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Climate Mitigation and Adaptation in Africa

EVIDENCE FROM PATENT DATA

Ivan Haščič, Jérôme Silva,
Nick Johnstone

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CLIMATE MITIGATION AND ADAPTATION IN AFRICA: EVIDENCE FROM PATENT DATA

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Keywords: Climate policy, Technology transfer, Technology diffusion, Innovation, Patents.

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ABSTRACT

This paper presents comparative data on innovation in selected climate change mitigation and adaptation technologies in the context of Africa. Such analysis informs policy aimed at encouraging international technology transfer and development of domestic innovation capacities. We present detailed analysis of the role of Africa in development of these technologies (invention), and then move on to examine Africa as a technology market (as reflected in patenting). In addition, we briefly touch upon the question of cross-border technology development (co-invention) in Africa. Despite Africa's generally low volume of inventive activity in these fields in comparison with other countries, inventive activity is disproportionately directed towards mitigation and adaptation technologies. In addition, the rate of international co-invention for most mitigation and adaptation technologies is much higher in Africa than in the rest of the world. And finally, rates of protection of climate technologies at African intellectual property offices are high relative to other technologies. Nonetheless, it must be emphasized that a relatively small number of inventions are protected in Africa, providing evidence that IP is not a barrier to technology transfer and diffusion.

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Keywords: Climate policy, Technology transfer, Technology diffusion, Innovation, Patents.

RÉSUMÉ

Ce rapport livre des données comparatives sur l'innovation concernant certaines technologies d'atténuation du changement climatique et d'adaptation à ses effets dans le contexte de l'Afrique. L'analyse de ces données éclaire l'élaboration des politiques visant à encourager les transferts internationaux de technologies et le renforcement des capacités nationales d'innovation. Nous proposons une analyse détaillée du rôle de l'Afrique dans la mise au point de ces technologies (invention), avant d'étudier le marché technologique qu'elle représente (à l'aune des dépôts de brevets). Nous abordons en outre brièvement la question du développement de technologies au niveau international (co-invention) en Afrique. Si l'activité inventive des pays africains dans ces domaines est généralement faible par rapport à d'autres pays, les technologies d'atténuation et d'adaptation y tiennent toutefois une place primordiale. Qui plus est, la co-invention internationale concernant la plupart de ces technologies est bien plus fréquente en Afrique que dans le reste du monde. Enfin, les offices africains de la propriété intellectuelle délivrent davantage de brevets aux technologies climatiques qu'aux autres technologies. Soulignons cependant que les inventions protégées sont relativement peu nombreuses en Afrique, et que la propriété intellectuelle n'y dresse donc pas d'obstacle au transfert et à la diffusion des technologies

Classification JEL : Q42, Q48, Q54, Q55, Q56, Q58, O31, O33, O38, O55.

Mots clé : politique climatique, transferts de technologies, diffusion des technologies, innovation, brevets.

FOREWORD

This paper is a contribution to the OECD Environment Directorate project on "Environmental Policy and Technological Innovation" (www.oecd.org/environment/innovation). It has been authored by Ivan Haščič, Jérôme Silva and Nick Johnstone of the OECD Environment Directorate. The search strategies upon which the data is derived were developed by a team of patent examiners led by Javier Hurtado-Albir and Victor Veefkind of the European Patent Office (EPO). The support of the EPO, and in particular Konstantinos Karachalios and Nikolaus Thumm, is gratefully acknowledged. The authors would like to thank Elisa Lanzi for helpful suggestions, Barbara Aiello for preparation of the manuscript and figures, and Tamás Medovarszki for assistance with data cleaning.

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EXECUTIVE SUMMARY

This paper presents comparative data on selected climate mitigation and adaptation technologies in the context of Africa. Such analysis is useful because it informs policy aimed at encouraging international technology transfer and development of domestic innovation capacities. It also sheds light on countries' potential to achieve development objectives.

The paper presents detailed analysis of the role of Africa in development of these technologies (invention), and then moves on to examine Africa as a technology market (as reflected in patenting). In addition, we briefly touch upon the question of cross-border technology development (co-invention) in Africa.

To the extent possible, we make an effort to place the data in a broader context of overall patenting trends. It must be emphasized that due to unequal data coverage of African countries care should be taken in interpreting some of the findings presented here. Again, we make efforts to account for these differences and construct normalized indicators (including relative technology advantage (RTA) and relative patent propensity (RPP)). Finally, we contrast our findings with indicators based on non-patent data sources (index of intellectual property (IP), trade flows, emission levels) insofar these are available for African countries. The following section summarizes the major findings of this paper.

Climate change mitigation technologies

The place of Africa in development of selected CCMTs

Over the period 1980-2009 there are 657 patents related to CCMTs with inventors residing in Africa countries. The most important fields are technologies related to energy storage and renewable energy. Not surprisingly, this represents only a fraction of the global efforts – 0.4% on average during 1980-2009. However, given the heterogeneity of the African continent, it is not surprising that some technologies and some countries stand out. In particular, South Africa alone represents an overwhelming share (84%) of Africa's inventions, followed by countries such as Egypt, Algeria, Morocco and Kenya.

Despite Africa's generally low volume of inventive activity, it is disproportionately directed towards mitigation technologies. More specifically, while inventive activity directed at mitigation technologies represents only 1% of overall inventive activity worldwide, it is as much as 3% in Africa. This applies, in particular, to certain fields such as biofuels, marine & tidal energy, waste-to-energy, and solar thermal energy. Nuclear energy technology represents an important share of Africa's inventive efforts. However, it is concentrated exclusively in South Africa. Apart from South Africa (which is active on many fronts), countries such as Ghana, Algeria and Senegal stand out because, compared to their overall efforts, they have the highest propensity to develop mitigation technologies.

It is interesting that only a small percentage of African inventions (10%) seek patent protection in African markets – a fact that might, of course, be related to the strength of IP regimes. In fact, most frequently African innovators seek protection in North American (USA 27%, Canada 10%) and European (EPO 24%, Germany 13%) jurisdictions. On the other hand, 6% of inventions seek protection in China and only 3% in Japan and Korea.

Africa as a market for selected CCMTs

Just under 3,000 CCMT inventions are registered with African intellectual property offices. However, given the manner by which the counts are generated these figures are more significantly affected than the

'inventor country' data due to the fact that coverage of African IP offices in PATSTAT is far from comprehensive.

Overall, less than 1% of mitigation-related patenting activity worldwide targets African countries, of which South Africa is the dominant market, followed by Morocco and Egypt. Still, it is interesting that world's inventors are more likely to seek protection in Africa when these inventions are mitigation-related. In this respect the OAPI region including many countries of Sub-Saharan Africa stands out. Mitigation technologies that are relatively frequently patented in Africa include biofuels, nuclear, CCS, marine & tidal, efficient combustion, waste-to-energy and solar thermal energy. Somewhat surprisingly, solar PV is relatively less frequently protected in Africa than worldwide. Patenting in wind, CCS and biofuels has been growing fast, while patenting in energy storage/hydrogen/fuel cells, nuclear and solar thermal energy has been decreasing.

What is the 'origin' of the inventions that are protected in Africa? Overwhelmingly, they have been invented in OECD countries and this fact has changed little over time. However, while in the 1980s over a half of all inventions patented in Africa originated in only two countries (United States and France), their share has come down significantly in the last decade as Germany has become the most important 'origin'. At the same time, the share of African countries has increased from less than 1% to over 8%. The shares of Japan and Korea are extremely low.

International collaboration in CCMT development in Africa

Overall, 23% of African inventions in mitigation technologies involve co-invention (inventors from more than one country). This contrasts with 12% of mitigation-related inventions co-invented worldwide, and 9% of all inventions (in all fields) co-invented worldwide. Hence, CCMT technologies have a generally greater rate of co-invention, but this is particularly the case in Africa.

Interestingly, South Africa, while ranking as the major inventor in Africa, is less likely to co-invent with others in developing mitigation technologies. Countries that are most likely to co-invent include Tunisia, Morocco, Egypt, Kenya and Mali – all of whom co-invent at least 50% of their inventions with inventors in other countries. The most frequent partner countries include the USA, the UK, Belgium, Germany, France, Sweden and Canada. Strikingly, there is very little evidence of intra-Africa co-invention, with a single documented case (Kenya-Egypt), suggesting that every African country is an "island" within the continent.

Climate change adaptation technologies

The place of Africa in development of selected 'adaptation' technologies

This paper also examines a set of technologies suitable for addressing specific environmental needs of African countries (here referred to as 'adaptation' technologies). The counts are generally low due to the rather specific nature of the sources. In total over the period 1980-2009 there are 56 climate adaptation technologies. Among the 'adaptation' technologies examined, inventive activity in Africa mostly targets water desalination (45%), followed by energy supply in remote locations (25%), solar water treatment (14%), rainwater collection (7%) and solar/wind-powered water pumping (7%). Surprisingly, given the available resources and potential demand, there are no African inventions in solar cooking.

Overall, the share of African inventors in worldwide efforts to develop adaptation technologies has been very low (0.26%). South Africa is the most important inventor country but its dominance is much less marked in the case of mitigation technologies. Other major inventor countries are Morocco and Egypt. Interestingly, a very high proportion of African adaptation inventions seek protection in Africa itself (81%) – a much greater share than is the case for mitigation technologies.

Africa as a market for selected 'adaptation' technologies

A total of 389 adaptation technologies are protected at African IP offices, with desalination being the most important field. Globally, while for mitigation technologies the principal market for patent protection is Europe, the most important market for adaptation technologies is Asia. The share of Africa is low in both cases, with only about 1% of world's patents for adaptation technologies registered with African patent offices. Again, South Africa is the country where such patent protection is sought most often, although to a lesser degree than for mitigation technologies. Conversely, the share of Sub-Saharan countries is greater.

Among the adaptation technologies examined, water desalination is by far the primary technology protected in Africa. However, several other adaptation technologies tend to be protected relatively more often in Africa than elsewhere in the world, including those related to resilience of the electricity supply grid to extreme weather events, solar water treatment, severe weather prediction and rainwater collection. It is rather surprising that there have been very few patents in fields that would seem highly relevant for addressing some of the Africa's most pressing environmental needs, such as solar cooking, efficient lighting for remote locations, and solar or wind-powered water pumping.

Overall, our analysis suggests that adaptation technologies (rather than mitigation technologies) are much more likely to be protected in Sub-Saharan and Northern Africa than in South Africa. For example, compared with other technologies, an adaptation technology is 7-times more likely to be protected in Sub-Saharan Africa (the ARIPO and OAPI regions). Nonetheless, it must be emphasized that a relatively small number of mitigation and adaptation inventions are protected in Africa, providing evidence that IP is not a barrier to technology transfer and diffusion.

The adaptation technologies patented in Africa originate predominantly in OECD countries (76%), with the USA and Germany the major inventors, followed by Australia (9%). Conversely, the shares of Japan and Korea are extremely low. The proportion of Africa's own inventions is as much as 17% - a much higher share than for mitigation.

SYNTHÈSE

Ce rapport livre des données comparatives sur l'innovation concernant certaines technologies d'atténuation du changement climatique et d'adaptation à ses effets dans le contexte de l'Afrique. L'analyse qu'il propose est utile en ce qu'elle éclaire l'élaboration des politiques visant à encourager les transferts internationaux de technologies et le renforcement des capacités nationales d'innovation. Elle renseigne par ailleurs sur le potentiel des pays en termes de concrétisation des objectifs de développement.

Ce rapport propose une analyse détaillée du rôle de l'Afrique dans la mise au point de ces technologies (invention), avant d'étudier le marché technologique qu'elle représente (à l'aune des dépôts de brevets). Il aborde en outre brièvement la question du développement de technologies au niveau international (co-invention) en Afrique.

