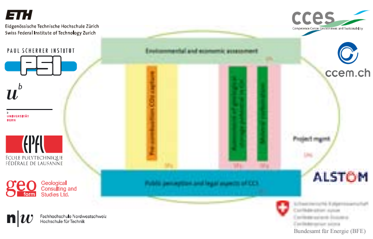
- What is the potential role of CCS in CH?
- What is the best strategy for CCS in CH?
- What are the societal/legal issues of CCS in CH?

CARMA project objectives (2009-2012)

- Assessment of potential role of CCS in CH
- New concepts for zero emission power plants
- Applicability of underground storage in CH
- Development of CO_2 storage know-how
- Exploration of legal and societal issues

Project structure

- CARMA is dived in **6 different subprojects** and follows an interdisciplinary approach: the team consists of **12 groups from 6 different research institutes** within Switzerland.



Sub-project 1 - SP1

Environmental and economic assessment

Tasks:
- Identification of the most relevant Swiss CO_2 sources
- Identification of CO_2 sinks in Switzerland and in the rest of Europe
- Evaluation of costs of the different CCS components
- Life Cycle Assessment (LCA) and environmental impact of CCS

Performance & Cost Measures	PC plant	IGCC	NGCC	Source
Increase in COE with CCS Geo-storage (US$/MWh)	20-47	14-30	12-27	IPCC 2005
Increase in COE with CCS EOR (US$/MWh)	6-29	1-14	6-20	
Cost of CO2 avoided¹ (US$/t CO2)	30-71	14-53	38-91	
Increase in COE with CCS Geo-storage (US$/MWh)	41.9	23.5	23.5	Rubin et al. 2007
Increase in COE with CCS EOR (US$/MWh)	20.5	3.3	14.4	
Cost of CO2 avoided (US$/t CO2)	49.7	23.0	63.0	
Increase in COE with CCS (US$/MWh)	60	36	34	Global CCS Institute 2009
Cost of CO2 avoided (US$/t CO2)	87	41	112	
Increase in COE with CCS (US$/MWh)	33.2	17.0	16.1	David & Herzog 2000
Cost of CO2 avoided (US$/t CO2)	49.0	28.0	49.0	
Increase in COE with CCS (US$/MWh)	46.8	21.6	16.7	Encyclopedia of Energy 2004
COE without CCS (€/MWh)	29.6	n.a.	59.9	Bauer et al. 2009
COE with CCS (€/MWh)	40.0	n.a.	86.9	
Increase in COE with CCS (€/MWh)	10.4	n.a.	27.0	

This table shows a literature review of economic assessment and cost models of CCS technology. CO_2 avoided had already taken into account for the efficiency penalty due to the additional energy requirement of carbon capture, transport and storage

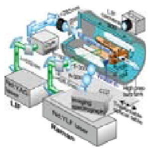
Project coordinator: Marco Mazzotti (marco.mazzotti@ipe.mavt.ethz.ch)
Project website: http://www.carma.ethz.ch

Sub-project 2 - SP2

Pre-Combustion CO_2 capture

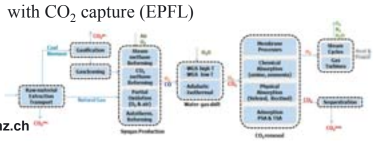
Task 1: homogeneous/heterogeneous (catalytic) combustion of hydrogen rich (>80 Vol.% H_2) fuel mixtures (PSI /FHNW)

Experimental apparatus: High-pressure, optically accessible test-rig equipped with Raman and OH-LIF for in-situ measurements



Experimental and numerical investigation of the ignition characteristics of hydrogen-rich fuels:
- combustion of pure hydrogen
- combustion of syngas (H_2/CO) mixtures

Task 2: thermo-economic modeling and optimization of power generation processes with CO_2 capture (EPFL)



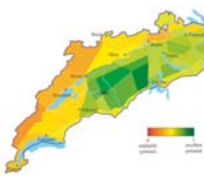
For each process option of this block flow diagram, thermo-economic models are developed and include thermodynamic and energy integration models, economic evaluation, and life-cycle analysis.

Sub-project 3 - SP3

Assessment of geological storage in Switzerland

- Mapping and evaluation of potential geological formations in Switzerland suitable for CO_2 storage from a structural, geological and hydrogeological point of view.
- Assessment of the seismicity induced by CO_2 injection and of the seismic hazard, based also on known cases of induced seismicity worldwide .

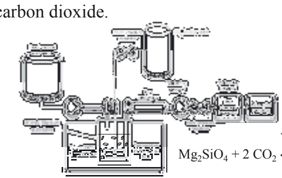
Subdivision of the Swiss Molasse Basin according to geological criteria relevant to CO_2 sequestration. Colors show provisional evaluation of CO_2 storage potential. Some regions appear very promising.



Sub-project 4 - SP4

Mineral carbonation

Goal: develop an aqueous mineral carbonation process that could become a realistic option for storage of carbon dioxide.



Olivine

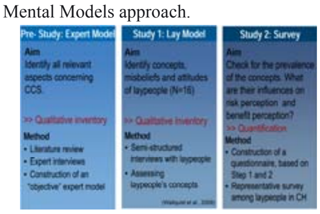
$$Mg_2SiO_4 + 2\,CO_2 \leftrightarrow 2\,MgCO_3 + SiO_2$$

- Experimental characterization of dissolution rate of olivine and precipitation rate of magnesite.
- Description of both processes by suitable models, combining mass balances and kinetic equations.
- The catalytic effect of organic salts on dissolution in a pH range suitable for direct magnesite precipitation is promising as it could allow for a faster and cost-effective mineral carbonation process.

Sub-project 5 - SP5

Public perception an legal aspects of CCS

- Investigation of laypeople's beliefs and misbelieves about CCS.
- The work is divided in three phases and is based on the Mental Models approach.



- Based in this work a communication can be developed and evaluated.

