The challenges of Jordan's electricity sector

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Jordan, as well as many other countries in the Middle East and North Africa (MENA) region, has experienced a significant increase of peak load and annual electricity demand within the last decade due to a strong growth of economy and population. The peak load of Jordan's interconnected system has more than doubled from about 1.200 MW in the year 2000 to 2.650 MW in 2010, which is equivalent to an average growth rate of 8 % per year. The electricity generated per year increased within the same time frame from 7.375 GWh/a to 14.683 GWh/a[1]. The observed strong escalation of both, peak load and annual electricity demand, will continue in the upcoming years resulting in a peak load of about 5.000 MW and an annual electricity demand of about 31.000 GWh/a in the year 2020. Taking into account decommissioning of some existing power plants, Jordan has to install up to 3.000 MW of new firm power generation capacity within the next decade in order to keep up with the strongly increasing electricity demand and maintaining the security of electricity supply[2].

Today, Jordan's existing power plant portfolio is highly dominated by fossil fuel-fired conventional power plants burning natural gas, heavy fuel oil and Diesel, which have a total installed capacity of about 3.500 MW. Contrary, the recent share of renewable energy (RE) technologies within Jordan's existing power plant portfolio can be almost neglected representing only 0.5 % of the total installed capacity[3]. Since conventional oil and gas reserves are very limited in Jordan, electricity supply depends almost totally on fossil fuel imports. In 2010, Jordan imported about 96 % of its primary energy from abroad at a cost of nearly one-fourth of the gross domestic product[4]. Before 2003, when the second Iraq war started, electricity was generated more or less exclusively by imported oil from Iraq at which a portion was for free and the rest at about one-third of the world market price. When oil supply from Iraq was halted at the outset of the war, Saudi Arabia, Kuwait and the United Arab Emirates stepped in. In addition, from 2003 on, natural gas was imported from Egypt on a large-scale via the Arab Gas Pipeline at a cost well below market prices. In 2010, annual natural gas imports have been in the range of 3 billion m³ whereby 80 % of the annual electricity demand was covered. However, since the resignation of Hosni Mubarak the prices for natural gas were not only increased but also the Arab Gas Pipeline, which supplies