Nous nous efforçons dans toute la mesure du possible de placer les données dans un contexte élargi en observant les tendances générales des dépôts de brevets. En raison de la couverture inégale des données dans les différents pays africains, nous invitons à la prudence dans l'interprétation de certaines des conclusions présentées ici. Nous essayons naturellement de tenir compte de ces différences et d'élaborer des indicateurs normalisés (notamment sur l'avantage technologique relatif et la propension relative à déposer des brevets). Nous confrontons enfin nos résultats à des indicateurs fondés sur des sources de données autres que les brevets (indicateur sur la propriété intellectuelle, flux commerciaux, niveaux d'émission) lorsque ceux-ci sont disponibles pour les pays africains. Les principales conclusions du rapport sont résumées ci-dessous.

Technologies d'atténuation du changement climatique

La place de l'Afrique dans le développement de certaines technologies d'atténuation du changement climatique

Dans le domaine des technologies d'atténuation du changement climatique, 657 brevets ont été déposés en Afrique entre 1980 et 2009. Ils concernaient essentiellement des technologies liées au stockage de l'énergie et aux énergies renouvelables. Certes, cela ne représente qu'une infime partie de l'effort mondial – 0.4 % en moyenne sur la période 1980-2009 – mais le continent africain étant hétérogène, certaines technologies et certains pays se distinguent particulièrement. C'est notamment le cas de l'Afrique du Sud qui, à elle seule, produit non moins de 84 % des inventions africaines, suivie de pays tels que l'Égypte, l'Algérie, le Maroc et le Kenya.

Si l'activité inventive des pays africains est généralement faible, les technologies d'atténuation y tiennent toutefois une place primordiale. En effet, l'activité inventive consacrée aux technologies d'atténuation représente 3 % de l'activité inventive totale en Afrique, contre 1 % seulement à l'échelle mondiale. Plusieurs domaines sont plus particulièrement concernés : les biocarburants, l'énergie marine et marémotrice, la valorisation énergétique des déchets, et l'énergie solaire thermique. La technologie nucléaire constitue une part importante de l'effort inventif de l'Afrique mais ce domaine reste exclusivement cantonné à l'Afrique du Sud. Outre l'Afrique du Sud (active sur de nombreux fronts), des pays tels que le Ghana, l'Algérie et le Sénégal se démarquent pour avoir la plus forte propension, au regard de leur effort global, à développer des technologies d'atténuation.

Il est intéressant de constater que seul un faible pourcentage des inventions africaines (10 %) font l'objet d'une demande de brevet sur les marchés africains – une situation sans doute liée à la qualité des régimes de propriété intellectuelle. Les inventeurs africains ont en effet tendance à faire breveter leurs inventions en Amérique du Nord (27 % aux États-Unis, 10 % au Canada) et en Europe (24 % auprès de l'OEB, 13 % en Allemagne). Enfin, 6 % des demandes de brevet sont déposées en Chine et 3 % seulement le sont au Japon et en Corée.

L'Afrique, un marché pour certaines technologies d'atténuation du changement climatique

Les offices africains de la propriété intellectuelle recensent un peu moins de 3 000 inventions dans le domaine des technologies d'atténuation du changement climatique. Or, compte tenu de la méthode de comptabilisation employée, ces chiffres sont entachés d'incertitudes encore plus grandes que les données sur les 'pays d'invention' du fait de la couverture pour le moins incomplète, dans PATSTAT, des offices africains des brevets.

À l'échelle mondiale, moins de 1 % des demandes de brevets pour des technologies d'atténuation sont déposées dans des pays africains et, en la matière, l'Afrique du Sud est le marché dominant, suivie par le Maroc et l'Égypte. Il est cependant intéressant de constater que les inventeurs, d'où qu'ils viennent, sont plus susceptibles de demander un brevet en Afrique si leur invention concerne l'atténuation du changement climatique. Les pays de l'OAPI, situés en Afrique sub-saharienne pour beaucoup d'entre eux, se distinguent à cet égard. Les technologies d'atténuation relativement fréquemment brevetées en Afrique ont trait aux biocarburants, au nucléaire, au captage et stockage du carbone (CSC), à l'énergie marine et marémotrice, à la combustion efficace, à la valorisation énergétique des déchets et à l'énergie solaire thermique. Paradoxalement, le solaire photovoltaïque est relativement moins fréquemment protégé en Afrique que dans le reste du monde. Dans les domaines de l'éolien, du CSC et des biocarburants, les brevets se développent rapidement, alors qu'ils sont en recul dans ceux du stockage de l'énergie, des technologies de l'hydrogène et des piles à combustible, ainsi que du nucléaire et de l'énergie solaire thermique.

Quelle est « l'origine » des inventions brevetées en Afrique ? Une écrasante majorité d'entre elles proviennent de pays de l'OCDE, et depuis toujours. Cependant, alors que dans les années 1980, plus de la moitié des inventions brevetées en Afrique étaient originaires de deux pays (les États-Unis et la France), ces dix dernières années l'Allemagne s'est imposée comme la principale « source » de brevets, au détriment des États-Unis et de la France qui ont vu leur part baisser considérablement. Parallèlement, la contribution des pays africains est passée de moins de 1 % à plus de 8 %. La part du Japon et de la Corée demeure extrêmement faible.

Collaboration internationale dans le développement des technologies d'atténuation du changement climatique en Afrique

Globalement, 23 % des inventions africaines en matière de technologies d'atténuation sont des co-inventions (les inventeurs proviennent de plus d'un pays), ce qui est beaucoup si l'on considère qu'à l'échelle mondiale, le pourcentage de co-inventions est de 12 % dans le domaine des technologies d'atténuation et de 9 % toutes inventions et tous domaines confondus. Le taux de co-invention est donc généralement plus élevé pour les technologies d'atténuation du changement climatique, et cette tendance se vérifie particulièrement en Afrique.

Paradoxalement, malgré son statut d'inventeur le plus prolifique du continent, l'Afrique du Sud semble moins versée dans la co-invention en ce qui concerne les technologies d'atténuation. Les pays les plus susceptibles de participer à des projets de co-invention sont la Tunisie, le Maroc, l'Égypte, le Kenya et le Mali – au moins 50 % des inventions de ces pays sont d'ailleurs le fruit d'une collaboration avec des

inventeurs étrangers. Les pays partenaires dont l'implication est la plus fréquente sont les États-Unis, le Royaume-Uni, la Belgique, l'Allemagne, la France, la Suède et le Canada. Fait marquant, les exemples de co-invention africano- africaine sont très rares. On recense un seul cas avéré (Kenya-Égypte), ce qui laisse penser que chaque pays africain est une « île » dans le continent.

Technologies d'adaptation au changement climatique

La place de l'Afrique dans le développement de certaines technologies « d'adaptation »

Ce rapport examine également un ensemble de technologies permettant de répondre aux besoins environnementaux spécifiques des pays africains (et appelées ici technologies « d'adaptation »). On en dénombre relativement peu en raison de la nature assez spécifique de leurs sources. Au total, sur la période 1980-2009, 56 technologies d'adaptation au changement climatique ont été recensées. Parmi les technologies examinées, l'activité inventive de l'Afrique porte majoritairement sur le dessalement de l'eau (45 %), l'approvisionnement en énergie des régions reculées (25 %), le traitement solaire de l'eau (14 %), la récupération des eaux de pluie (7 %) et le pompage solaire/éolien de l'eau (7 %). En revanche, en dépit de ses ressources disponibles et de la demande potentielle, l'Afrique n'est à l'origine d'aucune invention dans le domaine des cuisinières solaires.

Globalement, la part des inventeurs africains dans l'effort mondial de développement de technologies d'adaptation est très réduite (0.26 %). L'Afrique du Sud est certes le principal producteur africain d'inventions mais en matière d'adaptation, sa prédominance est moins marquée que dans le cas des technologies d'atténuation. Le Maroc et l'Égypte sont aussi d'importants inventeurs. Il est intéressant de noter que les demandes de brevet pour des inventions africaines liées à l'adaptation sont très majoritairement déposées en Afrique (81 %) – une proportion bien plus élevée que pour les technologies d'atténuation.

L'Afrique, un marché pour certaines technologies « d'adaptation »

Les offices africains de la propriété intellectuelle recensent 389 technologies d'adaptation brevetées et le domaine du dessalement de l'eau est le plus représenté. Globalement, alors que pour les technologies d'atténuation la principale destination des demandes de brevet est l'Europe, pour les technologies d'adaptation il s'agit de l'Asie. Dans un cas comme dans l'autre, l'Afrique tient une place marginale, les offices africains des brevets ne recevant que 1 % des dépôts de brevets internationaux pour des technologies d'adaptation. Là encore, les demandes de brevet sont principalement déposées en Afrique du Sud, bien que dans une moindre mesure par rapport aux technologies d'atténuation. En revanche, les pays subsahariens sont davantage représentés.

De toutes les technologies d'adaptation examinées, le dessalement de l'eau arrive en tête des technologies protégées en Afrique. D'autres technologies d'adaptation semblent cependant faire l'objet de demandes de brevets plus fréquentes en Afrique que dans le reste du monde, notamment celles concernant la résistance des réseaux de distribution d'électricité à des conditions météorologiques extrêmes, le traitement solaire de l'eau, la prévision d'épisodes météorologiques violents, et la collecte des eaux de pluie. Paradoxalement, très peu de brevets sont déposés dans des domaines tels que les cuisinières solaires, l'éclairage dans les régions reculées et le pompage solaire ou éolien alors que cela permettrait de répondre à certains des besoins environnementaux les plus critiques du continent.

Dans l'ensemble, il ressort de notre analyse que les technologies d'adaptation (davantage que les technologies d'atténuation) sont beaucoup plus susceptibles d'être protégées en Afrique subsaharienne et en Afrique du Nord qu'en Afrique du Sud. Ainsi, par rapport à d'autres technologies, une technologie d'adaptation est sept fois plus susceptible d'être brevetée en Afrique subsaharienne (zones ARIPO et

OAPI). Soulignons cependant que les inventions protégées, qu'il s'agisse de technologies d'atténuation ou d'adaptation, sont relativement peu nombreuses en Afrique, et que la propriété intellectuelle n'y dresse donc pas d'obstacle au transfert et à la diffusion des technologies.

Les technologies d'adaptation brevetées en Afrique proviennent essentiellement de pays de l'OCDE (à 76 %), les principaux inventeurs étant les États-Unis et l'Allemagne, suivis par l'Australie (9 %). La part du Japon et de la Corée demeure en revanche très faible. Les inventions africaines représentent quant à elles non moins de 17 % des inventions dans le domaine des technologies d'adaptation - soit bien plus que pour les technologies d'atténuation.

موجز تنفيذي

تعرض هذه الوقة بيانات مقارنة عن مجموعة مختارة من تكنولوجيات التخفيف من تغيّر المناخ والتكيّف مع تغير المناخ في السياق المتعلق بأفريقيا. وهذا التحليل مفيد لأنه يدخل في تشكيل السياسة الهادفة إلى التشجيع على نقل التكنولوجيا على الصعيد الدولي وتنمية قدرات الابتكار المحلية. وهي أيضاً تلقي الضوء على ما لدى بلداننا من إمكانات لتحقيق الأهداف الإنمائية.

وتعرض الورقة تحليلاً تفصيلياً لدور أفريقيا في تطوير هذه التكنولوجيات (الاختراع)، ثم تنتقل إلى بحث وضع أفريقيا باعتبارها سوقاً للتكنولوجيا (كما يتجلي في تسجيل براءات الاختراع). وبالإضافة إلى ذلك، فإننا نتناول بإيجاز مسألة تطوير التكنولوجيا عبر الحدود (الاختراع المشترك) في أفريقيا.

وإننا نقوم، قدر الإمكان، ببذل جهد لوضع البيانات المعنية في سياق أوسع قوامه الاتجاهات المتعلقة بتسجيل براءات الاختراع على وجه الإجمال. ويجب التأكيد على أنه ينبغي توخي الحرص عند تفسير بعض الاستنتاجات المعروضة هنا، لكون البيانات المتعلقة بالبلدان الأفريقية لا توجد بصورة متساوية. ومرة أخرى، فإننا نبذل جهوداً لتفسير هذه الاختلافات ولبناء مؤشرات ذات وضع عادي (بما في ذلك الميزة التكنولوجية النسبية والاتجاه النسبي المتعلق بالبراءات). وأخيراً، فإننا نقارن استنتاجاتنا بالمؤشرات القائمة على مصادر البيانات غير المتعلقة بالبراءات (الرقم القياسي للملكية الفكرية، وتدفقات التجارة، ومستويات الانبعاثات) بقدر توافر هذه البيانات بخصوص البلدان الأفريقية. ويلخص الفرع التالي الاستنتاجات الرئيسية التي تخلص إليها هذه الورقة.