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Energietagung 11. Juni 2010

Combustion Technologies for Gas Turbine Power Generation with CO_2 Mitigation

S. Karagiannidis, X. Zheng, J. Mantzaras, R. Kaufmann, Paul Scherrer Institute, Combustion Fundamentals Group, Villigen-PSI
M. Matuszewski, D. Erne, P. Jansohn, Paul Scherrer Institute, Lean Premixed Combustion Group, Villigen-PSI
S. Reimer, D. Winkler, M. Seppi, T. Griffin, Fachhochschule Nordwestschweiz, Windisch

Project Goals

Investigation of Natural Gas combustion stability
under Flue Gas Recirculation conditions (FGR) with low oxygen excess

- Testing at simulated SEV (second stage) combustion conditions of ALSTOM GT26
- Addresses the challenge of developing a GT with mitigated CO_2 emissions
- Combustion with hydrogen-based fuels and simulated natural gas investigated

Combustion Research at PSI / CFG

Fundamental studies on catalytic and gas-phase chemical kinetics of CH_4/C_2H_6 mixtures combustion with H_2O/CO_2 dilution

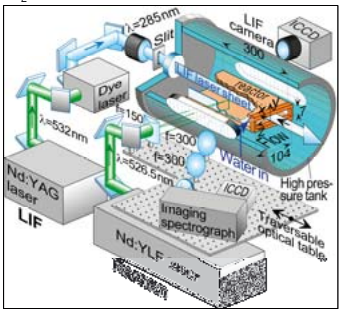

Fig.1 Optically accessible, channel-flow reactor with Raman and OH-LIF laser diagnostics setup.

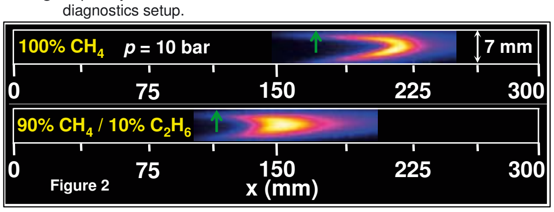

Fig. 2 Homogeneous ignition distance measurements of pure CH_4 and simulated NG (CH_4/C_2H_6) combustion under high-pressure, high-temperature, FGR conditions (Fig. 2: p = 10 bar, Tin = 843 K, φ = 0.85, 50% FGR).

Combustion Research at PSI /LPC

Experimental studies on operability limits and fundamental studies on laminar flame propagation under various FGR and equivalence ratios.

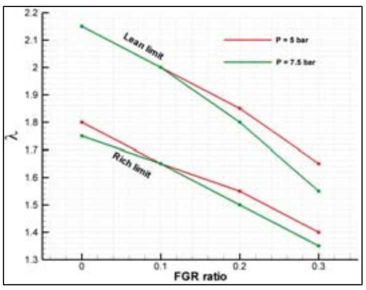

Fig. 3 Measured lean and rich operability limits as a function of FGR ratio at two pressures (methane fuel).

The operability limits are based on 20 ppm constraint on CO emission.
For the lean limit this value corresponds to a lean blow-out. For the rich limit, the rise in CO production is related to CO_2 dissociation. The aim is to find, within these limits, conditions providing the desired flame temperature of 1750 K (marked with green dots on Fig. 4).

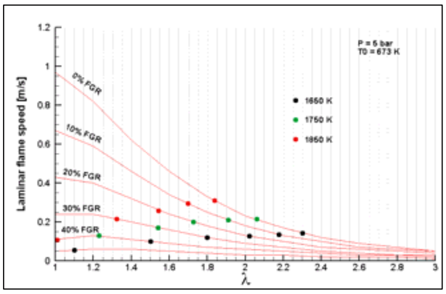

Fig. 4 Predicted laminar flame speeds as a function of equivalence ratio, for 6 different FGR ratios (methane fuel).

Combustion Research at FHNW

The influence of flue gas recirculation (FGR) on the combustion stability of natural gas was investigated in a small scale high pressure test rig (Mini-Hoch-Druck) (Fig. 5). In this rig conditions for normal and reheat gas turbine combustors can be achieved. Flue gas recirculation decreases the excess amount of oxygen in the combustor and reduces the reactivity of the fuel/oxidant mixture. Adding H_2 to natural gas can increase reactivity, thus compensating for the inhibiting effects of FGR. In Fig 6. the required amount of H_2 addition (indicated as mole fraction H_2 in the fuel mix) to achieve the same flame stability (inferred by the measured CO emissions) at different FGR ratios (denoted by the varying O_2 content) is shown.

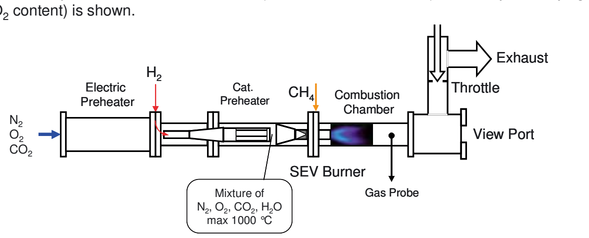

Fig. 5 Lab scale, high pressure rig to simulate gas turbine combustion.

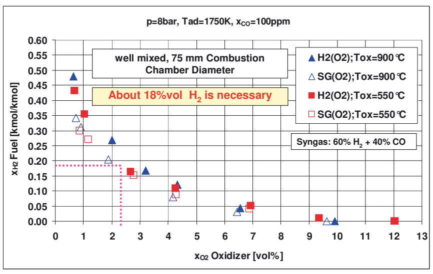

Fig. 6 Amount of hydrogen addition required to stabilize natural gas combustion at various levels of flue gas recirculation.

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Energietagung 11. Juni 2010

Micro-Solid Oxide Fuel Cells

ONEBAT

Battery replacement using miniaturized micro-solid oxide fuel cells

A. Bieberle-Hütter and L.J. Gauckler , Nonmetallic Inorganic Materials, ETH Zurich, anja.bieberle@mat.ethz.ch

Collaboration

ETH Eidgenössische Technische Hochschule Zürich, Swiss Federal Institute of Technology Zurich, LTNT – Prof. Poulikakos

EPFL École Polytechnique Fédérale de Lausanne – Prof. Muralt

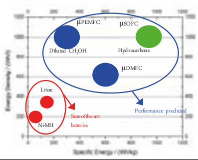
zhaw School of Engineering, ICP Institute of Computational Physics – Prof. Hocker

NTB Interstaatliche Hochschule für Technik Buchs – Prof. Bernard

Motivation

SOFC much better than rechargeable batteries:

- Geographical independence
- Immediate charging
- High energy density



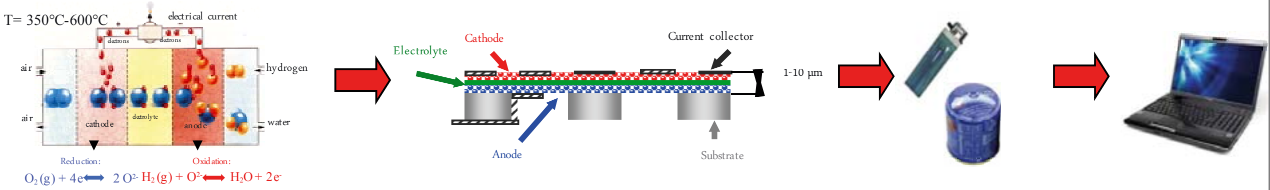
Application

- Portable, electronic devices
- Battery charger
- Industrial scanner
- Portable digital assistants
- Laptops

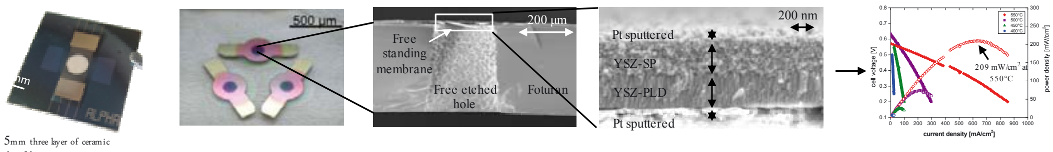
Industry

- Electronics
- Energy
- Medical
- Transportation
- Security

Principle | **Free-standing SOFC membrane** + **Fuel** = **Power delivery**

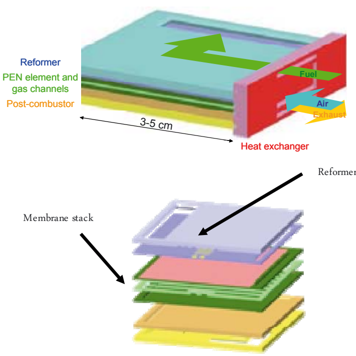


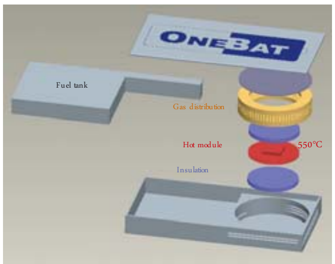
Free standing membranes



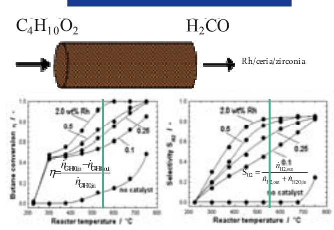
5mm three layer of ceramic thin films

System integration





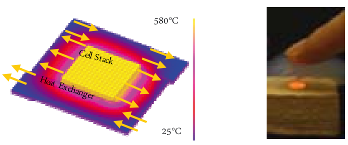
Gas processing unit



At 550°C > 90% of butane can be converted to hydrogen.

The selectivity of hydrogen at 550°C is > 80%.

Thermal management



Temperature gradient of 500°C is feasible.

Fuel reformer

37 mm³ reactor volume

Containing 10 mg catalyst with 20 wt% Rh, 10 nm average diameter

producing H_2 and CO with an energy content of 2.2 W

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ThinPV Cost efficient thin film photovoltaics for future electricity generation

S. Wenger, M. Grätzel - *Laboratoire de photonique et interfaces, Ecole Polytechnique Fédérale de Lausanne (EPFL)*, A. Feltrin, C. Ballif – *PVLab, EPFL*, S. Seyrling, A. N. Tiwari –, *Thin Films and Photovoltaics, Swiss Federal Laboratories for Materials Science and Technology Dübendorf (Empa)*, B. Legradic, C. Hollenstein – *Centre de Recherches en Physique des Plasmas, EPFL*, B. Ruhstaller – *Institute for Computational Physics, Zürcher Hochschule für Angewandte Wissenschaften (ZHAW)*, F. Bin, F. Nüesch - *Laboratory for Functional Polymers, Empa*

The project in brief

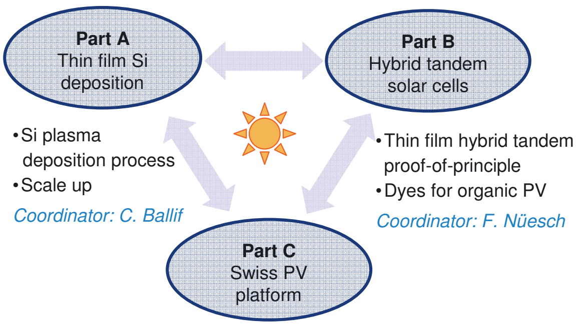
Strategic goals

- Gather main Swiss research groups and companies in the thin film photovoltaic (PV) sector
- Promote cross-disciplinary collaborations
- Achieve break-troughs in device efficiency and cost-efficient production
- Establish a platform with educational activities

Key Figures

- Joining Swiss thin film PV technology competences (6 academic partners)
- Co-financed by CCEM and Swisselectric Research
- Project duration: 2007-2010

Project structure



Networking and educational events

Coordinators: S. Wenger, F. Nüesch

Project coordination and contact

Dr. Frank Nüesch, Empa, Überlandstrasse 129, 8600 Dübendorf

frank.nueesch@empa.ch

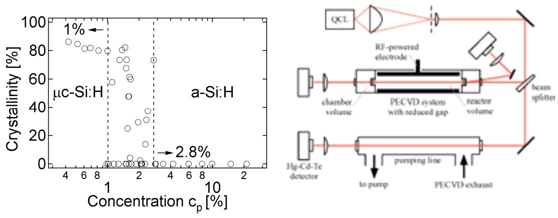
http://thinpv.empa.ch

Main results

Part A – Thin film Si deposition

Development of advanced in-situ plasma diagnostic tools

- e.g. Mid-infrared absorption spectroscopy to determine silane concentration

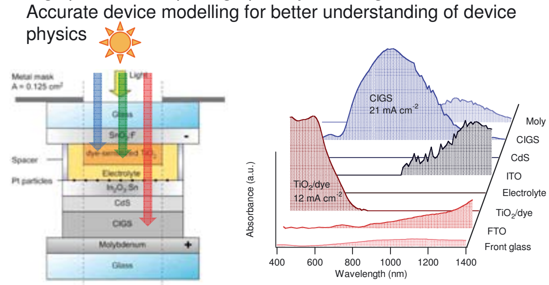


Amorphous-to-microcrystalline Si transition (left). The silane concentration within the plasma, cp, was measured with an infrared laser spectrometer using a quantum cascade laser (right), while the crystallinity was determined ex-situ by Raman spectroscopy