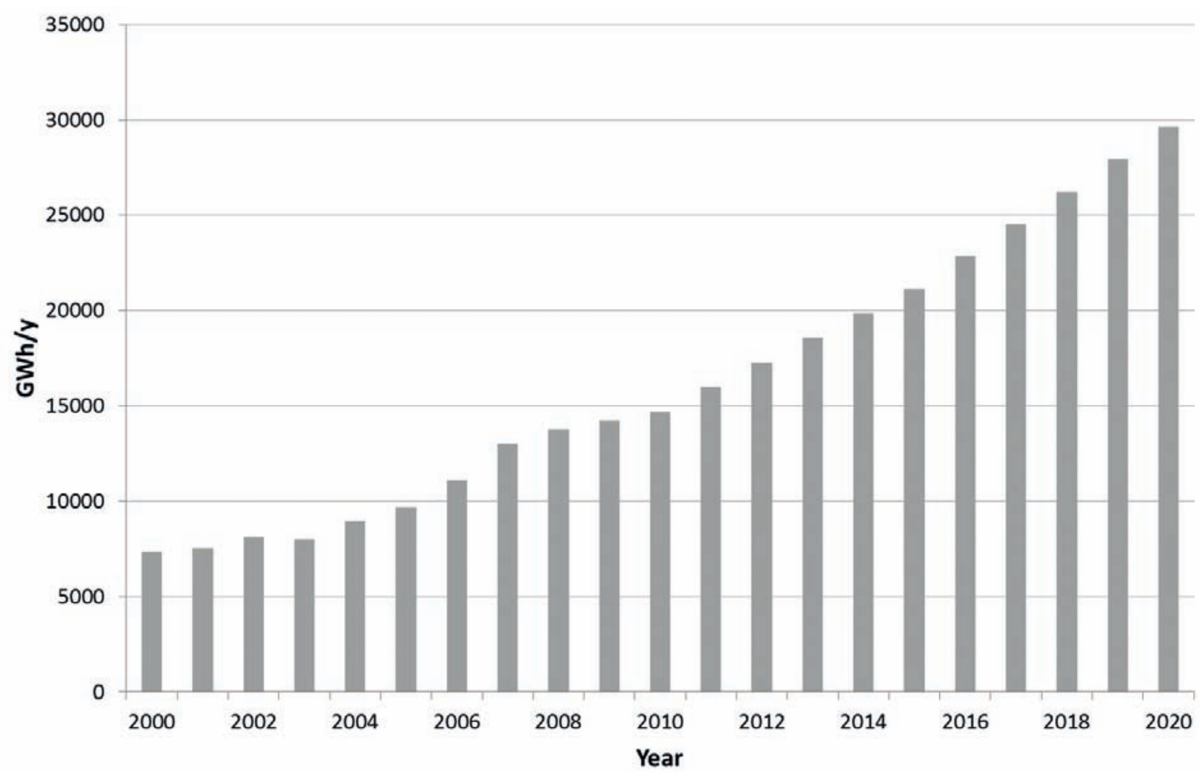

Figure 1: Development of electricity demand in Jordan from 2000 – 2020[1,2]

besides Jordan also Israel and Syria, has been attacked several times. Therefore, Jordan has had to increase its oil imports significantly. Since nowadays, Jordan imports oil for a price just slightly below world market prices and world market prices remain on a very high level, electricity generation costs have increased significantly and cause painful burden on Jordan's national budget[5].

Due to the high fuel cost, an increase of electricity rates is on the cards within the next months. Recently, the National Electric Power Company (NEPCO) warned that its budget deficit has reached "critical levels", according to energy officials[6].The future challenges for Jordan's electricity authorities have become obvious in recent years. Reliable electricity supply at reasonable prices is a key factor for Jordan in order to ensure future economic development. Therefore, electricity sector authorities are looking for solutions to keep up with the increasing electricity demand and to make Jordan more independent from fossil fuel imports and its associated high risk of price volatility and availability.

Due to the outstanding potential of especially solar but also wind resources in Jordan, the large-scale deployment of RE technologies for power generation has the potential to play a major role in order to solve the challen-