تكنولوجيات التخفيف من تغير المناخ (تكنولوجيات التخفيف)
مكانة أفريقيا في مجال تطوير مجموعة مختارة من تكنولوجيات التخفيف

خلال الفترة 1980-2009، كانت توجد 657 براءة اختراع تتصل بتكنولوجيات التخفيف من تغيّر المناخ (تكنولوجيات التخفيف) يقيم مخترعوها في بلدان أفريقية. وأهم المجالات المعنية هي التكنولوجيات المتصلة بتخزين الطاقة وبالطاقة المتجددة. ومن غير المستغرب أن هذا لا يمثل سوى نزر يسير من الجهود العالمية – 0,4 في المائة في المتوسط أثناء الفترة 1980-2009. بيد أنه بالنظر إلى عدم تجانس القارة الأفريقية، فمن غير المستغرب أن بعض التكنولوجيات وبعض البلدان تبرز عن غيرها. فجنوب أفريقيا وحدها، بصورة خاصة، تمثل نصيباً مهيمناً (84٪) من الاختراعات في أفريقيا، تليها بلدان مثل مصر والجزائر والمغرب وكينيا.

وعلى الرغم من الحجم المنخفض للنشاط الاختراعي لأفريقيا بصورة عامة، فإنه موجه على نحو غير متناسب نحو تكنولوجيات التخفيف. وبصورة أكثر تحديداً، ففي حين أن النشاط الاختراعي الموجه نحو تكنولوجيات التخفيف لا يمثل سوى 1٪ من النشاط الاختراعي الإجمالي على نطاق العالم، فإنه يصل إلى 3٪ في أفريقيا. وهذا ينطبق خصوصاً على ميادين معينة مثل الوقود الأحيائي، والطاقة البحرية وطاقة المد والجزر، وتحويل النفايات إلى طاقة، والطاقة الحرارية الشمسية. وتمثل تكنولوجيا الطاقة النووية نصيباً هاماً من جهود الاختراع في أفريقيا. بيد أن ذلك يتركز بصورة حصرية في جنوب أفريقيا. وإلى جانب جنوب

أفريقيا (التي لها نشاط فعال على كثير من الجبهات)، تبرز أيضاً في هذا الصدد بلدان مثل غانا والجزائر والسنغال لأنها، بالمقارنة مع جهودها الإجمالية، لديها أعلى ميل إلى تطوير تكنولوجيات التخفيف.

ومن المثير للاهتمام أن نسبة مئوية صغيرة فقط من الاختراعات الأفريقية (10٪) تطلب حماية ببراءة اختراع في الأسواق الأفريقية – وهي حقيقة يمكن بطبيعة الحال أن تكون ذات صلة بقوة نظم حماية الملكية الفكرية. وفي الواقع، فإن المخترعين الأفارقة يطلبون في معظم الأحيان الحماية في الولاية القضائية لكل من أمريكا الشمالية (الولايات المتحدة: 27٪، وكندا: 10٪) وأوروبا (المكتب الأوروبي لبراءات الاختراع: 24٪، وألمانيا: 13٪). ومن الناحية الأخرى، يسعى أصحاب نسبة 6٪ من الاختراعات إلى الحصول على الحماية في الصين، و3٪ فقط في اليابان وكوريا.

أفريقيا كسوق لمجموعة مختارة من تكنولوجيات التخفيف من تغيّر المناخ

يُسجَّل في المكاتب الأفريقية للملكية الفكرية أقل بقليل من 3000 اختراع من اختراعات تكنولوجيات التخفيف من تغيّر المناخ. بيد أنه بالنظر إلى الطريقة التي تُحسب بها الأعداد، فإن هذه الأرقام تخضع لتأثيرات أكبر بكثير مما يحدث مع بيانات 'بلد الاختراع' بسبب أن تغطية المكاتب الأفريقية للملكية الفكرية في 'قاعدة البيانات الإحصائية لبراءات الاختراع'، التابعة للمكتب الأوروبي لبراءات الاختراع، بعيدة عن أن تكون شاملة.

وعلى وجه الإجمال، فإن نسبة تقل عن 1٪ من نشاط تسجيل براءات الاختراع المتصلة بالتخفيف على نطاق العالم تستهدف البلدان الأفريقية، التي تشكل جنوب أفريقيا السوق المهيمنة فيها، تليها المغرب ومصر. ومع ذلك، فمن المثير للاهتمام أن احتمال سعي المخترعين في العالم إلى التمتع بالحماية في أفريقيا يصبح احتمالاً أكبر حين تتصل هذه الاختراعات بتكنولوجيات التخفيف. وتبرز في هذا الصدد منطقة المنظمة الأفريقية للملكية الفكرية التي تشمل بلداناً كثيرة في أفريقيا الواقعة جنوب الصحراء الكبرى. وتكنولوجيات التخفيف التي يجري على نحو متواتر نسبياً تسجيلها ببراءات اختراع في أفريقيا تشمل الوقود الأحيائي، والطاقة النووية، واحتجاز الكربون وتخزينه، والطاقة البحرية وطاقة المد والجزر، والاحتراق الفعال، وتحويل النفايات إلى طاقة، والطاقة الحرارية الشمسية. ومما يبعث على الدهشة إلى حد ما أن وتيرة حماية تكنولوجيا الطاقة الكهرضوئية الشمسية في أفريقيا أقل نسبياً منها على نطاق العالم. أما تسجيل براءات الاختراع بشأن تكنولوجيات طاقة الريح، واحتجاز الكربون وتخزينه، والوقود الأحيائي فقد ظل ينمو بسرعة، في حين أن تسجيل البراءات بشأن تخزين الطاقة/خلايا الهيدروجين/خلايا الوقود والطاقة النووية والطاقة الحرارية الشمسية قد ظل يتناقص.

ما هو 'منشأ' الاختراعات التي تجري حمايتها في أفريقيا؟ هذه الاختراعات هي بشكل كاسح اختراعات استُحدثت في البلدان الأعضاء في منظمة التعاون والتنمية في الميدان الاقتصادي، ولم تتغير هذه الحقيقة تغيّراً يُعتد به على مر الوقت. بيد أنه في حين أن أكثر من نصف جميع الاختراعات المحمية ببراءات في أفريقيا كانت في الثمانينات من القرن العشرين ترجع في منشئها إلى بلدين اثنين فقط (الولايات المتحدة الأمريكية وفرنسا)، فإن نصيبهما قد تضاءل بشكل هام في العقد الأخير بالنظر إلى أن ألمانيا قد أصبحت أهم 'منشأ' في هذا الصدد. وفي الوقت نفسه، ازداد نصيب البلدان الأفريقية من أقل من 1٪ إلى أكثر من 8٪. أما نصيبا اليابان وكوريا فهما منخفضان للغاية.

التعاون الدولي في مجال تطوير تكنولوجيات التخفيف من تغيّر المناخ في أفريقيا

على وجه الإجمال، فإن نسبة 23٪ من الاختراعات الأفريقية في مجال تكنولوجيات التخفيف تنطوي على اختراع مشترك (أي ينتمي المخترعون إلى أكثر من بلد واحد). وهذا مقابل نسبة 12٪ للاختراعات المتصلة بالتخفيف المنطوية على اختراع مشترك على نطاق العالم، و9٪ من جميع الاختراعات (في جميع

الميادين) المنطوية على اختراع مشترك على نطاق العالم. ومن ثم، فإن تكنولوجيات التخفيف من تغيّر المناخ تتسم بمعدل اختراع مشترك أكبر بصورة عامة، ولكن ذلك هو الحالة بصورة خاصة في أفريقيا.

ومن المثير للاهتمام أن احتمال قيام جنوب أفريقيا بالاختراع المشترك مع بلدان أخرى في مجال استحداث تكنولوجيات التخفيف هو احتمال أقل، بالنظر إلى أنها تشغل مكانة المخترع الرئيسي في أفريقيا. والبلدان الأكثر احتمالاً لأن تدخل في اختراعات مشتركة مع غيرها تشمل تونس والمغرب ومصر وكينيا ومالي – وهي جميعاً تقوم مع مخترعين في بلدان أخرى بالاختراع المشترك لما نسبته 50٪ على الأقل من اختراعاتها. والبلدان الشريكة التي يُلجأ إليها على النحو الأكثر تواتراً من حيث الاختراع المشترك تشمل الولايات المتحدة الأمريكية، والمملكة المتحدة، وبلجيكا، وألمانيا، وفرنسا، والسويد، وكندا. ومن الغريب أنه لا توجد سوى أدلة ضئيلة على القيام باختراعات مشتركة داخل أفريقيا نفسها، باستثناء حالة واحدة موثقة (هي مصر-كينيا)، مما يشير إلى أن كل بلد أفريقي يشكل "جزيرة منعزلة" داخل القارة.

تكنولوجيات التكيّف مع تغيّر المناخ (تكنولوجيات التكيّف)

مكانة أفريقيا في مجال استحداث مجموعة مختارة من تكنولوجيات 'التكيّف'

تبحث هذه الورقة أيضاً مجموعة من التكنولوجيات الملائمة لتلبية الاحتياجات البيئية المحددة للبلدان الأفريقية (ويُشار إليها فيما يلي باسم 'تكنولوجيات التكيّف'). وأعداد هذه التكنولوجيات في حالة أفريقيا منخفضة بوجه عام بسبب الطبيعة المحددة نوعاً ما للمصادر. وخلال الفترة 1980-2009، كان يوجد ما مجموعه 56 تكنولوجيا من تكنولوجيات 'التكيّف' مع تغيّر المناخ. ومن بين تكنولوجيات 'التكيّف' التي بُحثت، اتضح أن النشاط الاختراعي في أفريقيا قد استهدف في معظمه تحلية مياه البحر (45٪)، يليها إمدادات الطاقة في الأماكن النائية (25٪)، والمعالجة الشمسية للمياه (14٪)، وتجميع مياه الأمطار (7٪)، وضخ المياه باستخدام الطاقة الشمسية/طاقة الرياح (7٪). ومن المثير للدهشة، في ضوء الموارد المتاحة والطلب المحتمل، أنه لا توجد اختراعات أفريقية في مجال الطهي الشمسي.

وعلى وجه الإجمال، ظل نصيب المخترعين الأفارقة في الجهود العالمية الرامية إلى تطوير تكنولوجيات التكيّف منخفضاً للغاية (0,26). وجنوب أفريقيا هي أهم بلد مخترع في أفريقيا ولكن هيمنتها أقل بروزاً في حالة تكنولوجيات التكيّف. ومن البلدان المخترعة الرئيسية الأخرى المغرب ومصر. ومن المثير للاهتمام أن نسبة مرتفعة جداً من اختراعات التكيّف الأفريقية تطلب الحماية في أفريقيا ذاتها (81٪) – وهي نسبة أعلى بكثير منها في حالة تكنولوجيات التخفيف.

أفريقيا كسوق لمجموعة مختارة من تكنولوجيات 'التكيّف' مع تغيّر المناخ (تكنولوجيات التكيّف)

يتمتع ما مجموعه 389 تكنولوجيا من 'تكنولوجيات التكيّف' بالحماية في المكاتب الأفريقية للملكية الفكرية، وتشكل تحلية مياه البحر أهم مجال في هذا الصدد. أما على نطاق العالم، ففي حين أن السوق الرئيسية لحماية براءات الاختراع بخصوص تكنولوجيات التكيّف هي أوروبا، فإن أهم سوق لتكنولوجيات التكيّف هي آسيا. ونصيب أفريقيا منخفض في الحالتين كلتيهما، إذ يبلغ على مستوى العالم 1٪ فقط من براءات الاختراع لتكنولوجيات التكيّف المسجَّلة لدى المكاتب الأفريقية لبراءات الاختراع. ومرة أخرى، فإن جنوب أفريقيا هي البلد الذي تُطلب فيه هذه الحماية لبراءات الاختراع أكثر من أي مكان آخر، رغم أن ذلك هو بدرجة أقل منه في حالة تكنولوجيات التخفيف. وعلى العكس من ذلك، فإن نصيب البلدان الواقعة جنوب الصحراء الكبرى أكبر.