Part B – Hybrid tandem solar cells

Novel device concepts and materials for next-generation PV

- Successful assembly of monolithic dye solar cell / CIGS tandem device for enhanced light harvesting
- High performance photographic dyes for organic PV
- Accurate device modelling for better understanding of device physics



*Splitting the solar spectrum in a **tandem solar cell**. Visible light is absorbed by the dye solar cell, and near-infrared light is absorbed by the CIGS cell (left). Using coherent and incoherent optical simulation, the absorption of the individual layers can be calculated (right)*

Part C – Swiss PV platform

Education, networking, promoting synergies & collaborations

- 4 workshops/conferences organized by ThinPV, e.g. international PhD workshop in Ascona, 2008
- 6 new project proposals among partners, 3 successful

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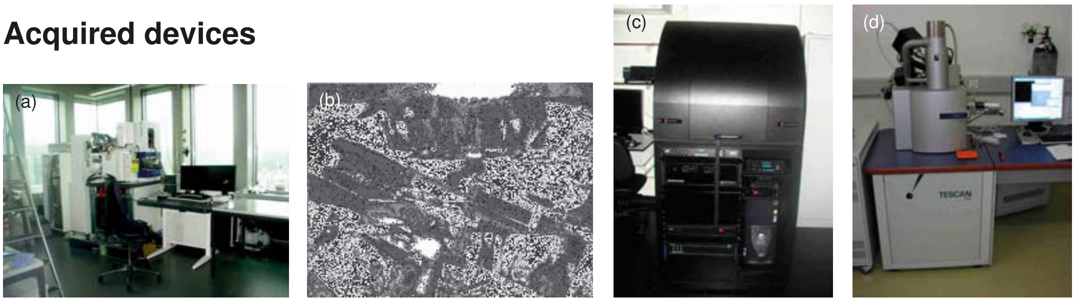
Platform for High Temperature Materials (PHiTEM)

N. Baluc (EPFL-CRPP), W. Hoffelner (PSI-NES-LWV), J. Michler (EMPA Thun)

Objectives

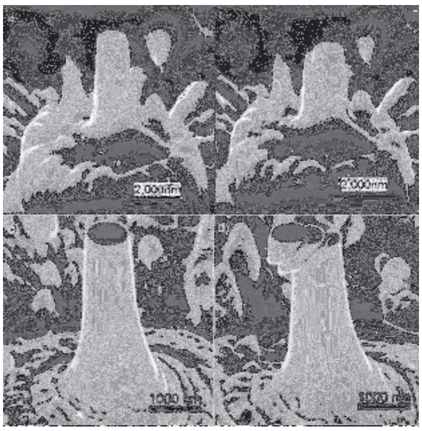
The PHiTEM project is aimed at acquiring experimental devices, manpower and competences allowing for multiscale characterization of advanced high-temperature materials, including irradiated, i.e., radioactive ones.

Acquired devices

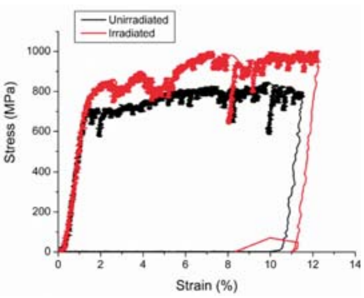


(a) Focused ion beam (FIB) at the PSI, (b) indenter stage from Hysitron destined to a scanning electron microscope (SEM) at the EMPA Thun, (c) nano-indenter at the PSI, (d) Orsay Physics ion gun integrated into a Tescan SEM at the EMPA Thun.

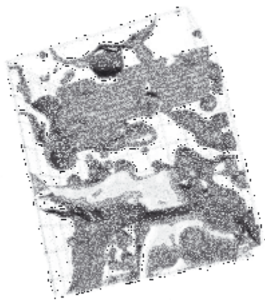
Examples of scientific achievements



Micro-pillars fabricated using the FIB at the PSI: (a, b) unirradiated and (c, d) ion-irradiated micro-pillars from the annealed PM2000 ODS ferritic steel, (a, c) before and (b, d) after compression tests in the nano-indenter at the PSI.



Compression tests in the nano-indenter at the PSI: typical load-displacement curves for unirradiated and ion-irradiated micro-pillars, revealing a significant irradiation-induced hardening (increase in yield strength).



FIB/SEM 3D reconstruction of percolating porosity, consisting of wide, empty, interconnected channels, in a sintered W-1Y_2O_3 material.

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Energietagung 11. Juni 2010

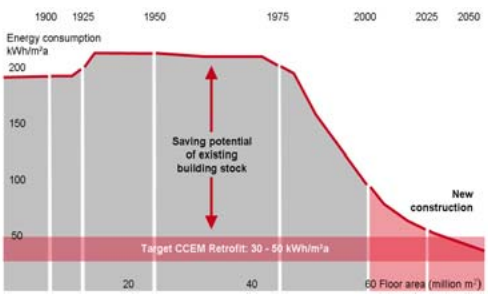
CCEM Retrofit

Mark Zimmermann, Empa
Peter Schwehr, HSLU

Advanced energy efficient renovation of buildings

The importance of building renewal for sustainable development is unquestionable. CCEM-Retrofit has chosen a completely new approach for solving this problem.