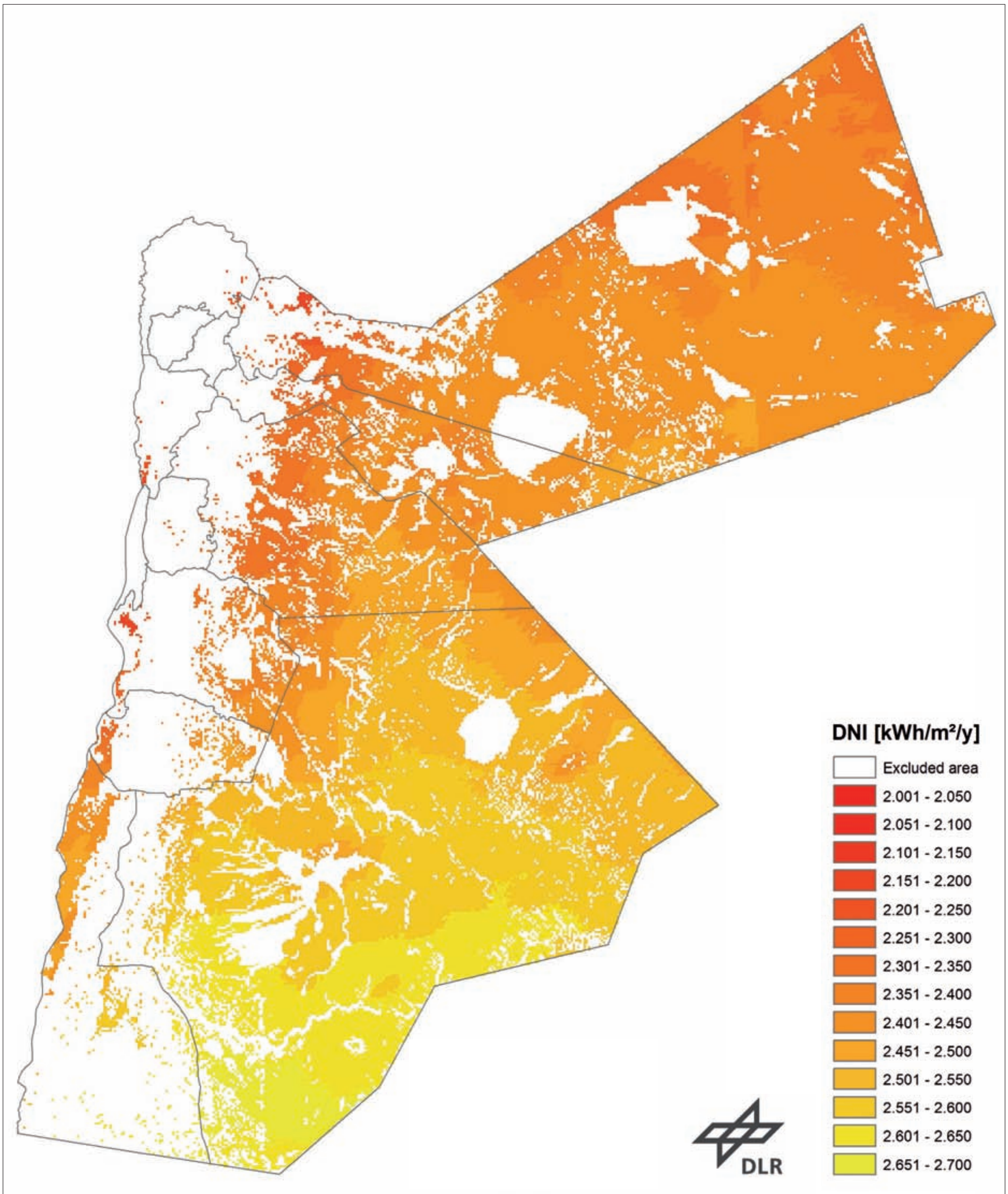

Figure 2: Direct normal irradiation (DNI) on suitable sites for concentrating solar power (CSP) plants in Jordan. The DNI is the "fuel" of CSP plants (data generated by www.solemi.com)

ges of Jordan's electricity sector. On the one hand, using RE technologies will decrease Jordan's dependence from fossil fuel imports and therefore the risk of fuel shortages due to failure of fuel supply from non-domestic sources. On the other hand, due to the relatively low and stable power generation costs of RE technologies at favorable sites like in Jordan, RE technologies will significantly absorb the escalation of future electricity generation costs of Jordan's power plant portfolio and serve therefore in some extent as an insurance against increasing fossil fuel prices. In addition, the large-scale deployment of RE technologies will create thousands of jobs that will contribute to the economic development of Jordan.

Jordan's electricity authorities have identified the potential of RE technologies and passed the "Renewable Energy and Energy Efficiency Law (REEL) 2012" in April 2012 that requires the national electric utility to purchase generation from RE technologies. In December of 2012, as a response of the REEL, the Electricity Regulatory Commission has introduced feed-in-tariffs for RE technologies in order to trigger investments of the private sector into the deployment of RE technologies. Such type of support scheme for RE technologies is also used in Germany within its "Erneuerbare-Energien-Gesetz (EEG)". In the same time when support schemes for RE technologies were introduced the Jordan parliament decided to cancel the plans for constructing nuclear power plants[7].

When transforming Jordan's energy portfolio towards RE technologies, the concentrating solar power (CSP) technology will have a key role due to the large primary resource potential and its technical characteristics, especially its capability to provide firm capacity and flexible power on demand. CSP plants consist of the three major components solar thermal collector field, thermal energy storage and conventional thermal power block. The power block is usually a conventional air-cooled Rankine-cycle together with a fossil fuel- or biofuel-fired back-up boiler. Whereas power generation by photovoltaic (PV) systems and wind turbines is directly linked to the temporal availability of the respective fluctuating primary energy resource (non-dispatchable technologies), power generation of CSP plants can be decoupled from the temporal availability of the solar resource due to the utilization of the storage system and the back-up boiler. The thermal energy collected by the solar field can be either used directly to run the steam turbine or can be fully or partially stored in the storage system for power generation after sunset or cloudy periods during the day. The back-up boiler can generate steam in cases when no solar energy is available and the storage system is empty due to longer sunless periods. Thus, CSP plants can provide firm and flexible power generation capacity and deliver dispatchable power on demand in the same way as conventional fossil fuel-fired power plants but producing about 90 % of its annual electricity output by solar