ومن بين تكنولوجيات 'التكيّف' التي بُحثت، اتضح أن تحلية مياه البحر تشكل حتى الآن التكنولوجيا الرئيسية المتمتعة بحماية البراءات في أفريقيا. بيد أنه توجد عدة تكنولوجيات تكيّف أخرى تتمتع ،كاتجاه عام، بحماية أكبر نسبياً في أفريقيا منها في الأماكن الأخرى من العالم، بما في ذلك التكنولوجيات المتصلة بقدرة شبكة الإمداد بالكهرباء على التكيّف مع الأحداث المناخية المتطرفة، والمعالجة الشمسية للمياه، والتنبؤ بالطقس

الحاد، وتجميع مياه الأمطار. ومن المثير للدهشة نوعاً ما أنه لم تُسجَّل سوى قلة ضئيلة من برءات الاختراع في ميادين تبدو وثيقة الصلة إلى حد مرتفع بتلبية بعض أشد الاحتياجات البيئية في أفريقيا إلحاحاً، مثل الطهي الشمسي، والإنارة ذات الكفاءة للأماكن النائية، وضخ المياه باستخدام الطاقة الشمسية أو طاقة الرياح.

وعلى وجه الإجمال، يشير تحليلنا إلى أن تكنولوجيات التكيّف (وليس تكنولوجيات التخفيف) هي التي لديها احتمال لأن تتمتع بالحماية في أفريقيا الواقعة جنوب الصحراء الكبرى وشمال أفريقيا أكبر منه في جنوب أفريقيا. وعلى سبيل المثال فإن احتمال حماية تكنولوجيا التكيّف ببراءات اختراع، بالمقارنة مع التكنولوجيات الأخرى، هو أكبر بمقدار سبع مرات في أفريقيا الواقعة جنوب الصحراء الكبرى (منطقة المنظمة الإقليمية الأفريقية للملكية الفكرية ومنطقة المنظمة الأفريقية للملكية الفكرية). ومع ذلك، يجب التأكيد على أن عدداً صغيراً نسبياً من الاختراعات المتعلقة بالتخفيف والتكيّف يتمتع بالحماية في أفريقيا، مما يدل على أن حماية الملكية الفكرية ليست حاجزاً أمام نقل التكنولوجيا ونشرها.

وتكنولوجيات التكيّف المسجلة ببراءات اختراع في أفريقيا تعود في منشئها بدرجة كاسحة إلى بلدان منظمة التعاون والتنمية في الميدان الاقتصادي (76٪)، فتشكل الولايات المتحدة الأمريكية وألمانيا جهتي الاختراعات الرئيسيتين، تليهما استراليا (9٪). وعلى العكس من ذلك، فإن نصيب كل من اليابان وكوريا منخفض إلى أبعد حد. وتصل نسبة الاختراعات الخاصة بأفريقيا إلى 17٪ - وهو نصيب أعلى بكثير من مثيله المتعلق بتكنولوجيات التخفيف.

CLIMATE MITIGATION AND ADAPTATION IN AFRICA: EVIDENCE FROM PATENT DATA

1. Introduction

Encouraging international technology transfer and development of domestic innovation capacities in developing countries are of key importance to both climate change mitigation and adaptation efforts. Moreover, consideration of the broader development objectives in this context is equally important, and such objective may be complementary with the development of domestic climate mitigation and adaptation capacity.

Potential complementarity between mitigation, adaptation and development objectives is particularly important in Africa and the expected net benefits are high. First, with respect to mitigation efforts, the generally low level of sunk costs create a unique opportunity for investment in new energy generation capacities – a sector characterized by very long capital turnover cycles (see OECD 2012a).[1]

Second, the costs of adaptation are expected to be particularly high in Africa. Agrawala *et al.* (2010) estimate that Sub-Saharan Africa, together with the Indian sub-continent, are the two regions with the highest adaptation costs as a share of GDP.[2] In addition to the magnitude of expected damages, it has been suggested that the 'optimal' level of adaptation in Africa is high[3] because adaptation actions have the potential to be highly effective – both due to greater certainty over the direction of climate change impacts in Africa than elsewhere (e.g. more or less rain) as well as due to the nature of climate change impacts in Africa (e.g. less damages from extreme weather than elsewhere) (see Agrawala *et al.* 2010).[4]

Last, but not least, there is a high degree of complementarity between adaptation and development in Africa because adaptation efforts have the potential to contribute to climate-resilient development (OECD 2011; OECD 2009; Grantham Institute 2009).

This study builds on previous work conducted using patent data on a set of 'clean' energy technologies (see EPO/UNEP/ICTSD 2010; Haščič *et al.* 2010). These efforts were part of a broader stream of work to develop tagging algorithms to identify an extended set of mitigation technologies in the energy sector – the Y02 scheme (Veefkind *et al.* 2012). The present study contributes to this work in two major respects:

First, the study analyses patent data relating to the 'extended' set of mitigation technologies in the specific context of Africa. This alone is a significant undertaking because similar information of relevance to Africa is to date very limited.

[1] Moreover, there are indications that energy generation using renewable sources may be more cost-competitive in these countries despite the frequently lacking explicit support for renewables deployment. This is in contrast to the situation in many developed countries where conventional generation sources have to a great degree been subsidized, thus raising the bar for new entrants such as renewables.

[2] Conversely, countries such as Japan, USA and China "fall at the lower end of spectrum of adaptation costs as a % of GDP, although the costs in absolute terms can be substantial" (Agrawala *et al.* 2010).

[3] This means that adaptation in Africa implies a high benefit/cost ratio and a high level of benefits in general.

[4] It should also be noted that Sub-Saharan Africa is the region for which "the two regional models diverge with regard to the optimal mix of adaptation investments". This is due to the different treatment of investments in strengthening the underlying *public health infrastructure*, considered as a pre-requisite for adapting to these impacts (Agrawala *et al.* 2010).

Second, this study analyses brand-new data relating to a set of technologies of particular relevance to Africa.[5] This is an important step because it is the first time that analysis of patenting activity relating to such technologies is conducted.[6] In sum, the fields covered in this paper include:

Mitigation technologies (Y02-tags)

- Renewable energy
  - WIND
  - SOLAR PV
  - SOLAR THERMAL
  - GEOTHERMAL
  - MARINE & TIDAL
  - HYDRO CONVENTIONAL
- Combustion-related technologies
  - BIOFUELS
  - WASTE-TO-ENERGY
  - EFFICIENT COMBUSTION
  - CARBON CAPTURE AND STORAGE
- EFFICIENT ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION
- ENERGY STORAGE, HYDROGEN, FUEL CELLS
- NUCLEAR ENERGY
- OTHER Y02 NOT ELSEWHERE CLASSIFIED

Adaptation technologies (Z-tags)

- DESALINATION
- Off-grid water supply

[5] The specific components of the new tagging scheme related to developing countries (here referred to as "Z-tags") have been developed by a team of patent examiners at the European Patent Office, led by Javier Hurtado-Albir and Victor Veefkind.

[6] Agrawala *et al.* (2012) used patent data to analyse innovation in the area of adaptation-related agricultural biotechnology, in particular with respect to abiotic stress associated with climate change (drought, soil salinity and temperature extremes).

  - RAINWATER COLLECTION
  - WATERPUMP SOLAR_WIND
  - SOLAR WATER TREATMENT
    - SOLAR WATER TREATMENT – POTABILIZATION
- Dispersed electricity transmission
  - HIGH VOLTAGE DIRECT CURRENT
- Remote energy services
  - ENERGY SUPPLY – REMOTE
  - EFFICIENT LIGHTING – REMOTE
  - SOLAR COOKING
- Weather-related
  - RESILIENCE OF ELECTRICITY GRID
  - SEVERE WEATHER PREDICTION

However, it must be borne in mind that the data presented are based upon information provided only by a sub-set of African intellectual property authorities (IP offices). While data for the most important African IP offices is available and presented here, the analysis in this paper is nevertheless biased by this shortcoming (particularly with respect to market protection). Implications for the invention and co-invention data presented are less acute since some of this information can be obtained indirectly through other IP offices.

In what follows, Section 2 briefly discusses the methodology adopted to conduct the analysis. This is followed by two substantive sections – Section 3 presents analysis of patenting activity in mitigation technologies in the energy sector (Y02 tags), while Section 4 presents analysis of selected fields related to adaptation (new Z-tags). In both cases, we first discuss the role of Africa in development of these technologies (invention), and then move on to examine Africa as a technology market (as reflected in patenting). We also briefly touch upon the question of cross-border technology development (co-invention). Section 5 concludes the paper.

2. Methodology

2.1. Geographic scope

In addition to considering Africa as a whole, analysis is conducted at a more disaggregated level where adequate data is available, including at the level of sub-regions:

a) *Northern Africa* (Morocco, Algeria, Tunisia, Libya, Egypt);

b) South Africa;

c) *Sub-Saharan Africa* (remaining countries, including the OAPI and ARIPO regions).

2.2. Patent search strategies

Concerning mitigation technologies, relevant patent documents were identified using the recently-developed classes Y02C and Y02E of the ECLA that classify patent documents in selected climate change mitigation technologies related to energy supply (see Annex A).

However, given the rather limited volume of patents related to Africa, presenting the data at a highly disaggregated level is often meaningless. Instead, in this study the data is presented at a somewhat aggregated level – for 14 technological fields that are both sufficiently 'thick' and meaningful for policy-makers.

In many respects, the Y02-tags have been designed around developed countries' technological priorities. As such, many of the technologies identified may not be fully 'appropriate' in the developing country context. And while Africa's economies are rather economically heterogeneous, the results of this analysis confirm that the above presumption is largely true.

As a complement, Section 4 presents data on technologies that may be appropriate to meet the specific needs of African countries – including those relevant to climate change adaptation as well as mitigation of specific environmental needs. For simplicity, we refer to them as 'adaptation' technologies. See Annex B for the description of the fields.[7] Although this is clearly a very restricted set of technologies, it is a first and important step.

2.3. Construction of patent statistics

In both cases, the data is analysed by examining the country of the inventor(s), country of the applicant (patentee), and application authority (patent office). While in much of the previous work by authors of this paper a case was made for using 'claimed priorities' (as opposed to 'singular' priorities) as an indicator of inventive activity, in this study we do not make this distinction due to the very limited volume of inventive activity in Africa. We use all priority applications (incl. both singular and claimed priorities) to measure the number of patented inventions.

In addition, we use duplicate applications to analyse patenting activity of African inventors abroad, or of foreign inventors in Africa. In all cases, we construct counts of patent applications (i.e. registered by the patent system but not necessarily valid patents).

Overall, we identified 580154 patent applications tagged using the Y02 scheme (Annex A2), of which there were 2804 applications registered with an African patent office (Annex A5), and 657 African priorities (Annex A3; single-priority patent families with an African inventor) during 1980 to 2009. We found no patent family members of these documents in PATSTAT that would not be Y-tagged.

We then identified the patent applications that have been tagged using the new Z scheme, and searched for any family members that share the same priority but may not have been 'Z-tagged'. The benefit of such 'expansion' is about 15%. This is not surprising given that the exploratory tags have not yet been fully integrated into PATSTAT. Overall, we identified 47108 patent applications relevant to the Z scheme (Annex B2), of which there were 389 applications registered with an African patent office (Annex B5), and 56 African priorities (Annex B3; single-priority patent families with an African inventor) during 1980 to 2009.

[7] The scheme has been developed by a team of patent examiners at the European Patent Office, lead by Javier Hurtado-Albir and Victor Veefkind.