- **The concept is based on highly standardized and prefabricated renovation modules for façades and roofs.**
- **It is minimising the primary energy consumption to the level of Minergie-P or Passive House standard (30-50 kWh/m²·year for heating, cooling, ventilation and hot water, per gross floor area).**
- **It is improving comfort, space use and quality of living in old buildings.**
- **It is offering an integrated and cost-effective construction process.**



Heating energy demand and heated floor area in relation to year of construction of dwellings in Zurich

Prefabricated modules with integrated ventilation ducts are creating a highly insulating new building envelope

A new building envelope is laid around the existing building. It has the quality of a new building construction. This new building envelope allows to improve the façades, to add room extensions or a new attic floor. It is perfectly insulated, physically sound and it offers an excellent comfort. A mechanical ventilation system with heat recovery is integrated in the façade and roof modules. Optimised construction processes, high quality standards and reliable budgeting are important features of this concept.

Renovation of a multi-family home in Zurich. A typical Swiss apartment block was changed into a modern low energy building with optimized space use, new large balconies and attractive attic apartment (Arch. Beat Kaempfen, Zurich)

Further information: www.empa-ren.ch/ccem-retrofit.htm

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CCEM House 2000 – SELF the Self Sufficient Home

Mark Zimmermann, Björn Olsson, Sandro Macchi, *Empa, Dübendorf, Switzerland*
Adriano Joss, Wouter Pronk, *Eawag, Dübendorf, Switzerland*

mark.zimmermann@empa.ch

Empa developed together with Eawag a novel concept for the house of the future.
SELF is a self sufficient space unit, which is independent from external energy and water supply. Its futuristic design and its multifunctional use are demonstrating independency and future. The space unit serves two persons for independent living and working, the whole year and throughout Europe.
Together with innovative building industries, Empa is exploring within the CCEM House2000 project the efficiency limits of modern energy technologies. The space unit is based on a self supporting light weight structure which is highly insulated with vacuum insulation and aerogels. It is well protected against heat and cold and uses phase change materials to provide a comfortable and well balanced indoor climate.
The supply is based on solar modules on the roof and the shading device. The generated electricity is stored in lithium-polymer-batteries before it is used for heating, cooling, ventilation, hot water production, electric appliances and pumps. Estival electricity surplus is used for the production of hydrogen, which will be used for cooking and heating support during very cold periods.
Independent living and workings also requires water supply. In collaboration with Eawag – the Swiss Institute for aquatic research – a novel technology for water treatment is being developed and tested. The system allows the purification of rain water and the recycling of used water, thus minimizing the water consumption.

Technical data

- Building shell: Self supporting Light weight construction from 28 mm glass-fibre reinforced PP honeycomb sandwich boards.
  High performance insulation VACUtex®-vip B vacuum insulation panels (VIP), 40 mm, λ 5 mW/(m·K) and Spaceloft Aerogel®, 10 mm, λ 15 mW/(m·K).
  U-value of opaque building envelope: 0.1 W/(m²·K)
- Phase change material DuPont Energain® heat storage panels, 5 mm, containing 60 % paraffin, melting temperature 22 °C, storage capacity 20 – 26 °C: ≈ 500 kJ/m²
- Glazings: Sky Frame Sliding doors with thermally separated aluminium profiles, with minimal exposed surface and highly insulating timber frame windows, glazings with integrated Heat Mirror® low-e film and krypton gas filling, U = 0.5 W/(m²·K)
- Solar system: Building integrated solar panels with 3'750 Watt peak, annual electricity production 4'375 kWh (in Zurich) resp. 5'285 (in Davos), 2 x 2 mm tempered glass modules with 1280 integrated solar cells, 125 x 125 mm, 23 % solar cell efficiency
- Batteries: 6 lithium polymer battery packs with a total electric capacity of 50.4 kWh
- Space conditioning: Aerosmart S compact unit Drexel& Weiss with integrated ventilation 105–210 m³/h, heat recovering (n 85-93%), heat pump 285 W, heating 970 W and hot water production (200 l).
- Hydrogen system: Electrolysis using seasonal electricity surplus to produce hydrogen, 120 kWh hydrogen metal-hydrid storage, catalytic heater for air prewarming at extreme outdoor temperatures and for cooking
- Fuelling station for electric vehicles for additional use of seasonal electricity surplus, sufficient for 80 – 100 km/d during 9 months (in Zurich)
- Water treatment: Separated drinking and grey water systems, each with 200 l capacity. Ultra-filtration of rain water for drinking, biological reactor and ultra-filtration for grey water recycling, used for dish washer and showers

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CCEM House 2000

Mark Zimmermann, Björn Olsson, Sandro Macchi, Empa
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SELF the Self Sufficient Home

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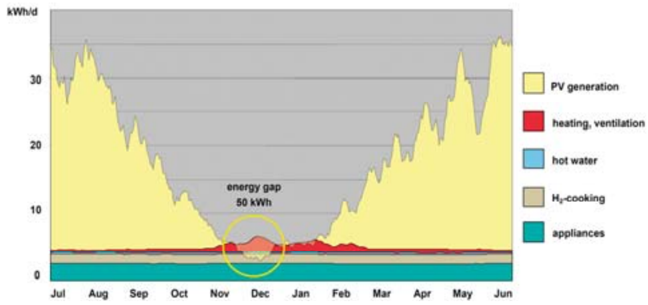
SELF is a demonstrator for advanced energy technologies that allow to operate a building independent from external energy and water supply



Energy balance of SELF during an average year (DRY) in Zurich. The summer electricity surplus has to be used to cover the winter energy gap, but can also be used for summer cooling and electric mobility.

Independent living and workings also requires water supply. In collaboration with Eawag – the Swiss Institute for aquatic research – a novel technology for water treatment is being developed and tested. The system using ultra-filtration and a bio-reactor for grey water treatment is operated only by gravity. It allows the purification of rain water and the recycling of used water, thus minimizing the water consumption.

