PUBLIZIERBARER ENDBERICHT

gilt für Studien aus der Programmlinie Forschung

A) Projektdaten

Kurztitel:	RE-ADJUST
Langtitel:	Adjusting efforts in the global greenhouse: Responding to trade, technology and responsibility challenges of European energy and climate policies
Programm inkl. Jahr:	ACRP, 5th Call
Dauer:	01.04.2013 bis 31.07.2015
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Klimafonds-Nr:	B286196
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B) Projektübersicht / Project overview

1 Kurzfassung

Der Import von Erneuerbarem Strom in die EU, beispielsweise aus Nordafrika im Rahmen des Desertec Konzepts, wird seit mehreren Jahren diskutiert, bis dato wurde jedoch kein Projekt verwirklicht. Wie schon im Rahmen der flexiblen Mechanismen des Kyoto-Protokolls sichtbar wurde können Handelsmechanismen zu geringeren Vermeidungskosten führen. Die sogenannten Kooperationsmechanismen der EU Erneuerbaren Energiedirektive, die dies ermöglichen sollten, wurden bislang außerhalb der EU jedoch nicht genützt.

Vor diesem Hintergrund untersuchte RE-ADJUST die Möglichkeiten und Herausforderungen von Solarstromimporten in die EU und betrachtete diese aus technischer, ökonomischer und ethischer Sicht sowie aus Sicht eines internationalen Effort Sharings. Darüber hinaus wurden aber auch Low Carbon Technologien in weiterem Sinne einer ökonomischen Bewertung unterworfen und dabei Potentiale und Kosten energieintensiver Sektoren in der EU, China und Indien betrachtet, und darauf aufbauend makroökonomische Effekte mit einem Computable General Equilibrium (CGE) Modell modelliert.

Es wurde das Minderungspotenzial von hunderten Minderungsoptionen in den energieintensiven Sektoren (Zement, Eisen- und Stahl, Energieerzeugung, Chemie, Papier und Zellstoff) für China, Indien und die EU für den Zeitraum 2030 unter Zugrundelegung unterschiedlicher CO_2-Preise untersucht. Diese Ergebnisse wurden in den GAINS Mitigation Effort calculator integriert. Es zeigt sich, dass Low Carbon Technologien in allen untersuchten Industriesektoren und Regionen bereits bei CO_2-Preisen unter 90 Euros/tCO_2eq kosteneffizient implementiert werden können. Das Einsparungspotenzial ist jedoch in China und Indien größer als in der EU, da Einsparungen bei fossilen Energieträgern mit geringeren Investitionskosten erzielbar sind. Aus makroökonomischer Sicht verursacht daher eine Low Carbon Strategy im Europäischen Alleingang höhere Kosten, wenn diese nicht mit einer Dekarbonisierung beispielsweise in den Schwellenländern China und Indien einhergeht. Weiters verstärkt internationaler Handel diesen Effekt im Fall eines europäischen Alleingangs.

Für den Import bzw. globalen Austausch von Solarstrom aus Fotovoltaik wurden verschiedene Szenarien erstellt, der Schwerpunkt lag auf Szenarien, die die EU und Nordafrika inkludierten. Angenommen wurde dabei, dass Strom aus Fotovoltaik produziert wird und in neuen Batterietechnologien wie Li-Ionen Batterien gespeichert wird. Beide Technologien unterliegen starken Kostendegressionen. Durch die Möglichkeit der Speicherung von Erneuerbarem Strom kann Strom bedarfsgerecht bereitgestellt werden und die immer größeren Fluktuationen, denen Europäische Stromnetze durch Erneuerbare Energieträger in der EU ausgesetzt sind, kompensieren. Ohne Berücksichtigung von länderspezifischen Risiken in der Berechnung der Stromgestehungskosten kann Strom für die EU bereits in der Größenordnung von nur 9 Cent/KWh bereitgestellt werden, was weit unter den Stromgestehungskosten in der EU bzw. von anderen Konzepten zum Solarstromimport in die EU liegt. Das erarbeitete Konzept ist jedoch noch weniger umsetzungsnahe als vergleichbare Konzepte, wie der Export von in CSP (Concentrated Solar Power) Anlagen erzeugtem Strom in die EU.

Im Sinne einer umfassenden Bewertung von Solarstromimporten wurden in RE-ADJUST neben technischen Konzepten auch ökonomische Effekte sowie ethische Aspekte untersucht. Aus ökonomischer Sicht wird - im Falle eines angenommenen Imports von 20% der gesamten Stromerzeugung durch Fotovoltaik in der EU im Jahr 2020 - in der EU der Wohlstand weniger verringert als in Falle eines inländischen Ausbaus und in den Exportländern der Wohlstand stark vergrößert. Die ethische Bewertung baut darauf auf, indem sie Wohlstandsvergrößerung für alle Parteien als positiv bewertet, bezieht aber noch weiter Kriterien ein, wie intergenerationelle Fairness, die das Ziel hat das 2°C Ziel zu erreichen. Sowohl Solarstromimporte als auch heimischer Ausbau erfüllen dieses Ziel. Während Wohlstandsvergrößerungen aus ethischer Sicht nicht durch

Kooperation mit Ländern erzielt werden sollten, in denen Diktaturen an der Macht sind, kommt es in den untersuchten Szenarien dennoch zu einer Gesamtverbesserung gegenüber einer rein europäischen Variante, auch wenn in Nordafrika noch keine wirklich demokratischen Systeme etabliert sind. Dennoch ist das Risiko für Investitionen aus Investorensicht hoch, wie RE-ADJUST gezeigt hat, was die Finanzierung und Kosten der geplanten Projekte beeinflusst. Exporte in die EU könnten hier risikomindernd wirken.

Aufbauend auf den qualitativen und quantitativen Ergebnissen des Projektes wurden in der Politiksynthese die Ansätze des RE-ADJUST Projekts mit bestehenden Konzepten für Solarstromimporte verglichen und Politikoptionen diskutiert. Das Projekt zeigte, dass jeder Ansatz für Solarstromimporte der Speicher beinhaltet, zu Kosteneinsparungen für die EU führen kann, da die EU weniger fossilen Strom als Ausgleichsenergie braucht, ihre Treibhausgasziele leichter erreichen kann und von positiven ökonomischen und ökologischen Externalitäten profitiert.

Die Kooperationsmechanismen, die auf kurzfristige kosteneffiziente Erreichung des Erneuerbaren Energieziels bis 2020 ausgerichtet waren, müssten durch neue Politikinstrumente ersetzt werden, die primär die aus Solarstromimporten resultierenden Treibhausgasminderungen berücksichtigen. Insgesamt könnte die EU durch Solarstromimporte frühzeitig bereits stärkere Treibhausgaseinsparungen erzielen als für 2030 geplant, könnte einen Lock-in fossiler Energieträger vermindern und würde ihre langfristen Vermeidungsziele leichter erreichen.

2 Executive Summary

Importing solar electricity from North Africa was discussed for several years, e.g. within the Desertec concept, up to today however no single project was implemented. International trade can allow tapping low abatement cost options; flexible climate mechanisms like the clean development mechanism are therefore also part of the Kyoto Protocol. While the electricity generation sector was considered immobile compared to industries that could relocate, rising flexibility with regard to where renewable electricity is produced opens up new opportunities to decarbonize the energy system more cost effectively but may also bring about new challenges. However, the cooperation mechanism of the EU renewable energy directive, that should enable renewable electricity trade, was not used so far outside of the EU.

Against this background the RE-ADJUST project examined the challenges of such a change of the electricity system from a technological, climate policy and economic point of view and also illuminated the involved fairness implications concerning international effort sharing. The second focus of the project was low-carbon technology options in a broader sense: namely technology potentials and costs in energy intensive industrial sectors in Europe, China and India. Building on technological and regional abatement cost analyses of these low carbon technology options up to 2030, the macroeconomic impacts of either tapping these potentials in Europe only or also in China and India were assessed.

The mitigation potential of hundreds of potential mitigation options were estimated and assessed across energy intensive industry sectors (e.g. for iron and steel, cement, chemicals, pulp and paper). These results were integrated into the GAINS Mitigation Effort calculator online tool. It could be shown that low carbon technologies in all assessed sectors were already cost effective below 90 Euro/tCO_2eq. The mitigation potential however is higher in China and India than in than in the EU. Form a macroeconomic perspective, a low carbon strategy in the EU is more expensive if not linked to abatement in emerging countries such as China and India. Moreover, international trade intensifies the costs for Europe in case of a unilateral approach.