2.4. Caveats and limitations

As noted in the Introduction, it is important to emphasise that the results presented in this study should be interpreted in the context of the 'idiosyncrasies' of PATSTAT, in particular with respect to the unequal coverage of countries over time. While country coverage is an important piece of information in general, it is particularly so with respect to Africa. In fact, there are only six patent authorities for which PATSTAT includes recent (post-2000) data, with four other authorities covered only partially (Table 1).

This has only a limited effect on our ability to identify inventions that have sought protection overseas (at an office that is covered in PATSTAT) or priority documents that have first sought protection in Africa and subsequently overseas ('claimed priorities'), because we can impute inventor information from other members of the same patent family. However, it does compromise our ability to identify inventions that have sought protection solely at African authorities (singulars) or duplicate applications of foreign patents registered with African authorities. We make efforts to qualify the findings presented here by comparing the trends in mitigation/adaptation with overall trends – measured as "PATSTAT TOTAL" counts that reflect the actual coverage of PATSTAT database.

Table 1. Coverage of data from African patent offices in PATSTAT

Authority		From	Until	Nb. of years covered 1980-2009
ZA	South Africa	1971	2010	30
EG	Egypt	1976	2011	30
AP	ARIPO [8]	1984	2011	26
MA	Morocco	1993	2011	17
OA	OAPI [9]	1992	2007	16
ZW	Zimbabwe	1980	1995	16
ZM	Zambia	1968	1994	15
MW	Malawi	1973	1994	15
KE	Kenya	1975	1989	10
DZ	Algeria	2002	2005	4

Source: EPO (2011b).

3. Patenting activity in selected mitigation technologies (Y02)

3.1. The place of Africa in technology development

Figure 1 gives the breakdown of inventive activity in Africa throughout the period 1980-2009. For presentational purposes, we aggregate the 14 technological fields into somewhat broader five major

[8] **The African Regional Intellectual Property Organisation (ARIPO)** has 17 Member States, including: Botswana, Gambia, Ghana, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, Sierra Leone, Somalia, Sudan, Swaziland, Uganda, Tanzania, Zambia and Zimbabwe.

[9] **The African Intellectual Property Organisation (OAPI)** has 15 Member States, including: Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Gabon, Guinea, Guinea-Bissau, Mali, Mauritania, Niger, Senegal, Togo.

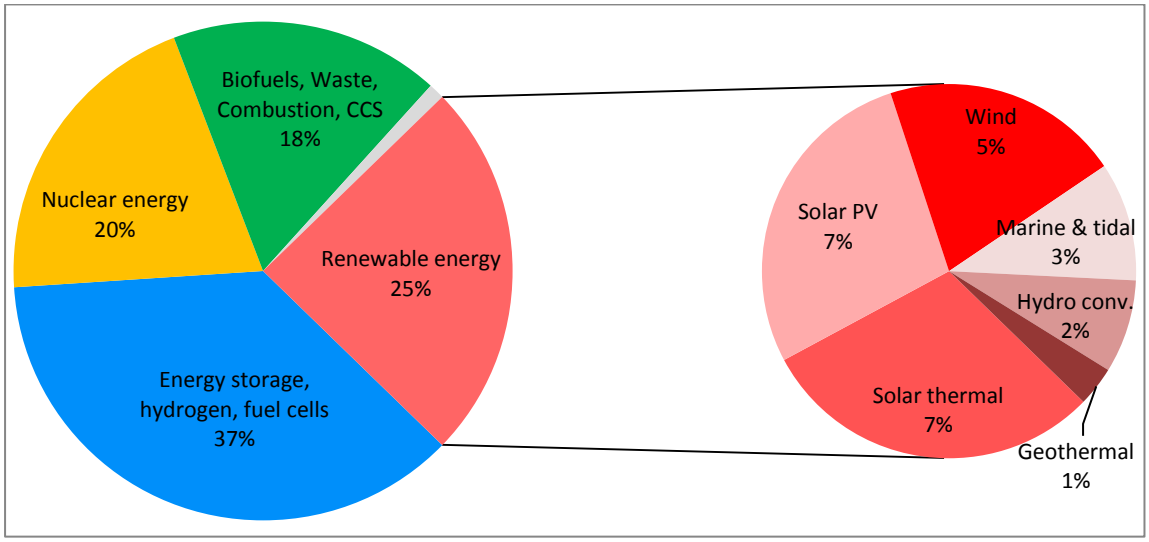
categories. The Figure shows that most inventive activity occurs in energy_storage/hydrogen/fuel_cell technologies (37%) and renewable energy (25%), in particular solar PV and solar thermal. This is followed by nuclear energy (20%) and biomass/waste/combustion/CCS technologies (18%), especially biofuels. Invention in efficient electricity generation/transmission/distribution is of marginal importance in Africa.

To put these figures in context, while in Africa biofuels account for 6.4% of its Y02 inventions (and 0.19% of all its patented inventions, in any field), worldwide the corresponding ratios would be 3.4% (and 0.036%). Hence, we can conclude that among all the Y02 mitigation technologies, Africa's inventive output in biofuels is relatively more important than what we observe worldwide. Other Y02 mitigation technologies that are relatively frequently invented in Africa are nuclear, marine & tidal, and energy from waste. On the other hand, solar PV is relatively less frequently developed in Africa than it is in the rest of the world (ROW). Inventive activity in wind and combustion technologies is of approximately the same importance as what we observe worldwide.

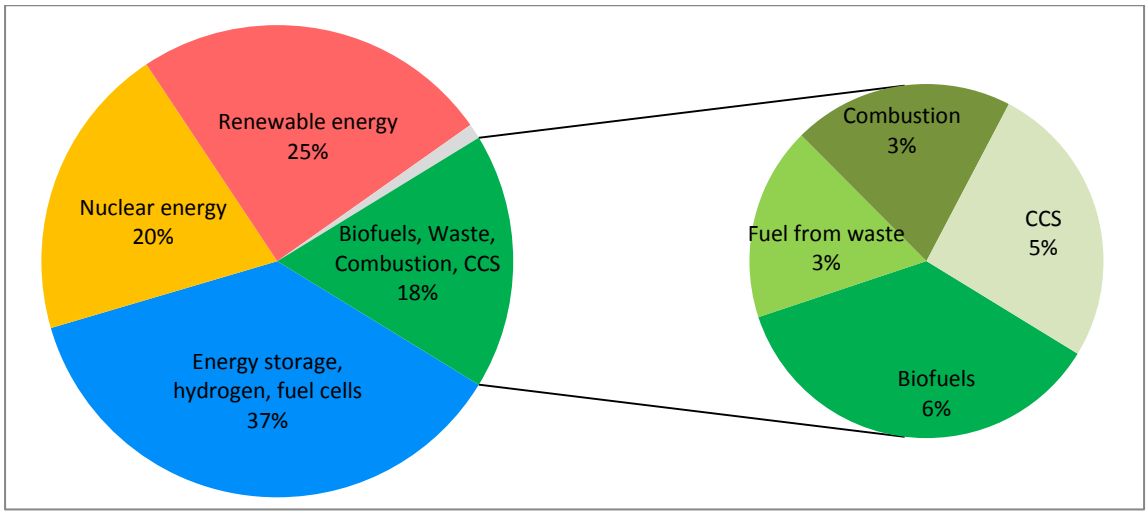
Figure 1. Inventive Activity in Africa: 1980-2009

(Selected mitigation technologies - Y02; Number of priorities)

a.



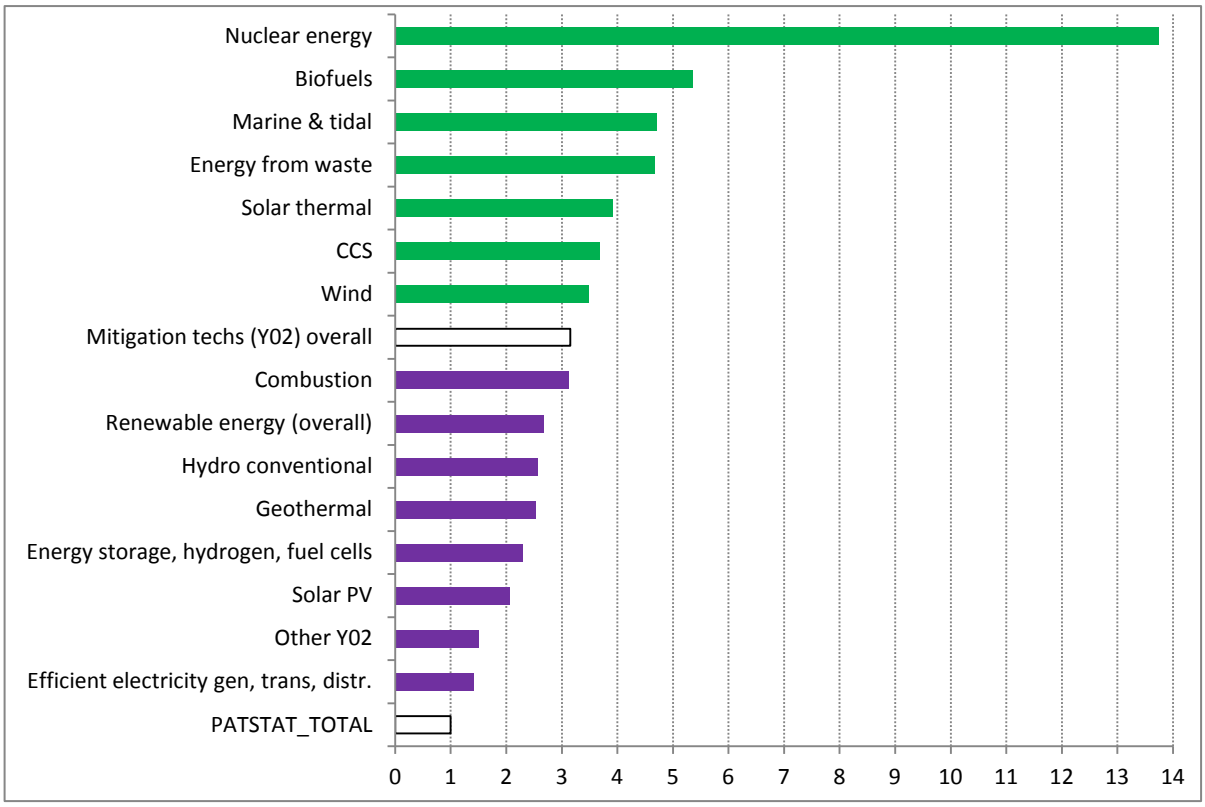
b.



Another way to assess Africa's inventive capacity is in terms of its **relative technological advantage (RTA)** in the various technologies, calculated as the share of Y02 priorities to TOTAL priorities in Africa versus worldwide, or as Africa's share of Y02 priorities worldwide compared to its share of TOTAL priorities. Hence, an RTA=1 indicates that the number of inventions in Africa relative to its overall number of inventions, is about the same as world average. An RTA>1 indicates that Africa invents relatively more in a given field than is the case for other regions of the world. For example, while invention in mitigation technologies (Y02) represents 3% of Africa's overall inventive activity this compares with only 1% worldwide, hence the RTA=3 (Figure 2). The ranking of the individual fields is the same as discussed above. Interestingly, all 14 mitigation fields examined have RTA>1. This means that despite Africa's generally low volume of inventive activity, it is disproportionately directed towards Y02 technologies!

Figure 2. Advantage of Africa versus World

(Share of Y02 priorities to TOTAL priorities in Africa versus worldwide, 1980-2009)



In terms of average growth rates between 1980 and 2009, while worldwide the number of inventions (priorities) in all technologies (TOTAL) has increased by 4% on average, it grew by 5% in Y02 fields. In Africa, not only has inventive activity overall (TOTAL) increased faster (9%), but Y02 activity grew by an extraordinary 59%, on average (Table 2).