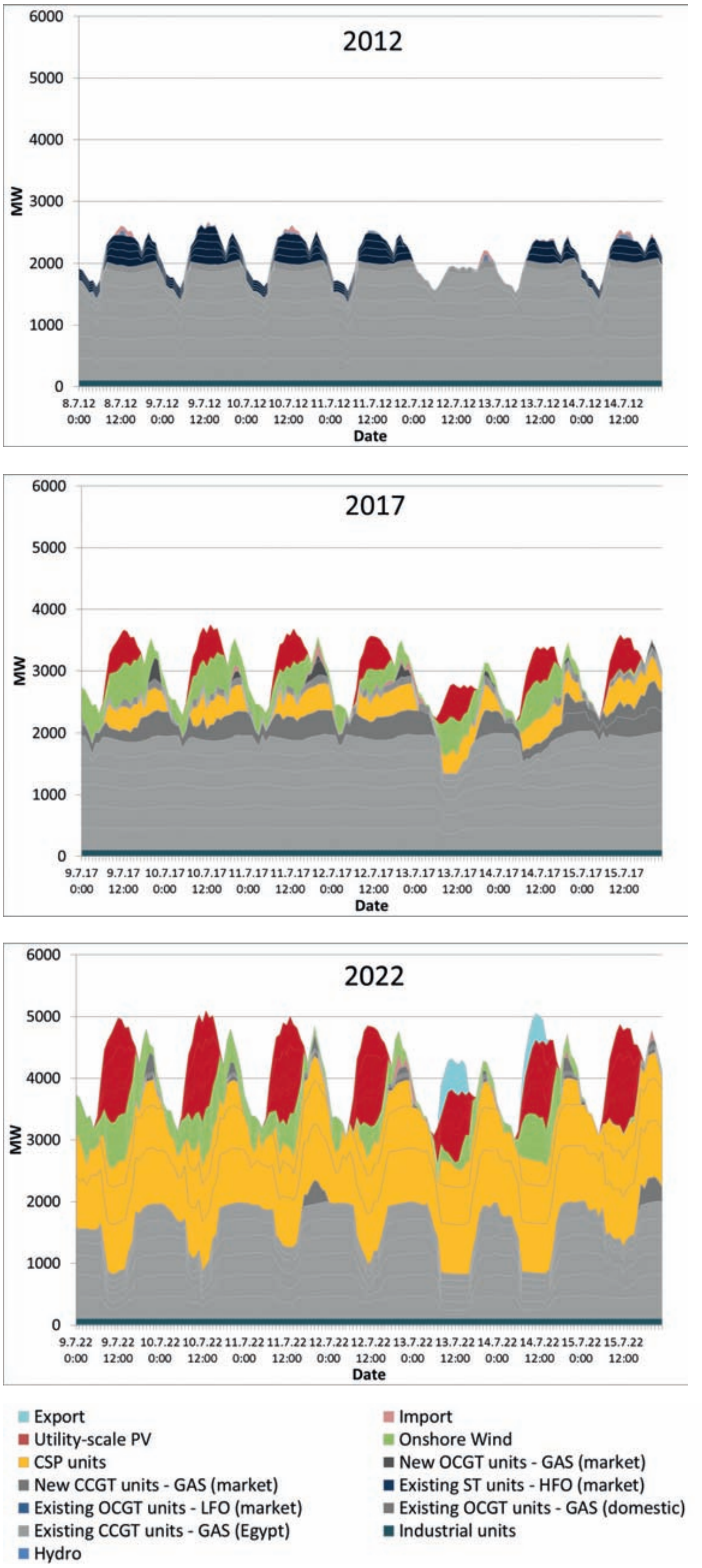

Figure 3: Power generation in Jordan in a selected summer week for the years 2012, 2017 and 2022 according to the results of the Jordan case study. RE technologies are integrated step-by-step whereby Jordan's dependence on fossil fuel imports is significantly reduced, security of electricity supply is maintained and total power generation costs are minimized[8].