For the import of solar electricity different scenarios were created, with a focus on scenarios including the EU and North Africa. It was assumed that electricity is generated with photovoltaic (PV) and surplus electricity is stored in Lio-Ion batteries. 16 network configurations of solar sites were assessed, spanning from different European networks, to grid configurations in which Europe is linked to various other world regions, up to a global configuration in which all world regions are linked. Costs are found lowest for the global network with sites in both hemispheres, but costs also differ significantly across different configurations as distributed networks mitigate diurnal and seasonal intermittency. Import-only configurations using high insolation sites generally require less capacity than configurations that additionally include European sites.

In order to enable a comprehensive assessment of solar electricity import besides technical concepts, macroeconomic effects but also ethical considerations were included. Assuming that 20% of the overall electricity production in the EU comes from PV solar imports in 2020, the macroeconomic and welfare effects of importing PV solar electricity are found positive for both Europe and the Middle East and North African (MENA) regions, compared to a scenario in which the same amount of electricity is produced within Europe. The ethical assessment built on this finding that welfare increases for all parties, but included also additional criteria, such as intergenerational fairness to meet the 2°C target. Both, domestic increase of solar electricity as well as solar electricity imports fulfill this later criterion of increasing intergenerational fairness. While increased welfare should from an ethical perspective not be achieved by cooperation with dictatorships, this is not the case for North African countries even if they do not yet have well-functioning democratic systems. Furthermore, the project has shown that the economic feasibility of renewable energy projects depends on the availability of affordable project financing, which itself reflects (perceived) investment risks in the MENA region. Solar electricity exports to the EU could reduce policy risks of the exporter countries and lead to a better economic feasibility of the project.

Based on the qualitative and qualitative findings of the project, within a policy synthesis, the RE-ADJUST PV import scenario was compared with existing concepts for solar electricity import and policy options were discussed. The project showed that all options for solar electricity imports that include storage systems may lead to cost savings for the EU, as the EU does not only receive additional renewable electricity that is within the cost ranges of renewable electricity in the EU, but also needs less fossil generation to provide dispatchable electricity, can meet its greenhouse gas targets easier, and can benefit from environmental and socioeconomic externalities.

The cooperation mechanisms that aimed to enable a cost efficient 2020 renewable target achievement would need to be substituted by new policy instruments that consider greenhouse gas savings of renewable electricity imports. Overall the EU could cost effectively achieve higher mitigation levels in 2030 than planned, could prevent a fossil lock-in, and could meet its long term targets more easily.

3 Hintergrund und Zielsetzung / Background and objectives

International climate negotiations do give an expression of common concern, but seem unlikely to provide a framework of clearly assigned and globally coordinated emission reduction targets anytime soon. It is thus unilateral (and individual) climate policy action e.g. by the European Union that seeks to achieve climate targets such as the 2 degree stabilization objective. However it is crucial that climate policy action by one country or region, such as the EU, is not globally ineffective, i.e. that it does not trigger feedbacks that partially or fully counterbalance emission reduction in this region by emission increases elsewhere. Recent results for Annex-I countries show that while they have been effective in stabilizing their domestic (i.e. production based) emissions, net imports of grey emissions in their trade flows have significantly increased over the last two decades, contributing to rising global emission levels (see e.g. Peters et al. 2011, Munoz and Steininger, 2010). Beside the interdependencies between climate policies and trade policies, there are critical interdependencies also between international climate and energy policies. While the electricity producing sector was considered static compared to industries that could relocate, rising flexibility with regard to where renewable electricity is produced open up new opportunities to decarbonize the energy system more cost effectively but may bring about also new challenges regarding fairness and justice.

According to the EU 2050 roadmap, the European Energy sector needs to be fully decarbonized by 2050. The EU renewable energy sources (RES) directive provides for "cooperation mechanisms" for EU internal trade with RES shares but also for RES electricity import from third countries in order to achieve the national EU RES targets up to 2020, however no similar policy mechanism is yet emerging for the 2030 horizon. The flexibility provided by the cooperation mechanism would allow for a cost-efficient 2020 renewable target achievement. Third countries that are in a particular focus for the EU are the northern African countries, such as Morocco, where large scale photovoltaic (PV) plants could be established, with generation costs far less than that in the EU. This emphasis on solar electricity is driven by the fact that investments in solar energy are now outpacing investments in all other forms of renewable energy. Bloomberg's 2011 "New Energy Finance" reports a 36% surge in total investment in solar technology, to $136.6bn which is nearly double the $74.9bn investment in wind power. Given the relative generation cost of solar versus wind this trend is likely to continue, shifting the centers of renewable electricity generation to southern countries.

Supplementing domestic action by measures abroad was also the concept of the flexible mechanisms of the Kyoto protocol. In contrast to carrying out emissions reductions in third countries under the Kyoto mechanisms that helped to cut the host countries' emissions, the RES cooperation mechanism with third countries differs conceptually as it also includes the physical import in the EU of electricity that is produced in the host countries. The EU could exploit low-cost RES potentials abroad that however may be needed also by the host countries for their long term economic development, i.e. such exploitation could come with significant opportunity costs e.g. for energy exporting countries implying questions of fairness and justice.

To achieve global stabilization in GHG concentrations, future policies need to be developed and analyzed under the perspective of their global effectiveness and fairness. The focus of this project acknowledged therefore economic, technological and ethical dimensions for designing international climate and energy policies and enhanced the methodological tools for analyzing these issues as they appear from the perspective of different world regions for 2020 and 2030. This analysis can be seen as a reflection of the use of flexibility mechanisms not only in emission regulation (flexibility mechanisms in the Kyoto Protocol), but also for the energy system more directly.

There are two core developments that can achieve significant (global) emission reduction in reshaping the energy system for the decarbonization of the economy, that involve trade, technology and responsibility challenges, and that therefore have been investigated in this project:

- **Large-scale renewable electricity:** When acknowledging the promising perspectives for technologies such as particularly solar electricity (SE) from PV, renewable energy production costs strongly vary across geographic locations, for SE rendering production locations in the South specifically interesting. We compare different configurations of large-scale distributed solar electricity supply for the EU and explore the justice and effectiveness implications of international trade in renewable energy given large scale grids covering different nations.

- **Energy-intensive production processes:** Specific perspectives for replacement of energy intensive products (which are increasingly imported from developing and newly industrializing countries to the EU) or decreasing their emission-intensity in production are to be followed for globally effective emission reduction. The carbon and macroeconomic implications of such technologies are explored.

The specific research questions this project intended to address are:

- What are the economic, carbon and justice implications for the EU and other world regions for the EU transition to a low-carbon, low energy? Can other world regions benefit from EU policy fostering low-carbon transitions (e.g. by technological spill-over), or will costs dominate (in terms of global emissions or burdens for other world regions)?
- For low carbon technology options in energy intensive industries: What are the economic costs for the EU and relevant other world regions for different low carbon technologies in energy intensive industry, low-carbon energy supply and location of production? What are the implications for international trade flows and GDP?
- For extensive use of renewable electricity imports into the EU: How may the costs of electricity from solar PV develop in the next 10-20 years? How would the emergence of a new solar-based energy system affect trade and income distribution across world regions? What technical, infrastructural, economic and political measures have to be taken in order to be able to enable a large-scale solar energy supply? Which responsibility questions arise due to a large scale solar electricity import into the EU?

4 Projektinhalt und Ergebnis(se) / Project content and results

4.1 Assessment of low-carbon technology options and regional GHG abatement cost

In this WP we have assessed the baseline (BAU) projection for all greenhouse gases, in particular for India and China, in a framework that is consistent with previous analysis of the Annex I countries. This analysis is based on a projection of a global energy scenario World Energy Outlook 2009 (WEO09), generated by the International Energy Agency (IEA). This scenario has the advantage that it has been used for a number of other analyses (e.g. by McKinsey’s cost curve analysis). Figure 1 shows the baseline development of GHG emissions in the WEO09 scenario until 2030.