Table 2. Average Annual Growth Rate in Inventive Activity: 1980-2008

	Africa	World
Mitigation technologies (Y02)	59%	5%
All technologies (PATSTAT_TOTAL)	9%	4%

Over time, inventive activity in Africa shows some rather surprising patterns. Two observations are noteworthy: First, development of nuclear energy technologies is startling, both in terms of relative volume of invention as well as in terms of its timing – with a spike of activity in early 2000s (Figure 3). This is in stark contrast with global trends which suggest a decreasing pattern over time (Figure 4). Second, another difference relative to the rest of the world is a strong performance of energy storage/hydrogen/fuel cell technologies in Africa between mid-1980s and mid-1990s. Finally, invention in renewable energy and in biomass/waste/combustion/CCS technologies have grown sharply in Africa in the last decade, trends that are similar to those observed globally.

Figure 3. Inventive Activity in Africa

(Selected mitigation technologies - Y02; Number of priorities, 3-year moving average)

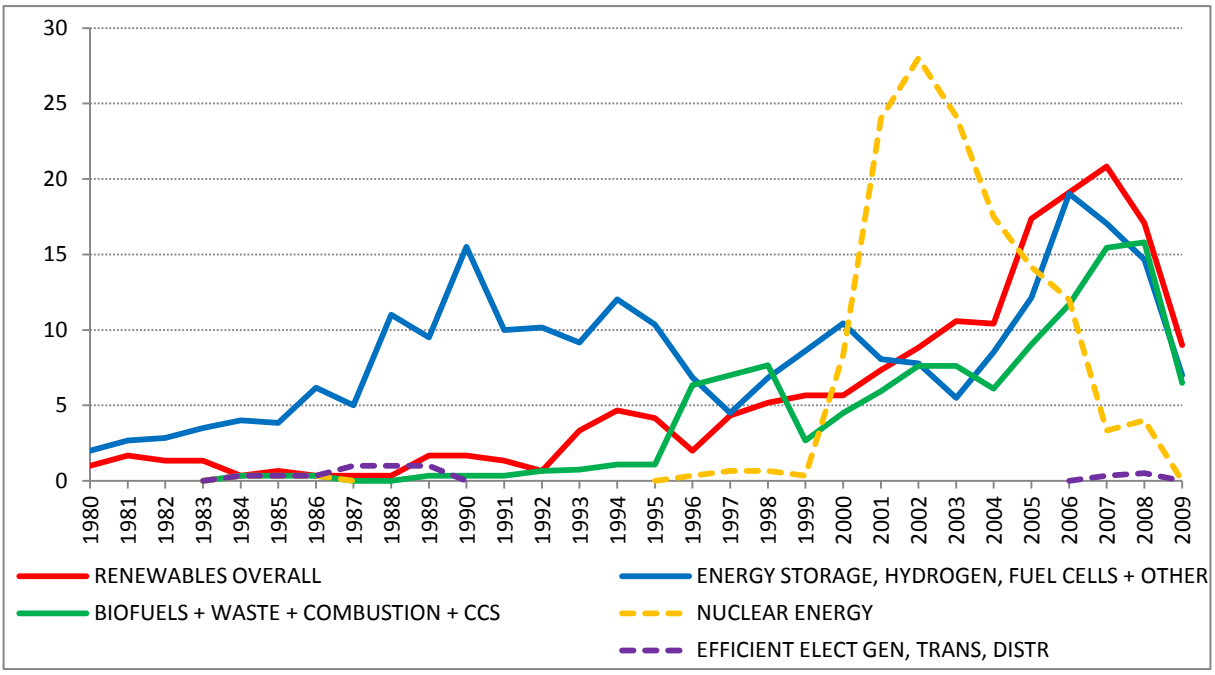
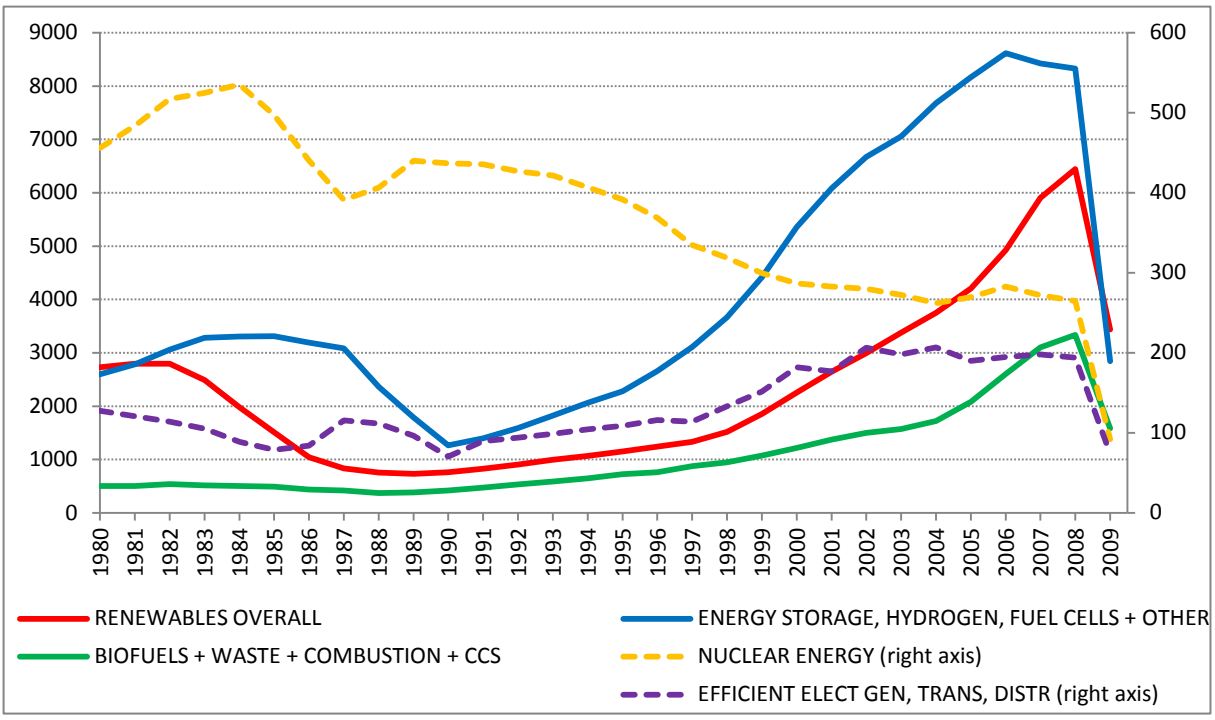


Figure 4. Inventive Activity Worldwide

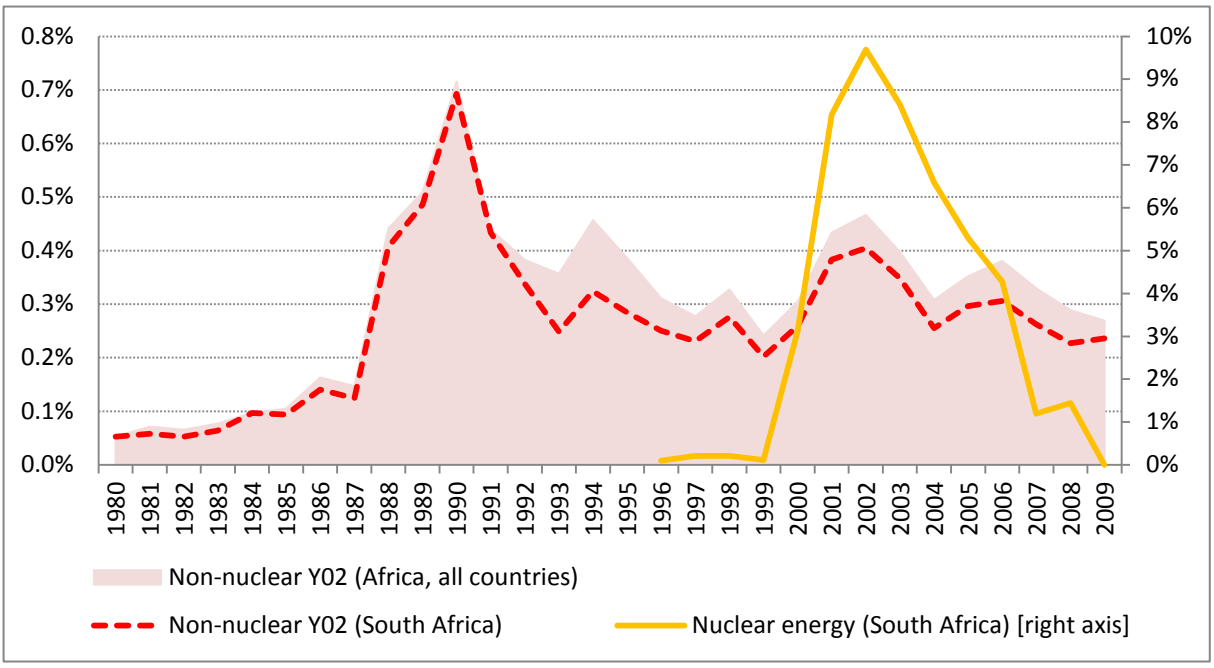
(Selected mitigation technologies - Y02; Number of priorities, 3-year moving average)



It must be re-emphasised that the volume of inventive activity in Africa represents only a fraction of the global efforts – 0.3% on average during 1980-2009 for all Y02 technologies. However, given the heterogeneity of the African continent, it is not surprising that some technologies and some countries stand out. In particular, South Africa represents an overwhelming share of Africa's inventions. Moreover, it is the only African country active in nuclear energy technology development (shown on right-hand scale in Figure 5).[10]

Figure 5. Share of World's Inventions with African Inventor

(Y02 mitigation techs, number of priorities, 3-year moving average)



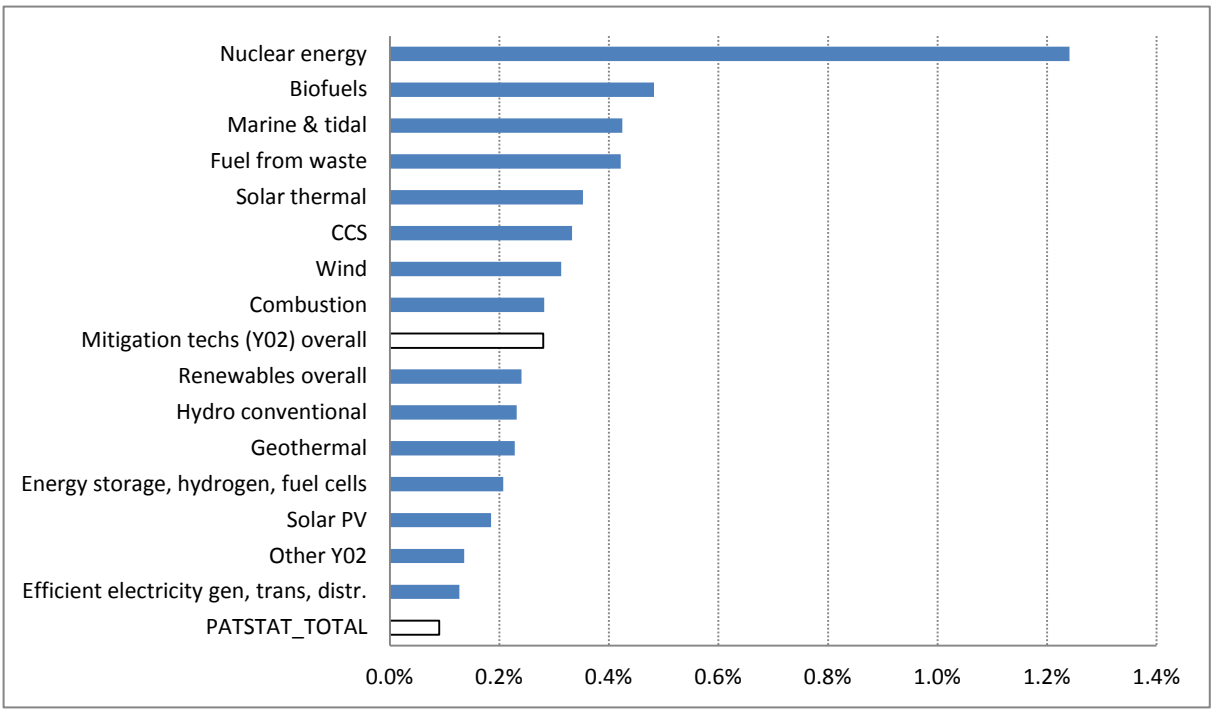
Note: For the period 1980-2009, and for all Y02 technologies, Africa's share is 0.28% on average, of which South Africa represents 0.24%, Northern Africa 0.02% and Sub-Saharan Africa equally 0.02%.