A typical CSP plant
Photo: SENER/TORRESOL ENERGY

energy. Due to their characteristics, CSP plants are highly suitable for balancing out daily load and the fluctuating power generation of PV systems and wind power plants and are therefore important to enable a large share of RE in the future electricity mix[8].

The electricity generation potential for renewable energy in Jordan is outstanding. For example, even after excluding all areas that are not suitable for siting CSP plants, the annual electricity generation potential of this solar power technology is more than 6.000 TWh/a which is several orders of magnitude higher than Jordan's electricity demand in the year 2050 which is expected to be in the range of 50 TWh/a[9].

Within a recent case study, the Department of System Analysis and Technology Assessment of the German Aerospace Center (DLR) has developed a ten-year-road-map for the optimized integration of RE technologies into Jordan's existing power plant portfolio. For this purpose, the optimization tool REMix-CEM (Renewable Energy Mix – Capacity Expansion Model) was applied which optimizes the capacity expansion of both, RE and conventional power generation technologies, and minimizes total costs of electricity supply while conserving security of electricity supply at any time. The analysis shows that CSP, PV and onshore wind power, due to the excellent solar and wind resources, are already competitive today in certain load segments of Jordan's electricity sector. Each of these technologies has specific characteristics that determine their application within the electricity system. For instance, PV and wind power serve as cheap "fossil fuel savers" within the peak load and base load segment. The CSP technology, as a dispatchable RE technology, delivers strongly required firm and flexible power generation capacity and has, due to its constant generation costs over the depreciation time, a significant advantage against other dispatchable technologies that require fossil fuel. Therefore, the CSP technology has the potential to become the back-bone of the future electricity sector in Jordan. Under the applied assumptions, the least cost option for Jordan's electricity sector is to introduce 2.200 MW of CSP, 2.100 MW of utility-scale PV and 1.000 MW of onshore wind power capacity until 2022. Following such a least-cost strategy, Jordan could increase the share of power generation by domestic RE technologies from about 0.3 % in 2012 to more than 47 % in the year 2022[8].

A strategy for the market introduction of renewable energy and especially concentrating solar power plants in the Middle East and North Africa will not necessarily require considerable subsidization and will not constitute a significant burden for electricity consumers in the region[10]. Due to the huge solar resources in Jordan and the MENA countries and significant improvements in renewable energy and power transmission technologies an EU-MENA energy partnership may generate the same integrative power as the once established European Coal and Steel Community "Montan Union" in the 50ties of the last century for Europe[11].

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Die Herausforderungen für Jordaniens Stromsektor

Jordanien, wie viele andere Länder im Nahen Osten und Nordafrika (MENA-Region), hat eine deutliche Steigerung der Spitzenlast und des jährlichen Strombedarfs in den letzten zehn Jahren aufgrund des starken Wirtschafts- und Bevölkerungswachstums erfahren. Heute wird der jordanische Kraftwerkspark sehr stark von fossil befeuerten konventionellen Kraftwerken dominiert, die Erdgas, Schweröl und Diesel verbrennen. Jordaniens Stromversorgung hängt im Prinzip vollständig von Importen fossiler Energieträger zu einem Preis knapp unter Weltmarktpreisen zu Kosten von fast einem Viertel des BIP ab, verursacht also eine schmerzhafte Belastung des jordanischen Staatshaushalts. Eine sichere Stromversorgung zu angemessenen Preisen ist ein entscheidender Faktor für die zukünftige wirtschaftliche Entwicklung des Landes. Aufgrund der hervorragenden Solar-, aber auch Wind-Ressourcen in Jordanien hat der Einsatz von Erneuerbaren Energien das Potenzial, eine wichtige Rolle bei der Lösung der Herausforderungen des jordanischen Stromsektors einzunehmen.