Further information: www.empa.ch/self

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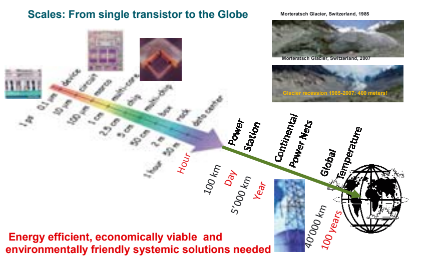
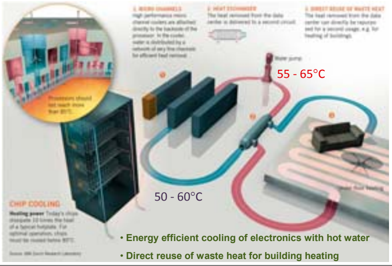
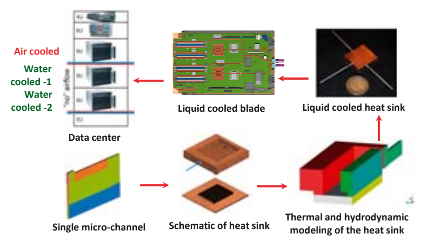
Direct Re-Use of Waste Heat from Liquid-Cooled Supercomputers: Towards Low Power, High Performance, Zero-Emission Computing and Datacenters

Peter Kasten*, Severin Zimmermann*, Manish K. Tiwari and Dimos Poulikakos
Laboratory of Thermodynamics in Emerging Technologies, ETH Zürich, Switzerland
* Equal contribution



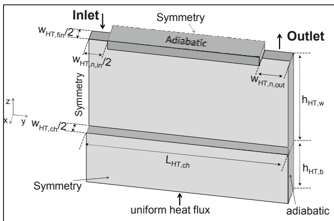




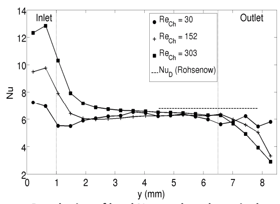
Application of high-performance micro-channel heat sinks

AQUASAR

- Installation of a prototype zero-emission liquid cooled data center
- Waste heat of the super-computer is fed into building heating system of ETH Zürich
- Comparative performance evaluation with respect to air-cooled data center
- Optimization of the integrated system based on exergy analysis



Single micro-channel model domain

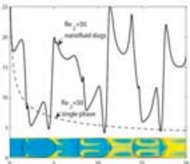


Developing of local Nu-number along single micro-channel

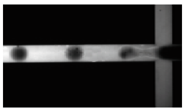
3D single micro-channel model

- Laminar flow, constant thermo-physical properties
- Uniform flow distribution to all channels

Rohsenow et al.: Handbook of Heat Transfer, 3rd Edition, McGraw-Hill, 1998.



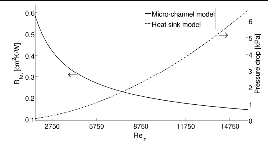
Local Nusselt number and temperature field for slug flow



Novel Coolants

- Preliminary theoretical work shows significant enhancement of heat transfer using emulsion with droplets sizes ~ channel size
- The objective is to synthesize emulsions stable in the temperature range of 50 °C to 70 °C
- The silicone oil/water emulsion (droplet dia. ~ 100 μm) prepared by using a co-flow focussing device is stable for 12 weeks at room temperature with no coalescence issues

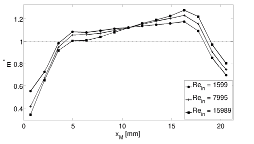
Domains of hydrodynamic heat sink model



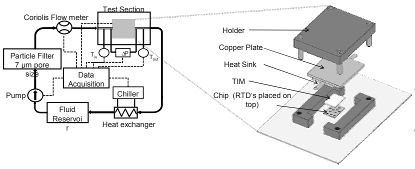
Thermal resistance and pressure drop in heat sink

3D heat sink model

- Micro-channels as porous media with orthotropic thermal conductivity
- Permeability determined empirically from micro-channel simulation
- Hydrodynamics k-ω turbulence model applied (Re_{in}= 1600-16000)



Normalized mass flux distribution in the heat sink



Experimental Setup

- Setup designed to measure thermal and hydrodynamic performance of heat sinks
- To be also used for validation of modeling results

Future Steps

Modeling

- Thermal characteristics of the heat sink
- Transient response of the heat sink
- Exergy analysis of liquid and the entire cooling system
- Parametric study for optimization

Experimental

- Adjusting system parameters of AQUASAR to optimize performance for different processor loads
- Emulsion stability characterizations at elevated temperatures
- Test of emulsions in single micro-channels

Partners

IBM Research Zürich, Group of Advanced Thermal Packaging
EPFL, Laboratory of Heat and Mass Transfer
ETH, Computational Science and Engineering Lab

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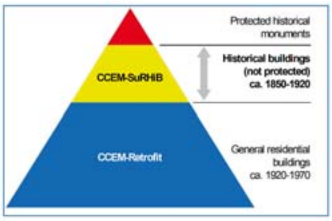
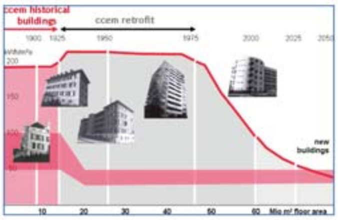
SuRHiB

Main Investigator: Jan Carmeliet, ETHZ.
Project Partners: Empa, EPFL, ETHZ, BFH, SUPSI

Sustainable renovation of historical buildings



CCEM-SuRHiB is dealing with the retrofit on non-protected historical buildings, which account for 20% of the existing building stock.



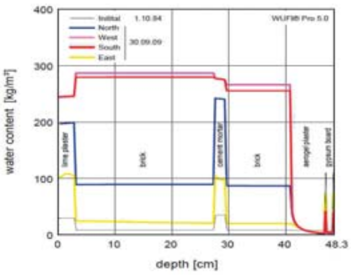
Heat and energy demand and heated floor area of dwellings in the Canton of Zurich.
The energy consumption of historical buildings should be reduced by 50-70% (50-100 kWh/(m²•a))

Building stock analysis

Building survey and archival research focuses on reference buildings selected by historic building research, interpretation and combined analysis by data mining and knowledge discovery. Several singular object studies emphasize the heterogeneity of details and constructions.

Moisture damage risks

Inside insulation retrofit changes the moisture balance of the wall and can lead to increased moisture damage risks. Due to climatic change, moisture damage risks might increase.

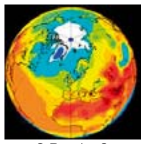


Advanced concepts for heating, cooling, comfort and moisture damage control

Specific concepts for low energy systems and humidity control are developed (e.g. wall heating to omit condensation). Special attention is given to natural ventilation in room spaces like cellars, in summer and transitional periods with high relative humidity, low surface temperatures and mould growth problems. An optimized control of building services is developed.