[10] To be precise, Egypt also has one nuclear patent.

Apart from nuclear energy, Africa has a relatively strong position in all Y02 fields (relative to Africa's position in other technologies) – most notably in biofuels, marine/tidal, and energy from waste (Figure 6).

Figure 6. Share of World's Inventions with African Inventor: 1980-2009

(Y02 mitigation techs, number of priorities)



South Africa alone is responsible for an overwhelming share (84%) of Africa's inventions in mitigation (Y02) technologies. Other inventor countries include Egypt, Algeria, Morocco and Kenya (Table 3). The volume of inventions allows South Africa to achieve a rather diversified "invention portfolio" – with a significant activity in energy storage/hydrogen/fuel cells, alongside with nuclear energy and renewables. This is in contrast to other major African inventor countries that have a less diversified portfolio and are active primarily in renewables.

Overall, South Africa ranks first amongst African countries in 12 out of the 14 fields studied, the exception being geothermal energy (Burundi) and "other Y02" technologies (Morocco) (Table 4). Detailed data on invention activity is available in Annex A3.

Table 3. Major African Inventor Countries: 1980-2009

(Y02 mitigation techs, number of priorities)

	Count	%	Invention portfolio
South Africa	553.3	84.2%	Energy storage, hydrogen, fuel cells (40%), Nuclear (25%), Renewables (19%)
Egypt	18.5	2.8%	Renewables (70%, esp. marine & tidal, hydro conv., solar), Energy storage, hydrogen, fuel cells (21%)
Algeria	12.2	1.9%	Renewables (66%, esp. solar thermal & PV), Energy storage, hydrogen, fuel cells (18%), CCS (16%)
Morocco	11.7	1.8%	Renewables (54%, esp. solar, wind, hydro conv.), Energy storage, hydrogen, fuel cells (50%)
Kenya	7.7	1.2%	Biofuels + Energy from waste (65%), Energy storage, hydrogen, fuel cells (28%)
Ghana	6.3	1.0%	Renewables (96%, esp. wind, marine & tidal)
Burundi	6.0	0.9%	Renewables (100%, esp. wind, solar thermal, geothermal)
Mali	4.5	0.7%	
Senegal	4.0	0.6%	
Zimbabwe	4.0	0.6%	
Tunisia	3.8	0.6%	
Rest of Africa	25.5	3.9%	
Africa Total	657	100%	

Note: The % shares in portfolio may sum to more than 100% because a single invention may be classified in more than one field.

Table 4. Major African inventor countries (1980-2009), by field

Field	Inventor country
Renewables overall	South Africa (63%), Egypt (8%)
Wind	South Africa (53%), Burundi (14%), Ghana (14%), Morocco (7%)
Solar PV	South Africa (72%), Algeria (14%)
Solar thermal	South Africa (46%), Algeria (13%), Burundi (10%), Morocco (6.5%), Senegal (6.5%)
Geothermal	Burundi (71%), Côte d'Ivoire (14%), Libya (14%)
Marine & tidal	South Africa (67%), Egypt (19%), Mauritius (9.5%)
Hydro conv.	South Africa (61%), Egypt (18%), Morocco (12%), Cameroon (6%)
Biofuels	South Africa (74%), Kenya (12%)
Energy from waste	South Africa (62%), Kenya (24%), Mali (9.5%)
Combustion	South Africa (99%)
CCS	South Africa (87%), Algeria (6.5%)
Nuclear energy	South Africa (99%)
Efficient electricity gen, trans, distr.	South Africa (80%), Morocco (20%)
Energy storage, hydrogen, fuel cells	South Africa (89%)
Other Y02	Morocco (100%)
All Y02	South Africa (77%)

To put these figures in context, South Africa's patented inventions (single-priority patent families) account for about 0.33% of the worldwide stock of inventions in mitigation technologies, that is more than twice as much as for all technology fields taken together (0.15%) (Table 5). The corresponding figures for Africa as a whole are 0.39% and 0.18%. This means that African inventors have a 'relative technological advantage' (RTA) in mitigation technologies because they are more likely to develop mitigation technologies than an 'average' technology (shown as 0.39/0.18=2.2 in Figure 7). Countries such as Ghana, Algeria and Senegal have the highest RTA in mitigation technologies. These figures are also shown in Map 1.

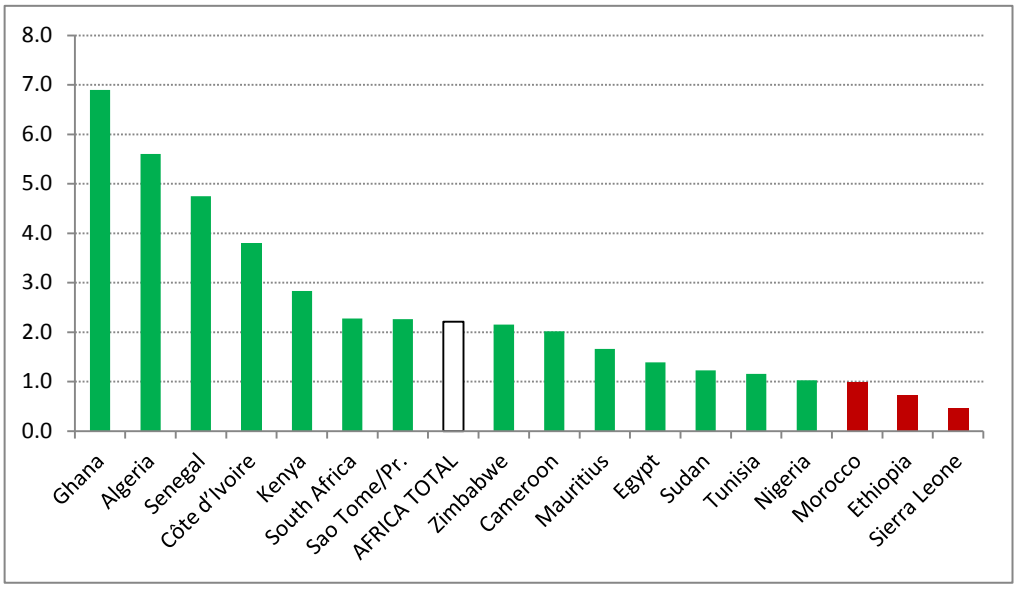
Table 5. The share of world's inventions that originate in Africa: 1980-2009

(Number of priorities with African inventor divided by number of priorities worldwide)

Inventor country	Y02 priorities	TOTAL priorities
South Africa	0.33%	0.15%
Egypt	0.01%	0.01%
Algeria	0.01%	0.00%
Morocco	0.01%	0.01%
Kenya	0.00%	0.00%
Africa total	0.39%	0.18%

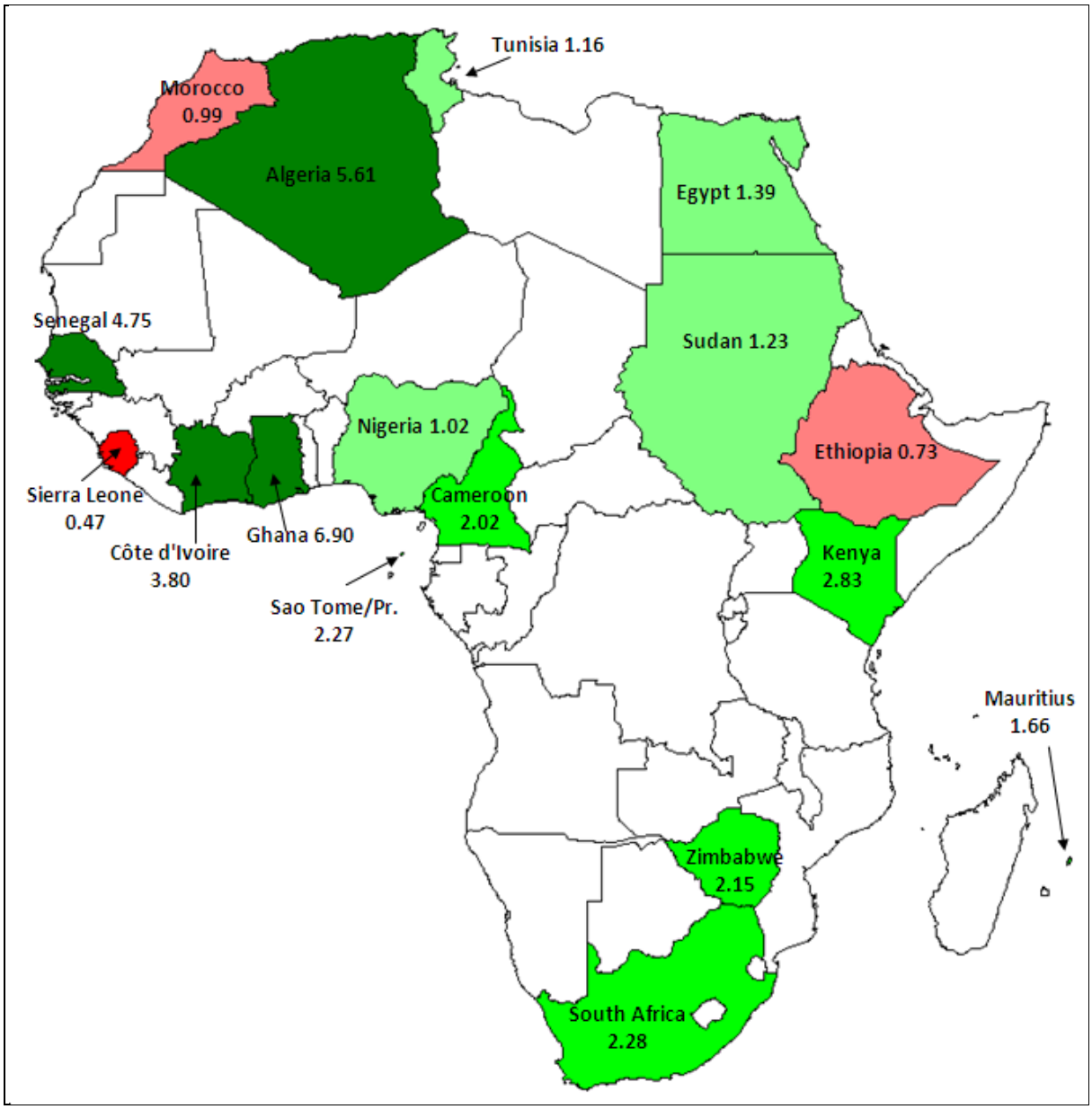
Figure 7. Relative Technological Advantage of African Countries

(Country's share of Y02 priorities worldwide compared to its share of TOTAL priorities, 1980-2009)