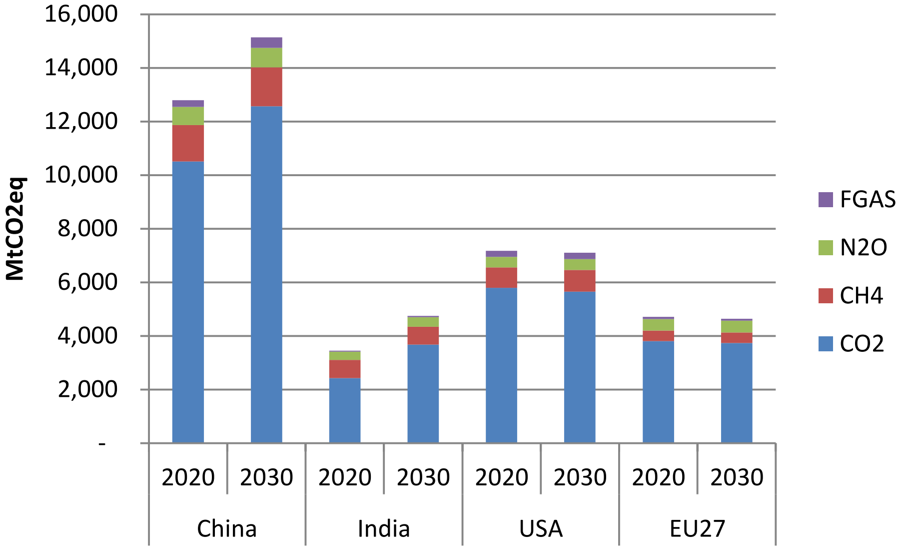
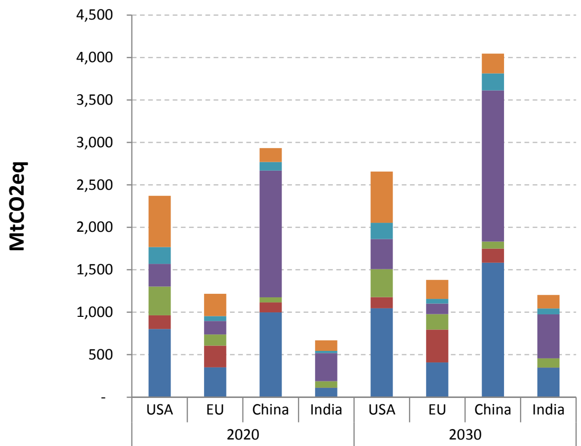


Figure 1: Baseline GHG emissions for major Annex I and developing countries



	2020				2030			
	USA	EU	China	India	USA	EU	China	India
Other	602	262	164	126	602	224	232	158
Transport fuels	198	59	101	25	190	55	201	70
Industry	267	158	1,493	332	356	123	1,780	517
Appliances	340	132	59	76	329	182	84	108
Buildings	162	255	117	0	132	387	165	0
PP	802	352	999	111	1,046	409	1,583	349

Figure 2: GHG mitigation potentials at 60€/tCO2eq for major emitters in 2020 and 2030

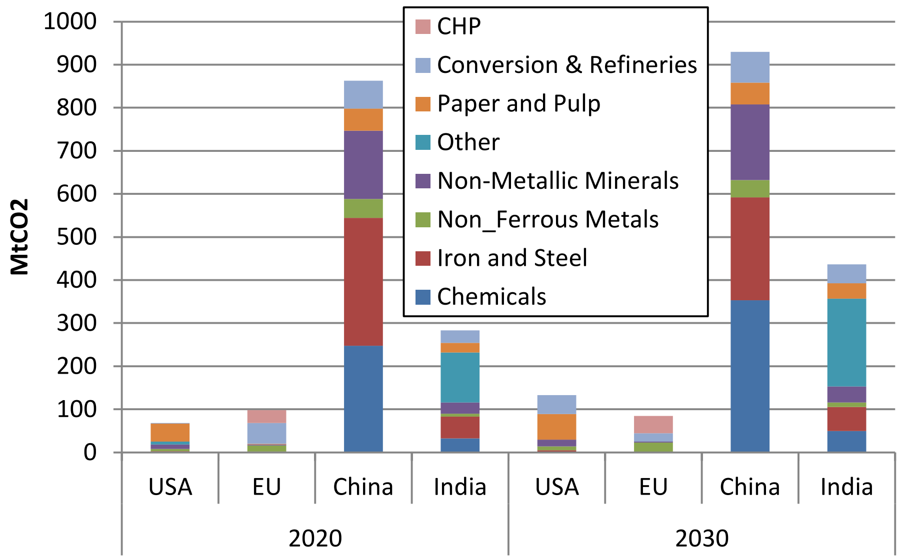


Figure 3: GHG mitigation potential at 60€/tCO2eq in energy-intensive industries in major emitting countries in 2020 and 2030.

Starting from the above BAU scenario we have estimated the mitigation potential for hundreds of potential mitigation technologies, which can be aggregated to relevant levels, for example, as in Figure 2, to the level of six key sectors. This aggregation can be refined, in particular, focussing on energy-intensive industries (central to this project), a differentiated picture emerges (Figure 3; for illustrative purposes a maximum shadow price of 60 €/tCO2eq was chosen here). The resulting cost-curve information has been used to update and expand the Mitigation Efforts Calculator online tool for use, e.g. in WP5 (Figure 4).

GAINS • MITIGATION EFFORTS CALCULATOR

Greenhouse gas - Air pollution Interactions and Synergies
International Institute for Applied Systems Analysis

Version 2.0 **Scenario** IEA 2009 **Year** 2020 Refresh Export Logout

No trading-no CDM ☑ **With trading-no CDM** ☐ **No trading-with CDM** ☐ **With trading-with CDM** ☐

	Base Year	Emission range in 2020		Emission target			Mitigation costs			Carbon price
	1990	Baseline	max. mitig.	Total	Change to	Per capita	total costs	% of GDP	Per capita	
	Mt CO2eq	Mt CO2eq	Mt CO2eq	Mt CO2eq	1990	tCO2eq/cap	bln €/yr	%	€/cap/yr	€/t CO2eq
Target for each Party					%			%		
Australia	516	573	342	573	+11.1 %	24.3	0.00	0.00 %	0.0	-100.0
Canada	486	766	490	766	+57.6 %	20.9	0.00	0.00 %	0.0	-100.0
China	4107	13023	8435	13023	+217.1 %	9.0	0.00	0.00 %	0.0	-100.0
EU 27[1)]	5163	4671	3036	4671	-9.5 %	9.4	0.00	0.00 %	0.0	-100.0
India	1403	3474	2144	3474	+147.6 %	2.6	0.00	0.00 %	0.0	-100.0
Japan	1180	1199	946	1199	+1.6 %	9.6	0.00	0.00 %	0.0	-100.0
New Zealand	41	82	57	82	+98.0 %	17.5	0.00	0.00 %	0.0	-100.0
Norway	36	63	48	63	+74.3 %	12.7	0.00	0.00 %	0.0	-100.0
Russian Federation	3506	2481	1639	2481	-29.2 %	18.9	0.00	0.00 %	0.0	-100.0
Switzerland	50	48	37	48	-4.2 %	6.4	0.00	0.00 %	0.0	-100.0
Ukraine	855	422	286	422	-50.6 %	9.8	0.00	0.00 %	0.0	-100.0
United States of America	5411	6969	4400	6969	+28.8 %	20.3	0.00	0.00 %	0.0	-100.0
Total	22755	33771	21860	33771	+48.4 %	8.5	0.00	0.00 %	0.0	

NOTE: ALL CALCULATIONS REFER TO DOMESTIC MEASURES ONLY, WITHOUT USE OF FLEXIBLE INSTRUMENTS

Figures printed in red mean that the target is unachievable with the mitigation measures considered in GAINS.
Figures printed in green indicate that the target is higher than baseline emissions, i.e., do not require any additional mitigation measures that are not included in the baseline projection.

Introductory video Contact Us

Figure 4: Updated interface (including now data for India and China) of the online GAINS Mitigation Efforts Calculator (MEC).

4.2 Technological and economic assessment of large-scale solar electricity

Methods to overcome solar intermittency and to evaluate and compare possible large-scale solar networks are of major importance. In this WP we evaluated 16 network configurations of solar sites (Table 1). Each network is built from at least one solar generation and storage site in the selected countries. These sites were selected based on a review of solar plants in the EUMENA region that are currently operating, planned, or under construction, together with additional high insolation solar sites. This resulted in a set of 101 solar sites spread across Europe (51 sites), Northern Africa (10 sites), tropical Africa (22 sites), Asia-Middle East (13 sites), plus five global sites (1 in North America, 2 in South America, and 2 in Australia). We scaled NASA Solar Sizer daily insolation data for each site to hourly values with our model and ran the optimization procedure to determine the minimally required generation and storage capacities for each configuration.

Table 1: Solar networks evaluated in WP 2, drawn from a set of 101 sites across Europe, Northern Africa, Tropical Africa, Asia, and five additional sites. The regional codes in the right column correspond to the CGE model.