التحديات التي تواجه قطاع الكهرباء في الأردن

يشهد الأردن كغيره من دول الشرق الأوسط وشمال إفريقيا (منطقة المينا)، ارتفاعًا واضحًا في ذروة الطلب على الكهرباء سنويًا خلال العقد الأخير، بسبب تضخم النمو السكاني والاقتصادي بشكل كبير. وتطغى اليوم في الأردن محطات توليد الطاقة من إحراق الوقود العضوي على المحطات التقليدية التي تولد الكهرباء من إحراق الغاز الطبيعي والوقود والديزل. تعتمد هذه المحطات بشكل أساسي على استيراد الوقود العضوي بسعر أقل من سعر السوق العالمي، الأمر الذي يكلّف ميزانية الحكومة الأردنية ما يقارب ربع إنتاجها المحلي الإجمالي، محملاً إياها أعباءً تفوق قدرتها. ويشكل دوام توليد الكهرباء بأسعار معقولة عاملاً حاسمًا لمستقبل التنمية الاقتصادية في البلاد. ونظرًا لمصادر الطاقة الشمسية ومصادر الرياح الممتازة في الأردن، فقط أصبح استخدام الطاقة المتجددة يلعب دورًا هامًا في حل المشكلات والتحديات التي تواجه قطاع الطاقة في الأردن.

Dipl.-Ing. Tobias Fichter

studierte Technologiemanagement mit Schwerpunkt Energiesysteme an den Universitäten Stuttgart und Göteburg. Seit Juni 2010 ist er wissenschaftlicher Mitarbeiter am Deutschen Zentrum für Luft- und Raumfahrt in der Abteilung Systemanalyse und Technikbewertung (http://www.dlr.de/tt/en). Dort arbeitet er an der Modellierung von Energiesystemen und an der Standortbewertung für Technologien erneuerbarer Energie. Seit Januar 2011 entsteht seine Doktorarbeit zur optimierten Integration erneuerbarer Energietechnologie in bestehende Energiesysteme, speziell in Ländern mit stark wachsendem Energiesektor.

Studied Technology Management at the University of Stuttgart (Germany) and at the Chalmers University of Technology in Gothenburg (Sweden) with focus on energy systems. Since 06/2010 he is research associate at the department of Systems Analysis and Technology Assessment at the German Aerospace Center (DLR) in Stuttgart. His work focuses on energy system modeling and site assessment for renewable energy technologies. Since 01/2011 he is working on his doctoral thesis which focuses on the optimized integration of renewable energy technologies into existing power plant portfolios of countries with strongly increasing electricity sectors.

المهندس توبياس فيتشر

درس إدارة التقنيات مع التركيز على أنظمة الطاقة في جامعتي شتوتغارت وجوتيبورغ. ومنذ شهر حزيران 2010 يعمل باحثًا في المركز الألماني للطيران والفضاء في قسم تحليل النظم والتقييم الهندسي (http://www.dlr.de/tt/en)، حيث يقوم بوضع نماذج لأنظمة الطاقة وتقديم تقييم ميداني لتقنيات الطاقة المتجددة. منذ يناير 2011 يطور نظريته الأمثل لإدماج تكنولوجيات الطاقة المتجددة في نظم الطاقة الحالية، و خاصة في البلدان التي يشهد فيها قطاع الطاقة نموًا سريعًا.

Dipl.-Ing. Jürgen Kern

studierte Luft- und Raumfahrttechnik an der Universität Stuttgart (Schwerpunkt neue Technologien und erneuerbare Energie). 1992 bis 2003 arbeitete er bei der Firma Schlaich Bergermann und Partner (Stuttgart) als Projektleiter an der Entwicklung von Technologien für solarthermische Kraftwerke (Parabolrinnen, Heliostate, Dish/Stirling-Motoren). 2004 gründete er die Firma kernenergien GmbH – the solar power company in Stuttgart, die er seitdem leitet (http://www.kernenergien.de/). Sie berät Projekte der Solarenergienutzung und Meerwasserentsalzung in strategischen, technischen und wirtschaftlichen Fragen. Seit 2004 ist Jürgen Kern auch leitender wissenschaftlicher Mitarbeiter am Deutschen Zentrum für Luft- und Raumfahrt in der Abteilung Systemanalyse und Technikbewertung (http://www.dlr.de/tt/en).