Impact of climatic change

Regional climate scenario data from Rossby Centre are used covering the period 1961-2100 with different emission scenarios, time resolutions, and different global models as drivers.



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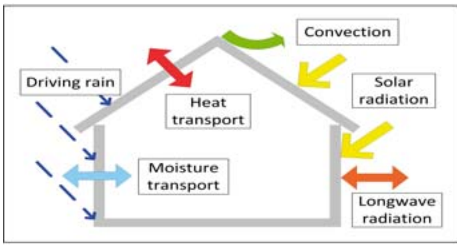

Highly insulating light weight plaster for inside insulation

An aerogel based vapor open plaster with a heat conductivity of 0.03 W/m•K has been developed for inside and outside application.

Concepts for solar integration

Development of technical and architectural guidelines for solar system integration in historical buildings and determination of solar energy opportunities.

Solar Agentur, Prix solaire suisse 2009.

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2nd Generation Biogas

S. Stucki, PSI, Project Coordinator

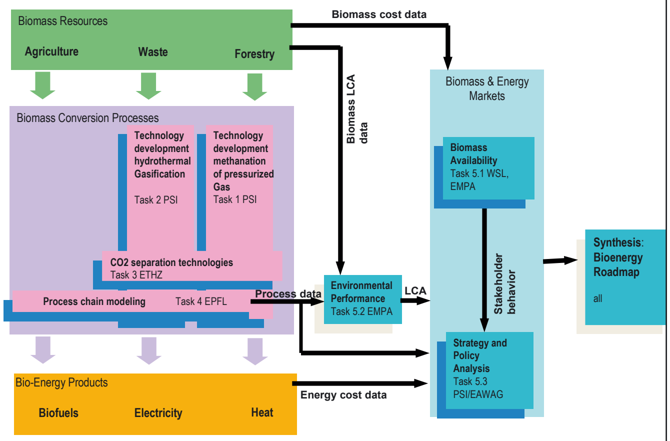
Project Results

Technologies for catalytic conversion of biomass to synthetic natural gas (SNG) have been shown to be feasible.

Comparison with competing technologies shows that SNG is the most efficient path to provide a secondary fuel from biomass resources.

The technologies under development are particularly suited to convert those biomass resources which have proved to be sustainable and quantitatively the most important ones in Switzerland: wood and manure.

Technology success as exemplified in the world's first demonstration plant for SNG from wood in Güssing/AT is not sufficient to convince investors that the technology is ready to be applied in the market unless incentives as introduced for renewable electricity ("kostendeckende Einspeisung") are created.



Tasks and Research Partners

1. Synthetic natural gas by methanation of producer gas; (PSI, T. Schildhauer, S. Biollaz).
2. Direct catalytic methanation of biomass in supercritical water to methane; (PSI, F. Vogel).
3. Assessment of technologies for the separation of CO_2 and trace components from methane-rich gas; (ETHZ, M. Mazzotti)
4. System modeling, analysis and optimal design for electricity, fuel and heat production from biomass (EPFL, F. Maréchal, M. Gassner)
5. Socio-economic assessment

   5.1 Availability of biomass resources (O. Thees, WSL; B. Steubing, EMPA)

   5.2. Environmental performance of 2nd generation biogas. (EMPA, R. Zah)

   5.3. Strategies and policies for the bioenergy innovation system. (S. Wirth, Eawag;)

External Funding Partners

Verband der Schweizerischen Gasindustrie, VSG

erdgas

Erdgas Ostschweiz, Gasverbund Mittelland, Gaznat

erdgas GAZNAT GVM Gasverbund Mittelland AG

Axpo Naturstromf

axpo

Bundesamt für Energie

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WOOD-GAS SOFC

Integrated Biomass - Solid Oxide Fuel Cell Cogeneration

J. Van herle, S. Diethelm, M. Morandin, F. Maréchal, S.Amelio, O. Thomann, S. Giacomini (EPFL-LENI)
J. Wochele, Ch. Ludwig, A. Schuler, M. Wellinger (PSI-CPM)
G. Nurk, P. Holtappels, A. Braun, E. Owuso-Adansi (EMPA-HLK)
S. Biollaz, F. Nagel, T. Schildhauer, U. Rhyner (PSI-TPE)

Scope

Wood fuel for electricity, via gasification, is attractive for CO_2 neutrality and energy supply diversification, but suffers from less favorable economics and relatively low system efficiency when using conventional conversion (engines, gas turbines). High temperature fuel cells (SOFC), owing to thermal integration of processing steps and to managable fuel quality tolerance, offer the perspective of small scale wood-to-electricity plants (<1 MW) with better efficiency. Research outcome is extensible to coal gas.

other funds

Problem / Challenge	Approach / Solution
1. Woodgas is charged with impurities and diluted	Online composition measurement of hot process gas
2. Impact of woodgas on fuel cell is unknown	SOFC catalyst studies with representative gas
3. Many system configurations are possible	Full system modeling using optimisation & integration
4. Can real fuel cells run on real woodgas ?	Hardware demonstration, including hot gas cleaning

1

Fig. 1.1. Woodgas impurities measured by ICP-OES, capturing fluctuations.
Fig. 1.2. Surface Ionisation Detector (SID) developed for alkali-metal monitoring.
Online trace analysis in hot gas can be performed reliably.

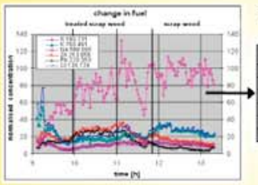
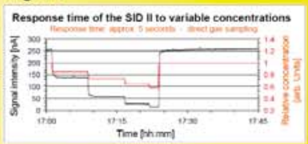


Fig. 1.1

Element	[illegible]	[illegible]
S	77.3	94.8
K	18.7	27.1
Na	9.6	10.7
Zn	28.6	13.7
Pb	24.9	5.8
As	1.04	0.13

Fig. 1.2



2

Fig. 2.1. HEXIS cell tested with 6 ppm KCl in fuel stream.
Fig. 2.2. HTceramix anode tested on carburisation from woodgas.
Fig. 2.3. HTceramix cell tested with woodgas.
Dilution and O-content of fuel affect performance. Impurities under further study.