	Type	Description	Countries
1	Europe	Central Europe	CEU
2	Europe	Central and Northern Europe	CEU+NEU
3	Europe	Mediterranean Europe	MEU
4	Europe	Central, Northern, and Mediterranean Europe	CEU+NEU+MEU
5	Europe	Europe	CEU+NEU+MEU+SROE
6	Europe + Import	EUMENA-Central	CEU+OIGA
7	Europe + Import	EUMENA-Mediterranean	CEU+MEU+OIGA
8	Europe + Import	EUMENA-All	CEU+NEU+MEU+SROE+OIGA
9	Import	MENA	OIGA
10	Europe + Import	EUMENA-Med-Tropical	CEU+MEU+OIGA+ part of AFR
11	Import	MENA-Tropical	OIGA+part of AFR
12	Europe + Import	EUMENA-Med-Asia	CEU+MEU+OIGA+part of RASI, ECO
13	Europe + Import	EUMENA-Med-Africa	CEU+MEU+OIGA+AFR
14	EU	Europe without Turkey	(Same as 5 but without Turkey)
15	Global import	Global selection of sites	All sites with > 2,000 kWh/a/m2
16	All	All 101 sites	

Four solar networks were then selected by the team for closer evaluation and for an assessment of associated welfare impacts in WP 3. Specifically, the team selected one European configuration: network 4 with sites in Northern, Central, and Mediterranean Europe, one EUMENA configuration (network 7 above with the addition of Northern European sites to facilitate comparison with network 4), and two import configurations: network 9 with sites in the MENA region and network 11 with sites in the MENA region and additional tropical African sites.

The comparison of these networks showed that import scenarios generally allow meeting the same load with considerably less storage and generation capacity than scenarios with some electricity production in Europe (Table 2). This is due to the lower insolation at the European sites. The required capacity is further reduced by increasing the spread across time zones and in particular by including tropical African sites (Table 2). The latter result is due to the low summer-winter insolation difference in the tropics, which we found to more than compensate the detrimental effect of the relatively high tropical cloud coverage. Connecting both hemispheres in a global network permitted the lowest storage and generation capacity. Given ongoing rapid cost decreases and expansion of production for li-ion batteries, the cost calculation for storage considers current and near future battery costs. To take care of uncertainties with regard to transmission costs, additional simulations were conducted, leading to ranges in addition to the mean value reported in Table 2.

Table 2: Electricity costs with and without transmission for the four selected networks (source Grossmann et al. 2015)

	Type	Countries	# of sites	Electricity generation costs [c/kWh]	Electricity generation costs with transmission [c/kWh]
1	Europe	Central, Northern, and Mediterranean Europe	46	16.6	16.8
2	Europe + Import	1 + MENA (Middle East-North Africa) countries	61	10.5	10.8
3	Import	MENA countries	15	5.9	6.4
4	Import	3 + tropical African countries	31	4.3	5.3

A highlight of WP2, reported together with external collaborator Wolf Grossmann, is the finding that the relationship between a given generation capacity G and the minimal storage S required to meet a given load profile with this capacity has the form of smooth isolines. This helps to optimize the needed storage capacities and therefore to minimize costs. The isolines describe the minimal combination of G and S needed to meet a given load. The isolines are shifted to the upper right (implying higher G and S) for configurations covering fewer time zones or degrees of latitude, fewer sites, or sites with lower insolation. Hence they facilitate quick comparison of different solar networks, as well as the evaluation of electricity costs under different cost assumptions for both PV generation capacity and storage. The isoline-relationship applies equally to small and large sites as well as networks of distributed sites. These isolines, termed G-S Isolines, are discussed in a paper published in the Proceedings of the National Academy of Sciences (Grossmann et al., 2015). Figure 1 shows G-S Isolines for eight of the solar configurations that were evaluated.
In Figure 5, the global configuration 15 needs the least resources (as it is least affected by intermittency); among the European configurations, configuration 3 (Mediterranean Europe) requires the least resources.

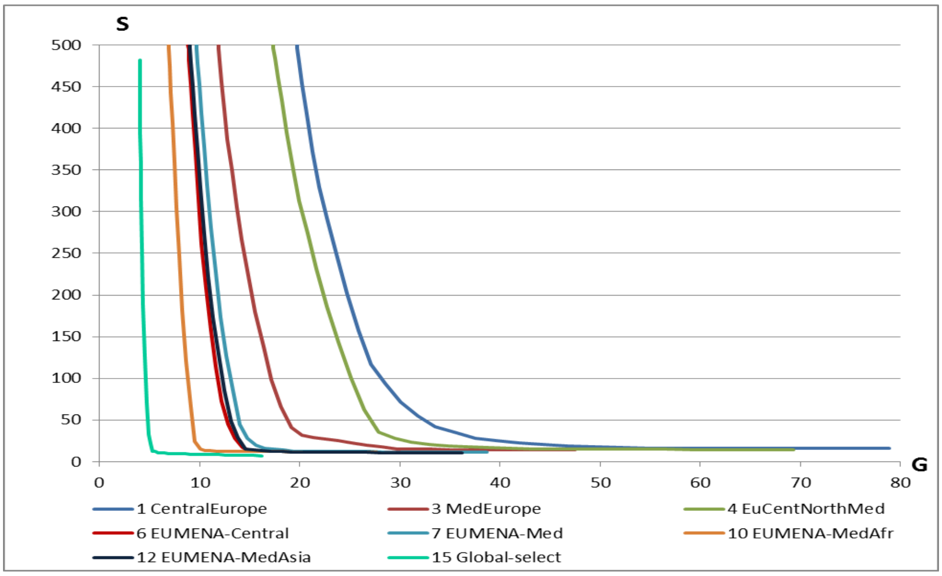


Figure 5: G-S Isolines for 8 of the 16 solar configurations (see Table 1). source: Grossmann et al. (2015)

An assessment of the possible development of solar electricity generation capacity over time was then conducted with cost estimates for three different stages. During the early stage (until ca

2020), site selection for solar networks is not optimized and little storage is used. During the mid-stage (until the late 2020s) some storage is used, but site selection is still not optimized with networks consisting of both small and large power plants and small residential generation sites. During a late stage site selection is increasingly optimized to enable lower costs and energy storage is in full use. Costs were assessed depending on the fraction of energy met from solar, with increasingly higher costs for larger fractions.

4.3 Macroeconomic and carbon assessment of policy scenarios (WP3; A)

4.3.1 Low carbon technology options in energy intensive industries – A comparison of EU, China, and India

In this analysis we investigate the regional cost (dis)advantages when low carbon technologies are only available in the EU (EU_Tech scenario), only available in China and India (INCH_Tech scenario), or available in all three regions (EUINCH_Tech scenario). In all three scenarios, we assume that carbon emissions are capped in accordance with the WEO 450 ppm scenario for 2030 (corresponding to a CO_2 price in Annex I countries of USD 110 and in non-Annex I countries of USD 65). We find that the availability of low carbon technologies in the six energy intensive industries (chemicals, pulp and paper, non-metallic minerals, iron and steel, petrochemicals, electricity) leads to substantial declines in carbon prices in Annex I and non-Annex I countries (by ~50% if technology is available in the respective region only). Nevertheless, low carbon technologies are available in EU at higher costs, and in India and China at lower costs, compared to the conventional technology in the respective sector in 2030. As a consequence, both sectoral output and GDP decline in EU due to cost increases in energy intensive sectors while output and GDP increase in China and India (Figure 6). Imports to the EU from North America, China and India increase while the opposite holds for EU exports. It is important to stress that substitution between different energy inputs and other inputs influence the strength of the GDP response, so that the qualitative insights of figure 6 are robust but that the magnitude of the regional effects might be different.

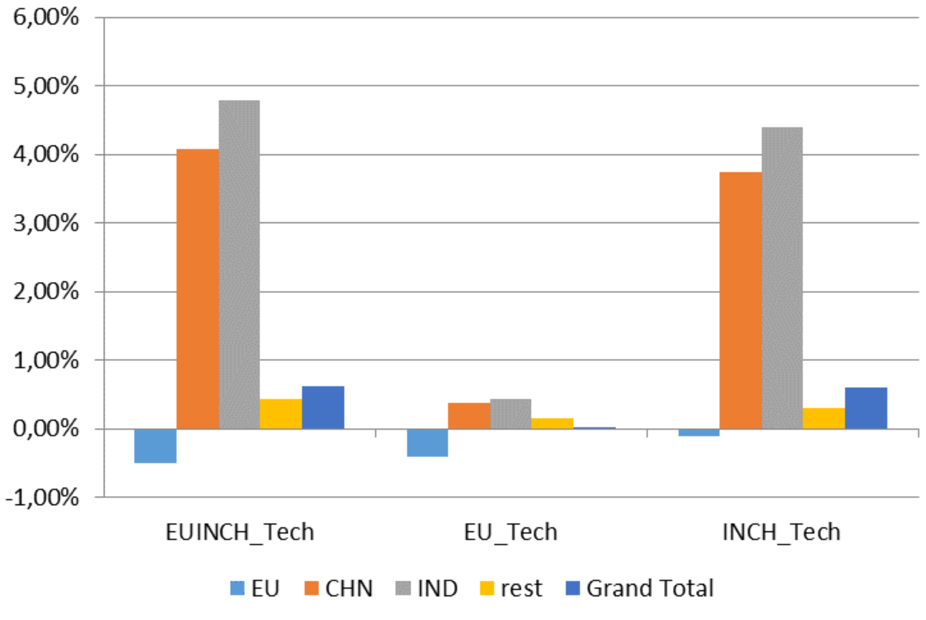


Figure 6: Effects on GDP by region in 2030 for different technology scenarios relative to Baseline. source: Nabernegg et al. (2015)