Studied Aeronautical Engineering at the University of Stuttgart with focus on new technologies and renewable energy. From 1992 to 2003 he worked as project manager at Schlaich Bergermann und Partner, Stuttgart on the technical development of concentrating solar power (CSP) technologies like parabolic trough, heliostats and dish/Stirling engines. Since 2004 his is founding and managing director of kernenergien GmbH – the solar power company, Stuttgart, focused on strategic, technical and economic consulting for solar energy and seawater desalination. In 2012 he joined the Systems Analysis and Technology Assessment department at the German Aerospace Center (DLR) as senior research associate.

المهندس يورغن كيرن

درس هندسة الملاحة الجوية والفضاء في جامعة شتوتغارت، مع التركيز على محور التقنيات الحديثة والطاقة المتجددة. عمل في الفترة من 1992-2003 مديراً لمشروع تطوير تقنيات تركيز الطاقة الحرارية الشمسية (مثل المجمّعات الحرارية ذات القطع المكافئ، ومرايا الحقل الشمسي العاكسة، ومحركات ستيرلنغ الشمسي) في شركة شلايخ بيرغرمان وشركاه في شتوتغارت. وفي عام 2004 أسس وترأس شركة كيرن إنرجين – شركة لتوليد الطاقة الشمسية في شتوتغارت. تقدم الشركة خدمات استشارية لمشاريع استخدام الطاقة الشمسية ومشاريع تحلية مياه البحر من نواحي استراتيجية وتقنية واقتصادية. وهو أحد كبار الباحثين في المركز الألماني للطيران والفضاء، في قسم تحليل النظم والتقييم الهندسي (http://www.dir.de/tt/en)، منذ عام 2004.

Dr. Franz Trieb

ist wissenschaftlicher Mitarbeiter und Projektleiter am Deutschen Zentrum für Luft- und Raumfahrt in der Abteilung Systemanalyse und Technikbewertung (http://www.dlr.de/tt/en). Dort arbeitet er an der Modellierung und Bewertung erneuerbarer Energieressourcen, an Marktstrategien für solarthermische Kraftwerke und der Langfristsicherung für die Energieversorgung. Er ist leitender Autor grundlegender Studien (MED-CSP, TRANS-CSP und AQUA-CSP), die letztlich zur DESERTEC-Initiative geführt haben.

Is research associate and project manager at the German Aerospace Center (DLR), Department of Systems Analysis and Technology Assessment, working on renewable energy resource assessment and modelling, market strategies for CSP and consistent long term scenarios for electricity supply. He is leading author of the studies MED-CSP, TRANS-CSP and AQUA-CSP that have led to the DESERTEC initiative.

الدكتور فرانز تريب

هو باحث ومدير مشاريع في المركز الألماني للطيران والفضاء، في قسم تحليل النظم والتقييم الهندسي (http://www.dlr.de/tt/en)، حيث يقوم بوضع نماذج وتقييم لمصادر الطاقة المتجددة، والقيام بدراسات استراتيجية لاحتياجات السوق لمصانع الطاقة الحرارية الشمسية، وتأمين إمدادات الطاقة لفترات طويلة. المؤلف الرئيسي للدراسات التمهيدية لمشروع الطاقة الشمسية في منطقة حوض البحر الأبيض المتوسط (MED-CSP)، ومشروع ربط دول حوض البحر الأبيض المتوسط لنقل الطاقة الشمسية (TRANS-CSP)، ومشروع تحلية مياه البحر باستخدام الطاقة الشمسية (AQUA-CSP)، والتي شكلت اللبنة الأساسية لقيام مبادرة ديزرتيك الصناعية لتوليد الطاقة من الصحراء.

Here in Aqaba, in the far south of Jordan, very often there is a strong seaward wind from the Wadi Araba; this shows the high potential of wind resources in the country

Photo: Andreas Berger