Fig. 2.1

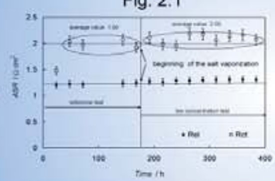


Fig. 2.2

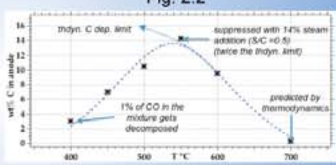
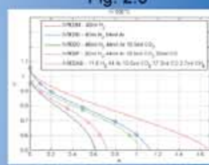
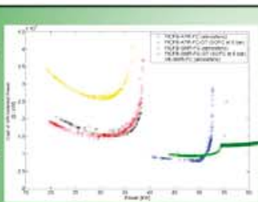


Fig. 2.3



3

Figure shows optimisation of integrated gasifier (20 kg/h wood) + hot cleaning + SOFC + turbine system reaches up to 60% LHV efficiency at cost of 10'000$/kW$_e$ (50 kW$_e$). SOFC=40% of cost.
System configurations exist with promising efficiency on small scale.



FICFB gasifier (TAR 5g/Nm³) + hot cleaning + steam cracking + SOFC

4

Fig. 4.1. Full system at PSI OLHB.
Fig. 4.2. 400 h run of hot candle filter (480 kg wood, 7 kg ash), no tar condensation above 450°C.
Fig. 4.3 1200 h run of single SOFC-tube on cleaned woodgas.
SOFCs can be operated on real woodgas.

Fig. 4.1

Fig. 4.2

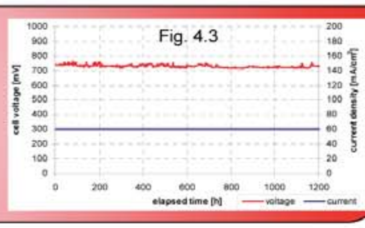


Fig. 4.3

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ARRMAT – Development, in situ investigations and application of attrition resistant reactive bed materials in fluidised-beds

S. Biollaz, T.J. Schildhauer, F. Clemens, J. Wambach, M. Nachtegaal, F. Vogel
Paul Scherrer Institut, Villigen PSI, Schweiz
Eidgenössische Materialprüfungs- und Forschungsanstalt, Dübendorf, Schweiz

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The aim of this project is to contribute to significant improvements along the process chain in the production of Synthetic Natural Gas (SNG) from dry biomass, such as the "SNG-from-wood" process. The first three steps of the conversion process (gasification, gas cleaning and methanation) may involve the use of catalyst in a fluidised bed reactor as gas-solid mass transfer and heat transfer are excellent in such reactors. Moreover, it has been shown that the moving of catalyst particles inside the fluidised bed methanation reactor can enhance the internal regeneration of catalyst particles thus lowering the rate of deactivation considerably.
For optimisation of SNG-from-wood processes, reactive materials are developed, which are mechanically stable, i.e. attrition resistant. Furthermore, the active sites should be well accessible for the raw product gas and firmly integrated into the structure of the carrier.
The attrition resistant reactive bed materials developed will be tested experimentally to identify optimal operation conditions. Further, in situ investigation will allow understanding of critical processes to avoid catalyst deactivation by poisoning (e.g. by sulphur) or fouling (e.g. due to carbon deposition). As in fluidised bed, gas phase is changing along the travel of the particles, state of the catalyst and therefore the chemical stability might change. In-situ investigation under the special hydrodynamic conditions inside the reactor with its oscillating gas compositions have to be considered. DRIFTS (for surface species) and XAS (for chemical state of material) techniques will be applied.

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ARRMAT

Development, in situ investigations and application of attrition resistant reactive bed materials in fluidised-beds

S. Biollaz[1], T. Schildhauer[1], F. Clemens[2], J. Wambach[1], M. Nachtegaal[1], F. Vogel[1]
[1]Paul-Scherrer-Institut Villigen, [2]EMPA Dübendorf

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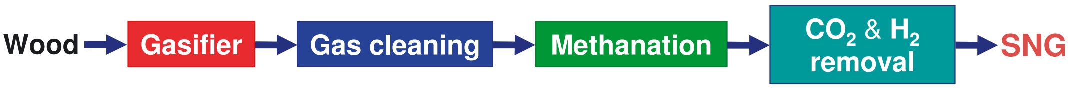

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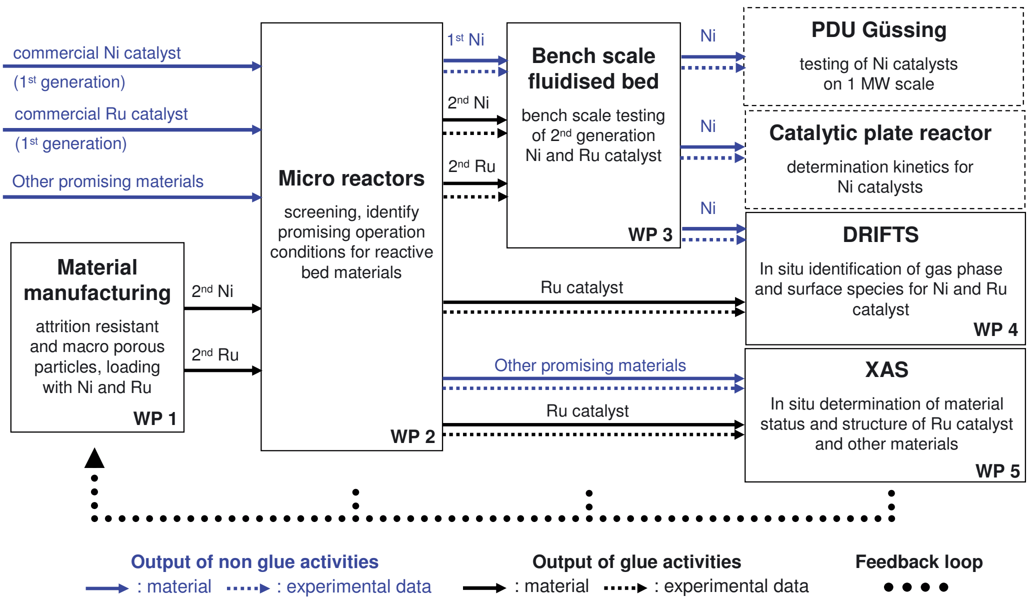

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