4.3.2 Large scale PV solar electricity generation in Europe or abroad?

In the macroeconomic assessment of different options for larger scale solar imports to Europe, we compared two scenarios. The Solar Domestic scenario (corresponding to the Europe configuration in Table 4 above) assumes that 20% of EU electricity use in 2020 is produced by PV solar and a feed-in tariff ensures that PV electricity is available at the cost of conventional electricity. In the Solar Import scenario (corresponding to the MENA+Tropical Import configuration in Table 4 above), we assume that 20% of EU electricity use in Europe (CEU, MEU, NEU) in 2020 is PV electricity imported from Middle East and North Africa (MENA) and the rest of Africa (AFR), and that 20% of the PV solar electricity remains in the country of generation. Moreover, 50% of capital costs are supplied by Europe whereas the remaining 50% come from the generating countries. Figure 7 illustrates how the solar electricity scenarios affect electricity generation and use in the European and MENA regions relative to the Baseline scenario without large scale PV solar generation.

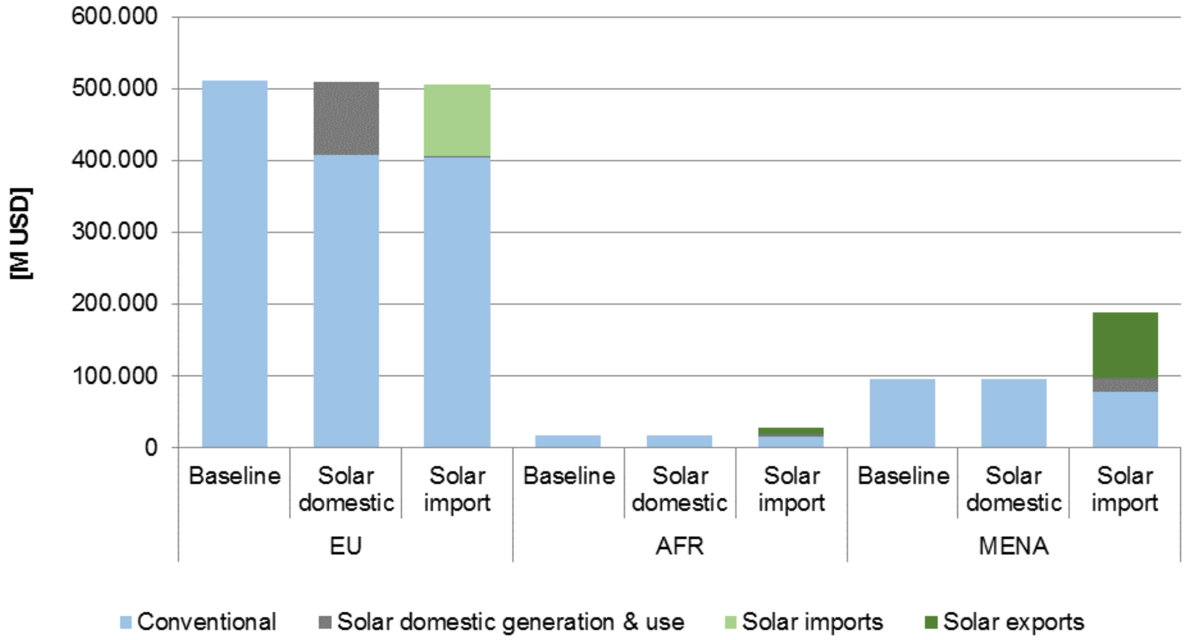


Figure 7: Electricity mix (in MUSD) by region and scenario in 2020: conventional electricity generation, domestic solar electricity generation for domestic use, imports and exports of solar electricity
source: Bednar-Friedl et al. (2015)

In the European regions, welfare (measured as % change in private consumption relative to the Baseline scenario) declines in both the Solar Domestic and the Solar Import scenario (Figure 8). In the Solar Domestic scenario, this decline is due to two influencing channels: when solar electricity is produced in Europe, a feed-in tariff is needed for achieving grid parity. This reduces public expenditures on consumption goods and increases the tax burden to households. As a consequence, purchasing power declines. In the Solar Import scenario, no subsidies are needed but as Europe contributes 50 % to capital costs in PV solar production in the MENA and AFR regions, this capital is no longer available in Europe. Even though capital income is distributed to European households, welfare declines in Europe, but much less than in the Solar Domestic scenario.

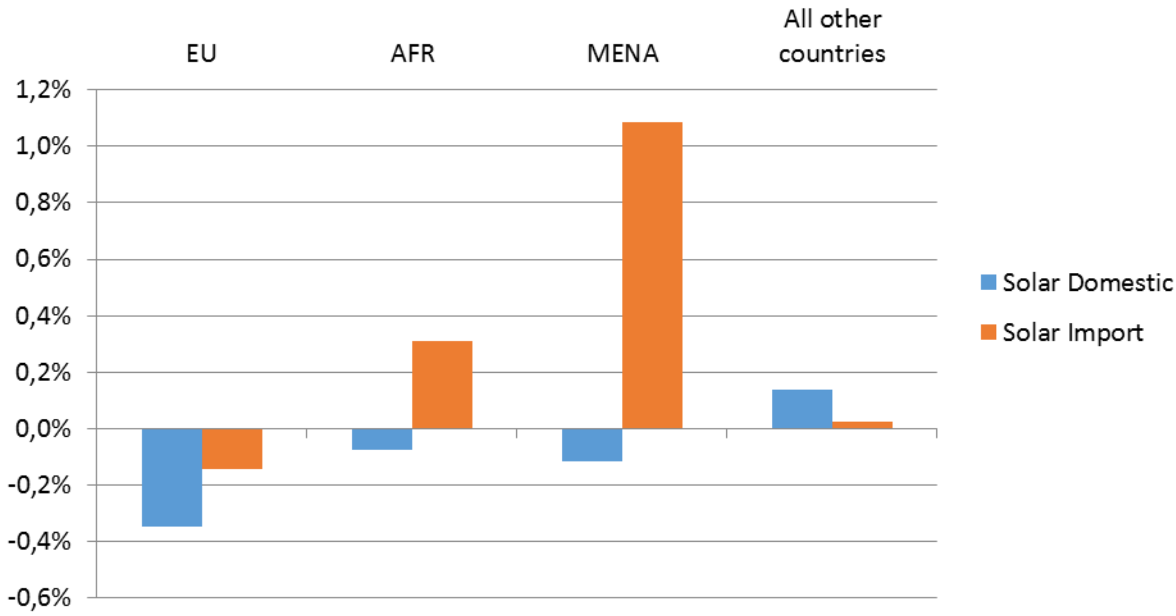


Figure 8: Welfare effects (% of Hicksian equivalent variation relative to Baseline) for scenarios Solar Domestic and Solar Import
source: Bednar-Friedl et al. (2015)

In the sensitivity analysis, we investigate the impact on model results of three key parameters: (i) transmission costs; (ii) the distribution of generation between MENA and AFR; and (iii) the cost contribution of EU regions to capital costs in solar production in PV exporting regions. Doubling transmission costs reduces the cost advantage of PV solar imports to domestic generation by 5% so that the key insight that PV solar imports are less costly than domestic solar production in Europe is robust. Uncertainty on transmission costs therefore again affects the magnitude of the welfare effects, but not the direction. Regarding the cost contribution of the EU, we find that a higher cost contribution share by Europe hardly affects welfare in Europe, but welfare in the MENA regions decreases with a higher cost contribution by Europe. To understand why welfare declines it is useful to investigate effects on capital markets. With a higher cost contribution of MENA regions, capital becomes scarcer leading to higher returns on capital and, due to substitution effects, to a lower wager rate. As capital income is a substantial part of factor income, particularly in MENA, a higher domestic contribution share, and therefore a lower European cost contribution share, leads to a welfare increase in MENA.

4.4 Normative principles of distribution of climate mitigation and adjustment costs

In this work package we have identified a wide range of theories and principles of international and intergenerational distributive justice that are important in the debate on what a fair distribution of the costs of climate and energy policy would amount to. We have investigated whether it is methodologically valid to focus on distributing the costs and benefits of climate change and of responding to climate change ‘in isolation’ from considerations of distributive justice more generally. Many have recently argued that the benefits and burdens of responding to climate change ought simply to be bundled with the overall basket of goods that theories of distributive justice are concerned with, and the appropriate object of principles of distributive justice is the overall combined basket of goods. The work package has developed contrary arguments that attempt to justify one of the major presuppositions of the project as a whole, namely that it is justified to apply normative principles of distributive justice to climate change in isolation.

That is the main highlight at the purely theoretical level. Given the current state of the debate in this field – where anti-isolationism is the dominant and orthodox position – a contribution that challenges the received view is important.

A more ‘practical’ highlight – though the isolationism debate has enormous practical significance further down the road – is the work done on providing criteria for assessing the choice of energy policy regimes, in particular the choice between producing solar energy domestically versus importing it in order to meet emissions targets. In this regard, the work package identified four general criteria to guide the assessment of this policy choice (and other similar policy choices). These are:

1. Effectiveness in terms of meeting (intergenerationally just) emission targets
2. Welfare effects
3. Compatibility with minimal requirements of justice
4. Contribution to bringing about justice

By applying these criteria, we came to the conclusion that given the clear advantage that the solar import scenario has in terms of welfare effects, the question in policy terms was not whether to choose import of solar energy or domestic solar production, but rather how to do solar import in just ways. We used criteria 3 and 4 to demonstrate how the normative principles one endorses could provide guidance on how to conduct the solar import policy.

4.5 Translating model results into policy design

Highlights of WP5 were the comparison of different approaches of solar electricity imports to the EU including the corresponding costs. We revisited the current support schemes in the EU for high cost countries. Examples for current high end support levels in the EU include the current auctions (200 €/MWh) under the UK Contract for Difference scheme as well as the current rate for “Wind on lakes” under the Dutch SDE+ scheme (112,50 €/MWh). The cost for CSP (Concentrated Solar Power) imports can already compete with the higher end of the marginal renewable costs in some EU countries, however CSP provides semi-dispatchable electricity. As WP5 showed, the RE-ADJUST approach that is supposed to provide dispatchable electricity, is cost-wise far cheaper than the CSP approach as it benefits from the strong cost decline of PV comparted to CSP. Dispatchable electricity could be provided for by only 77-147 Euro/MWh in 2020 (including transmission costs) as the modelling in WP 2 showed compared to the estimated 200 Euro/MWh for CSP imports.

Moreover, we find that financing costs are a crucial determinant of electricity generation costs of highly capital intensive RES technologies, such as large scale CSP and PV. The cost of capital is found to be driven by perceived risks of investors covering, amongst other factors, the regional risk profile (financing costs are found to be higher in less developed world regions such as MENA) as well as the RES technology’s risk profile, which itself depends e.g. on the length of the respective technology’s track record. Addressing these perceived risks by investors through de-risking strategies could have substantial positive impacts on CSP and PV electricity costs and in turn on the overall economy through reduced subsidy requirements.

However, costs are only one element in the comparison of the two solar power approaches. The CSP approach could consist of point-to point projects to the demand centres in the EU as the demand for dispatchable electricity is concentrated in a few number of EU countries. Also the RE-ADJUST approach would be a project of far larger dimension and would necessitate higher infrastructural investments until the cost-advantages can be gained.

Another highlight of WP5 is the assessment of the cooperation mechanisms of the renewable energy directive that provide for renewable electricity imports to the EU and allows the imported electricity to be counted to the member states’ 2020 renewable energy targets. No project under the cooperation mechanism has been implemented so far as the cost advantages of importing volatile renewable electricity to the EU were not obvious enough. As the import of dispatchable electricity will only lead to long term decarbonisation and thereby assist the transformation of the EU’s energy system but not to short term target achievement, new policy mechanisms in the 2030 framework have to take into account these emerging needs. The project showed that regardless of which solar electricity import concept would be implemented cost advantages may occur in the EU considering less fossil fuels needed for peak load electricity generation and positive economic and environmental externalities. Solar imports could be an environmental attractive alternative to extending the lifetime of fossil power plants or building new ones in the EU that would create a carbon lock in. Solar electricity imports may help to meet the 2030 greenhouse gas target of 40% more cost efficiently but would also allow to move to a more stringent 2030 greenhouse gas target. This would lead to additional socioeconomic benefits and would better align the EU's climate policy with global effort sharing considerations.

5 Schlussfolgerungen und Empfehlungen

Key findings of the project in relation to the research questions:

For low carbon technology options in energy intensive industries: What are the economic costs for the EU and relevant other world regions for different low carbon technologies in energy intensive industry, low-carbon energy supply and location of production? What are the implications for international trade flows and GDP?

- Low carbon technology options are available in all energy intensive industries, but marginal abatement cost differ both across sectors and regions, as demonstrated by cost differences between the EU, China and India. In general, the potential for cost savings is found to be larger for China and India relative to Europe because energy efficiency measures lead to larger fuel costs savings and smaller investment costs in these emerging economies.
- For China and India, we find that there is a limited potential for cost-effective energy savings even in the absence of a carbon price and that most of the energy savings potential is realized at carbon prices below 90 Euros/tCO2eq. Across energy-intensive industries, the potential for cost-effective efficiency measures is found to be largest in the iron and steel sector.
- From a macroeconomic perspective, a European low carbon strategy for energy intensive industries therefore involves extra cost, if not aligned with decarbonization in other world regions. Moreover, international trade intensifies the costs for Europe in case of a unilateral approach.

For extensive use of renewable electricity imports into the EU: How may the costs of electricity from solar develop in the next 10-20 years? How would the emergence of a new solar-based energy system affect trade and income distribution across world regions? Which responsibility questions arise due to a large scale solar electricity import into the EU? What technical, infrastructural, economic and political measures have to be taken in order to be able to enable a large-scale solar energy supply?

- A new concept of renewable electricity transfer was elaborated in RE-ADJUST. It is based on PV generation and Li-Ion battery storage that need to be optimized. When comparing the minimally required solar generation capacity and storage to consistently meet the European load for a selection of solar networks consisting of sites across Europe, North Africa, the Middle East, and selected other global regions, we find that electricity import scenarios from high insolation sites generally permit meeting the same load with considerably less storage and generation capacity and hence lower costs than scenarios with some electricity production in Europe; in addition, costs differ significantly across the other configurations investigated given the differing capacities of various distributed networks to mitigate diurnal and seasonal intermittency.
- The macroeconomic and welfare effects of importing PV solar electricity are positive for both Europe and the Middle East and North African (EUMENA) regions, compared to a scenario in which the same amount of electricity is produced within Europe. Lower technology costs in Middle East and North Africa lead to macroeconomic benefits in the EU. Imports of electricity from large scale PV solar in Middle East and North African regions can therefore considerably reduce costs of a low carbon strategy for Europe. A broad sensitivity analysis demonstrates that this result is robust for a wide range of transmission costs and different assumption regarding the location where PV solar is generated (in Middle East, North Africa, or Sub Saharan Africa).
- Normatively assessing specific policy choices in isolation from all other considerations of climate justice is best done by providing a combination of two things: 1) where possible,

determinate guidance and recommendation, i.e., where this can be provided on the basis of uncontroversial normative assumptions that are widely shared; and 2) a framework that allows relevant agents to work out the full normative assessment by identifying which considerations are relevant to the choice between policies and how. Normatively, and given qualifications, importing solar electricity is therefore to be preferred to producing electricity domestically. Overall importing solar electricity was seen as positive in the normative assessments as it has positive welfare effects for all parties, and fulfils the intergenerational justice principle, as solar imports as producing solar electricity in Europe aim to meet the 2°C target. Also even if no perfect democracies, the North African countries have no dictatorships anymore, what would disqualify them as exporting countries.

What are policy implications for the EU transition to a low-carbon, low energy? And in particular for extensive use of RES cooperation mechanisms with solar electricity: What technical, infrastructural, economic and political measures have to be taken in order to be able to enable a large-scale solar energy supply?

- The 2030 energy and climate framework has set the 27% renewable energy target only as EU wide target. Countries can propose national targets that may be upscale with a yet to defined governance mechanism to meet an aggregated 27%. Several policy options could enable a cost-efficient achievement of the 27% target including solar electricity imports. If imported solar electricity is dispatchable it could balance the variability of renewables in Europe.
- For importing renewable electricity the renewable energy directive provides for the cooperation mechanisms. These mechanisms are not part of the 2030 framework as no binding renewable energy targets at member states level exist, but the member states will have binding greenhouse gas targets and will need to implement corresponding policy mechanisms.
- The project showed that regardless of which solar electricity import concept would be implemented cost advantages would occur in the EU considering less fossil fuels needed for peak load electricity generation and positive economic and environmental externalities. Solar imports could be an environmental attractive alternative to extending the lifetime of fossil power plants or building new one in the EU that would create a carbon lock in.
- Solar electricity imports may help to meet the 2030 greenhouse gas target of 40% more cost efficiently but would also allow to move to a more stringent 2030 greenhouse gas target. This would better align the EU's climate policy with global effort sharing considerations
- Our analysis has shown that perceived risks by RES investors are a crucial influencing factor of financing costs of RES projects and hence determine the economic feasibility of specific RES projects. Hence, the development of de-risking strategies addressing these risks is crucial to foster RES deployment in the EUMENA region.

<u>Conclusions for specific target groups:</u>

- A dataset on low carbon technology options was generated and implemented in the GAINS Mitigation Efforts Calculator which is available at: http://gains.iiasa.ac.at/MEC/
- The project results will assist European/Austrian policy makers to design and implement climate and energy policy. In particular, the 2030 27% renewable target is seen only as minimum and options to meet it cheaper or to reach a higher share of renewables by solar electricity imports are relevant for policymakers. Also options for an early decarbonization of the energy system that will be relevant for the EU's greenhouse gas emission also in the post 2030 horizon, is currently highly relevant as the EU commission has started to develop post 2030 emission reduction pathway.

- For policymakers and for the broader public in particular the broader societal view is important that also considers economic or environmental externalities and questions of justice.
- Also industry is a target group of the project results as new concepts and their technical as well as economic properties were discussed and compared with existing approaches to import solar electricity.
- Last, science is a target group of the project as new data has been generated and models have been improved.

C) Projektdetails / Project details

6 Methodik / Methodology

The project was organized in 5 research WPs and one project management WP (see Figure 9). In WPs 1 and 2, the technological background was laid for the consideration of both low-carbon technology switches in energy intensive industries and for large-scale solar energy generation. In addition to technological information, cost data was be collected. Moreover, different scenarios were developed, regarding mitigation targets (and induced carbon prices) as well as RES energy system transformation. With this technological and cost information at hand, both economic and distributive assessments were undertaken in WPs 3 and 4, addressing questions such as effectiveness (avoidance of leakage), domestic and international economic consequences, and burden sharing of entailed benefits and costs. In a synthesis we derived the conclusions for designing policies and institutional settings which are then aligned with practical policy recommendations (WP5).

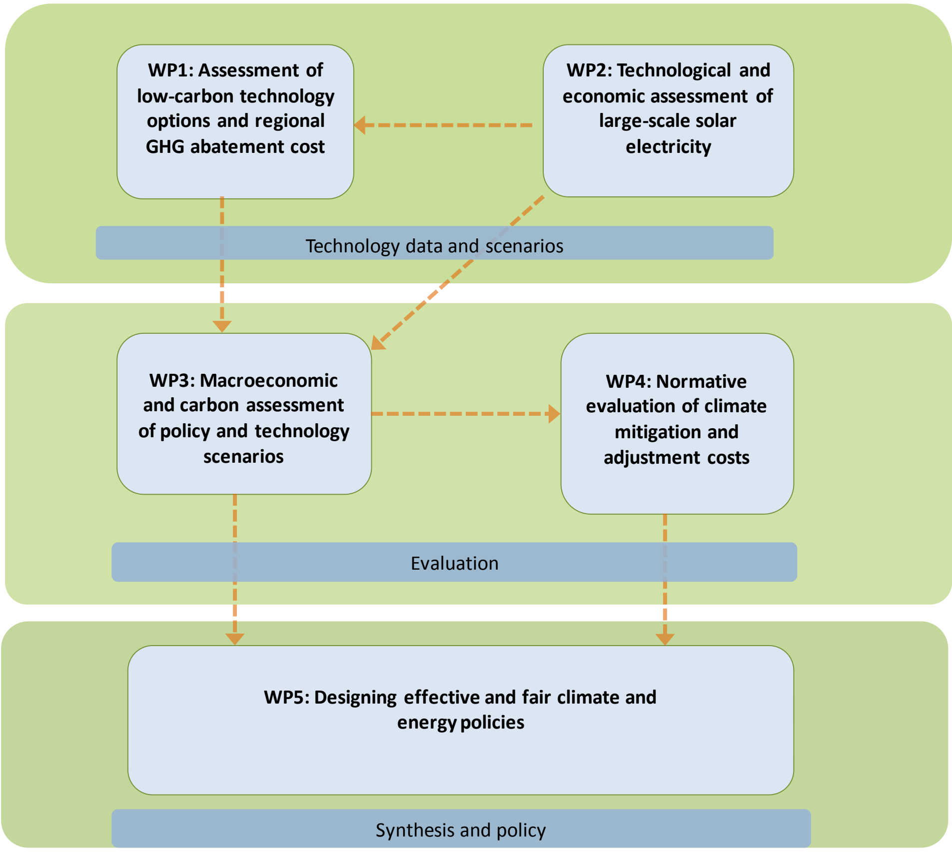


Figure 9: Work plan

<u>Assessment of low-carbon technology options and regional GHG abatement cost (WP1)</u>
This work package aimed to provide a good understanding of all available low-carbon technology options and a framework to treat them consistently at different temporal, spatial and sectoral scales. Technological parameters are collected and updated in the GAINS model databases, which are accessible online and free of charge not just to project participants but to the general public at large. GAINS provides a coherent framework to assess the cost-effectiveness of mitigation options in different sectors. The focus in this WP were the energy-intensive production sectors and

renewable energy technologies, and an overall assessment of potentials and costs in major developing economies like India and China. The mitigation potentials werre put into the context of baseline emission projections of all Kyoto gases, and the cost-effectiveness is assessed on the basis of marginal abatement cost curves. A comparison of mitigation efforts across both Annex I countries as well as, e.g. India and China is possible using an extended version of the Mitigation Efforts Calculator (MEC). In particular, mitigation potentials and costs for non-CO_2 gases in India and China were estimated and marginal abatement cost curves were calculated and included in the MEC.

Technological and economic assessment of large-scale solar electricity (WP2)
The aim of this WP was to estimate to what degree solar electricity can replace fossil energy in Europe up to 2050. This entails comparing a range of large-scale solar electricity networks (supply constellations) consisting of generation sites across Europe, Northern Africa, and the Middle East with regard to the minimal generation capacity and storage needed at each site to meet a given load. An additional network considered is a global solar configuration. This evaluation was done based on daily NASA Solar Sizer solar insolation data for the 20-year period 1986-2005 that were scaled to hourly values using a previously developed scaling method (Grossmann et al., 2013a) and a systems model that determines the minimally required generation capacity and storage for each supply constellation in order to meet the given load. Electricity costs were derived combining the results from this model with the current costs of PV panel production and installation and transmission lines.

Macroeconomic and carbon assessment of policy scenarios (WP3)
While the detailed technology models specify the technological potentials as well as their costs, they lack the feedback effects of other sectors and macroeconomic structures. To take account of these general equilibrium effects, we used therefore a multi-region multi-sector computable general equilibrium (CGE) model to assess both different low carbon technologies in energy intensive industries as well as for large-scale solar electricity. For that assessment, a multi-regional multi-sectoral CGE (computable general equilibrium) model for Europe, distinguishing for 3 sub-regions, its main trading partners in other world regions (North America, China, India), and potential large-scale solar generation regions (North Africa and Middle East region)was used. After preparing the model linkages to WPs 1 and 2 were prepared a set of policy and technology scenarios were developed jointly with WP1 & WP2 team members. Finally, quantitative economic and carbon emission impacts of regional climate and low-carbon energy policy, including international instruments for trade in RES electricity, were assessed with this CGE model.

Normative principles of distribution of climate mitigation and adjustment costs (WP4)
Besides the question of the effectiveness and feasibility of certain policy options, in particular with respect to renewable energies, the second focus of the project is the fair distribution of responsibilities and burdens between world regions like the EU for bringing about a transition to a low carbon economy. From a normative perspective we can distinguish different levels of analysis by asking the following questions: what would an ideal state of a low-carbon economy look like for different regions; how to evaluate different options of transition in different regions under current non-ideal conditions; and which region when understood as a collective agent has which duties and responsibilities for bringing about a transition to the ideal state of a low-carbon economy?

Translating model result into policy design (WP5)
Based on the results of the previous WPs, this WP assessed energy and climate policy concepts and mechanisms taking into account the flexibility of international trading with RES electricity (including the use of RES cooperation mechanism for the EU), ensuring global effectiveness (avoidance of carbon leakage) and global fairness in target setting and achievement. The focus of the policy analysis was on the EU.

A detailed description of the methodologies applied is available in the respective papers produced within this project.

7 Arbeits- und Zeitplan / Time and work plan

Tasks per Work package	Finalisation (MM/YY)
WP 1: Assessment of low-carbon technology potentials and regional GHG abatement cost	
Task 1.1: Data compilation and processing	06/14
Task 1.2: BAU scenario 2050	06/14
Task 1.3: Sectoral effort scenarios	03/15
Task 1.4: Regional abatement costs	09/14
WP 2: Technological and economic assessment of large-scale solar electricity	
Task 2.1: Literature review	09/13
Task 2.2: Assessment and comparison of several European variations of solar networks	12/13
Task2.3: Assessment of Desertec EUMENA network configuration	12/13
Task 2.4: Assessment of European-Asia network configurations	12/13
Task 2.5: Assessment of two solar energy import schemes, a) Sahara-Saudi and b) globally distributed sites	03/14
Task 2.6: Characterization of cost development over time	12/14
Task 2.7 Comparison of configurations	09/14
WP 3: Macroeconomic and carbon assessment of policy and technology scenarios	
Task 3.1: Model refinement	05/14
Task 3.2: Modeling of low carbon technology options in electricity and EITE sectors	12/14
Task 3.3: Modeling of policy instruments	03/15
Task 3.4: Reporting of economic and carbon impacts of policy options	06/15
WP 4: Principles of distribution of climate mitigation and adaptation costs	
Task 4.1: Comparative assessment of principles of intragenerational distributive justice	10/14
Task 4.2: Criteria for a fair distribution	10/14
Task 4.3: Normative Assessment framework	10/14
Task 4.4: Matrix and regional level principle catalogue	03/15
Task 4.5: Normative evaluation of the differing options of a transition to a low-carbon economy	03/15
WP 5: Translating model result into policy design	
Task 5.1: Integrated assessment of the technological, economic, distributional and emissions dimensions of selected scenarios	06/15
Task 5.2: Policy recommendations	07/15
WP 6: Project management	07/15
Task 6.1: Project team meetings	07/15
Task 6.2: International expert workshop	06/15
Task 6.3 Interim and final activity reports	07/15

8 Publikationen und Disseminierungsaktivitäten / Publications and dissemination

	Journal	Dissemi-nation	Presen-tation
1. Grossmann, W., Grossmann, I., Steininger, K., 2015. Solar electricity: supply isolines of generation capacity and storage. Proceedings oft he National Academy of Sciences 112: 3663–3668, www.pnas.org/cgi/doi/10.1073/pnas.1316781112.	x		
2. Grossmann, I., Grossmann, W., Potential for large-scale photovoltaic electricity supply in Europe. Unpublished manuscript, to be submitted.	x		
3. Schinko, T., Komendantova, N., 2016. De-risking Investment into Concentrated Solar Power in North Africa: Impacts on the Costs of Electricity Generation. Renewable Energy 92, 262–272.	x		
4. Nabernegg, S., Bednar-Friedl, B., Wagner, F., Cofala, J., Schinko, T., Mori-Clement, Y., 2015. Low Carbon Technologies in Energy Intensive Sectors: A Comparison across Europe, China and India for 2030, unpublished manuscript, to be submitted.	x		
5. Bednar-Friedl, B., Nabernegg, S., Grossmann, I., Grossmann, W., Schinko, T. 2015. Electricity imports from large-scale photovoltaics to Europe: Distributional Implications for Europe, Middle East and North African regions, unpublished manuscript, to be submitted.	x		
6. Meyer, L.H. and Sanklecha, P., 2014. How legitimate expectations matter in climate justice, Politics, Philosophy & Economics 13(4): 369-393.	x		
7. Sanklecha, P. (2015): "A Truly Splendid Isolation. Climate Change and Distributive Justice'. Unpublished manuscript, to be submitted.	x		
8. Steininger, K.W., Lininger, C., Meyer, L., Munoz, P., Schinko, T. (2015), Multiple carbon accounting to support just and effective climate policies, Nature Climate Change, published online 23 November 2015, doi: 10.1038/nclimate2867	x		
9. Türk, A., Grossmann, I., Grossmann, W., Laurien, F., Schinko, T. (2015) Re-adjusting Europe's energy and climate targets: opportunities from solar electricity imports. Policy Brief. To be published as Wegener Center Scientific Report.		x	
10. Schinko, T., Workshop on Multi-disciplinary perspectives on climate ethics, Como, Italy, September 26, 2013. Title of presentation: An economic and justice evaluation of burden sharing agreements: Matters of responsibility, ability, and equality.			x
11. Schinko, T., Klimatag 2014, April 2-4, 2014. Title of presentation: Photovoltaics in South America and prospects for regional development.			x
12. Bednar-Friedl, B., Invited talk at 4th CREE Research Workshop (CREE - Oslo Centre for Research on Environmentally friendly Energy), September 22-23, 2014, Oslo, Norway. Title of Presentation: International trade in electricity from large-scale solar generation: Implications for the European Union and other continents.			x
13. Bednar-Friedl, B., Nabernegg, S., 16. Österreichischer Klimatag, Vienna, April 28-30, 2015. Title of Presentation: Electricity imports			x

from large-scale photovoltaics to Europe: Distributional Implications for Europe, Middle East and North African Regions.			
14. Bednar-Friedl, B., Nabernegg, S., International Expert Workshop on “Low carbon technology transitions: The role of renewable electricity imports”, Haus der Forschung, Vienna, June 12, 2015. Title of Presentation: Electricity imports from large-scale photovoltaics to Europe: Distributional Implications for Europe, Middle East and Africa.			x
15. Grossmann, I., International Expert Workshop on “Low carbon technology transitions: The role of renewable electricity imports”, Haus der Forschung, Vienna, June 12, 2015. Title of presentation: Regional and Global PV Solar Grid Constellations: Capacity, Storage, and Costs.			x
16. Sanklecha, P., International Expert Workshop on “Low carbon technology transitions: The role of renewable electricity imports”, Haus der Forschung, Vienna, June 12, 2015. Title of presentation: Normative evaluation of carbon transition scenarios.			x
17. Türk, A., International Expert Workshop on “Low carbon technology transitions: The role of renewable electricity imports”, Haus der Forschung, Vienna, June 12, 2015. Title of presentation: Policy perspectives on PV solar imports.			x
18. Bednar-Friedl, B. Annual Conference of the European Association of Environmental and Resource Economists (EAERE 2015), Helsinki, Finland, June 24-27, 2015. Title of presentation: Electricity imports from large-scale photovoltaics to Europe: Distributional Implications for Europe, Middle East and North African Regions.			x
19. Schinko, T. Late summer workshop of the IIASA Young Scientists Summer Program (YSSP), Laxenburg, Austria, .August 25, 2014. Title of presentation: Governance of risks in financing concentrated solar power (CSP) investments in North Africa.			X
20. Nabernegg, S., FSR Climate 2015 Annual Conference “Economic Assessment of European Climate Policies”, 22-23 October, Florence. Title of presentation: Electricity imports from large-scale photovoltaics to Europe: Distributional Implications for Europe, Middle East and North African Regions.			x
21. Bednar-Friedl, B. (2016), Keynote Address at Climate Ethics and Economics Workshop, March 3-4, 2016, Goethe University of Frankfurt, Cluster of Excellence „Normative Orders“. Title of presentation: A fairness evaluation of European low carbon technology options abroad – Results from the RE-ADJUST project.			x

International Expert Workshop on

Low carbon technology transitions: The role of renewable electricity imports

Friday, 12 June 2015, 10:00 to 16:00

Haus der Forschung, Sensengasse 1, 1090 Vienna, Austria

Programme

10:00-10:15	**Welcome & Coffee**
10:15-10:30	Birgit Bednar-Friedl (University of Graz): Introduction
10:30-12:30	**Results from the RE-ADJUST Project**
	Iris Grossmann (Carnegie Mellon University): *Regional and Global PV Solar Grid Constellations: Capacity, Storage, and Costs*
	Birgit Bednar-Friedl, Stefan Nabernegg (University of Graz): *Electricity imports from large-scale photovoltaics to Europe: Distributional Implications for Europe, Middle East and Africa*
	Pranay Sanklecha (University of Graz), Andreas Türk (University of Graz; Joanneum Research): *Ethical and political perspectives on PV solar imports*
12:30-13:30	*Lunch*
13:30-15:30	**International Experiences**
	Nadejda Komendantova (International Institute for Applied Systems Analysis): *Expansion of Solar Electricity in the Middle East and North African Region: Addressing Risk Perceptions and Stakeholders Views*
	Jürgen Kern (German Aerospace Center): BETTER – Bringing Europe and Third Countries closer together Through Renewable Energies. A Framework for successful RES-E Expansion in NA
	Andreas Türk (University of Graz; Joanneum Research), Dora Fazekas (DIPOL Consulting Budapest): *Renewable electricity imports and implications for the EU ETS*
15:30-16:00	Summary and Wrap up