Map 1. Relative Technological Advantage of Africa

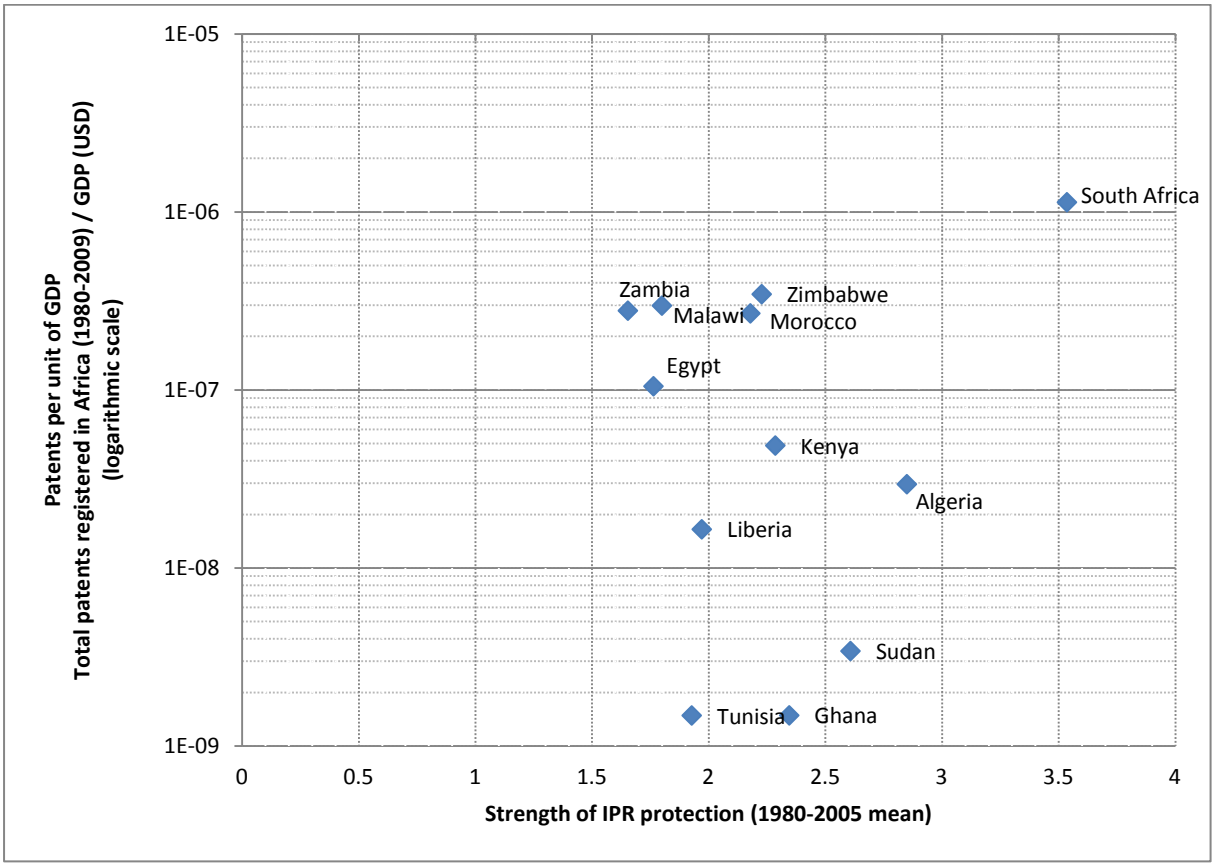
(Mitigation Technologies – Y02)



Note: The map shows countries with a minimum of 50 patent priorities in total (PATSTAT_TOTAL). This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries.

It is interesting that for only a small percentage of African inventions (10%) protection is sought in Africa. This may, of course, have something to do with the strength of IP regimes. In Figure 8 total patent counts per unit of GDP (1980-2009) are juxtaposed with the strength of intellectual property rights regimes.[11] There is a positive correlation overall but this is entirely due to the observation for South Africa; issues of data availability from many offices mean that great caution should be exercised in interpretation (see Section 2.4).

Figure 8. Total Patent Applications per GDP (1980-2009) and Strength of IP Regime



In fact, rather than in Africa, African innovators seek protection more often in the United States (27%), the EPO (24%), Germany (13%) and Canada (10%). On the other hand, only 6% of inventions seek protection in China and only 3% in Japan and Korea (Table 6). It is interesting to compare these figures with those for world's Y02 priorities. For example, while 14% of African Y02 inventions seek protection at the EPO, there would be as many as 22% of world's Y02 inventions that would do so. African Y02 inventors are thus less likely to seek protection at the EPO than the average world inventor. Perhaps the most striking is the difference for Japan and WIPO. However, it should be born in mind that we miss much African office data (see Section 2.4).

[11] The Ginarte-Park Index of Patent Rights (2005). For a discussion of the derivation of the index see Ginarte and Park (1997). See also Park and Lippoldt (2008) for the underlying data.

Table 6. Markets where protection for African inventions is sought: 1980-2009

(Selected mitigation technologies – Y02 tags)

Application authority (patent office)	African priorities	World priorities
United States	27%	41%
International Bureau of WIPO	15%	1%
European Patent Office (EPO)	14%	22%
Germany	13%	19%
Canada	10%	8%
China	6%	10%
South Africa	**5%**	**1%**
Austria	5%	3%
Korea	3%	6%
United Kingdom	3%	3%
Japan	3%	33%
Australia	2.3%	7%
African Intellectual Property Organization (OAPI)	**2.3%**	**0.1%**
Spain	1.9%	2.7%
Mexico	1.8%	1.1%
Egypt	**1.3%**	**0.05%**
Denmark	0.9%	1.3%
Norway	0.9%	1.0%
Morocco	**0.8%**	**0.1%**
Russia	0.7%	1.0%
Chinese Taipei	0.6%	1.3%
France	0.6%	4%
Eurasian Patent Organization (EAPO)	0.5%	0.2%
African Regional Industrial Property Org. (ARIPO)	**0.5%**	**0.01%**
Algeria	**0.3%**	**0.01%**
ROW	3%	10%
AFRICA OVERALL (all patent offices)	**10%**	**1.2%**

Note: The values sum here to more than 100% because an invention may seek protection in more than one jurisdiction, or through alternative routes (e.g. regional or international route).

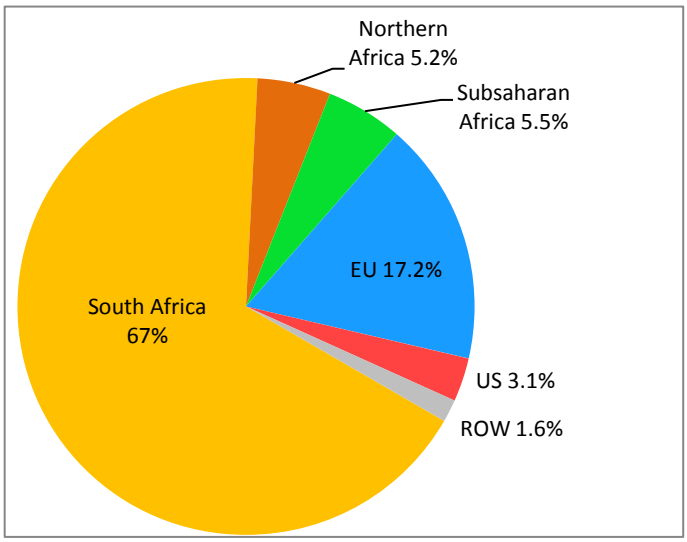
These patterns vary somewhat across different technological fields, but the US and the EPO remain the most frequent jurisdictions where patent protection for African inventions is sought. Other interesting cases include, for example, 9% of African priorities in wind energy and 11% in solar thermal seek protection in South Africa, solar thermal at OAPI (11% of African priorities), biofuels in Canada (11%), CCS in the UK and Norway (13 and 10%, respectively), energy storage/hydrogen/fuel cells in Germany and Canada (24% and 13%, respectively), and nuclear energy in China and Canada (12% in both cases). Detailed data on patenting activity by African countries is included in Annex A4.

Who 'owns' inventions originating in Africa? Not surprisingly, South Africa is the most important 'applicant country'. Overall, as many as 78% of African inventions (that is, patent families with priority in Africa) have been patented by applicants residing in Africa, including countries of northern Africa (esp. Algeria and Egypt) and Sub-Saharan Africa (Figure 9a). This share has increased to 87% in the last decade (Figure 9b). While historically countries of the European Union have accounted for much of remainder

(esp. Luxembourg), their share has decreased recently (with Belgium as the major applicant). This slack has been largely picked up by South Africans.[12]

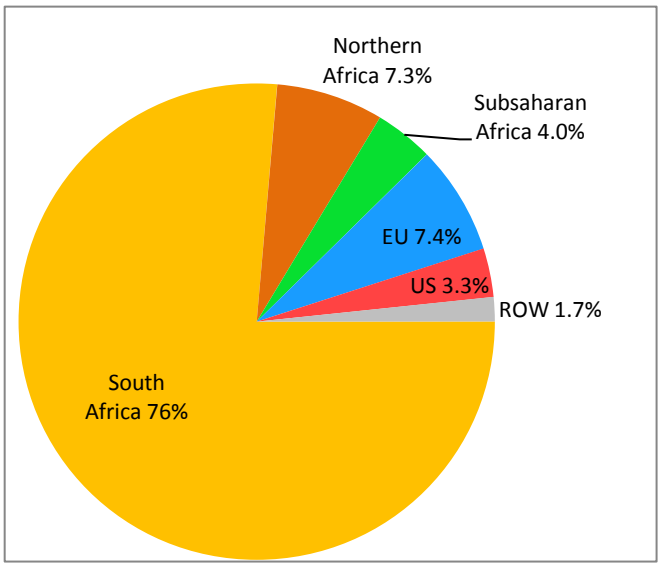
Figure 9. Ownership of African Inventions

(Selected mitigation technologies, Y02)



Note: Based on a total of 599 inventions during 1980-2009 for which the country of both the inventor and the applicant is known.

b. 2000-2009



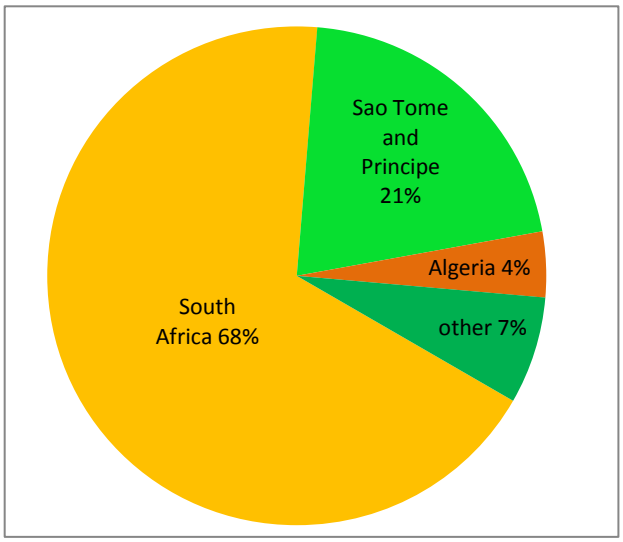
Note: Based on a total of 392 inventions during 2000-2009 for which the country of both the inventor and the applicant is known.

12 It should be noted that it is rather rare that applicant data be available for these applications. As such, these figures should be taken "with a grain of salt". This is in contrast to data on inventors (and co-invention) that is much more complete (where possible, we have imputed missing inventor data using information on other patent family members). Such imputation is not possible for applicants.

Conversely, when it comes to African ownership of foreign (that is, non-African) inventions, the major applicant country is South Africa, followed by Sao Tome and Principe and Algeria (Figure 10). Tax incentives may well play a role in explaining this distribution.

Figure 10. African Ownership of Foreign (Non-African) Inventions: 1980-2009

(Selected mitigation technologies, Y02)



Note: Based on a total of 118 inventions during 1980-2009 for which the country of both the inventor and the applicant is known.

Finally, Table 7 gives the most active African applicants (protecting African or non-African priorities). The list is dominated by South African patentees.

Table 7. Top African Patentees, Protecting Anywhere in the World: 1980-2009

(Country of the applicant; selected mitigation technologies Y02)

Standardized name	Country	Nb. of applications
PEBBLE BED MODULAR REACTOR	South Africa	74
TECHNOLOGY FINANCE CORPORATION	South Africa	24
SOUTH AFRICAN INVENTION DEV CORP	South Africa	22
SASOL TECHNOLOGY	South Africa	18
ESKOM	South Africa	15
FITTER JOHAN C.	South Africa	15
UNIVERSITY OF JOHANNESBURG	South Africa	11
ANGLO AMERICAN RESEARCH LABORATORIES	South Africa	8
STUDIENGESELLSCHAFT FUER ENERGIESPEICHER UND ANTRIEBSSYSTEME (SEA)	Sao Tome and Principe	7
GRINAKER EQUIPMENT CO	South Africa	6
UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG	South Africa	6
HIGHVELD STEEL AND VANADIUM CORPORATION	South Africa	5
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR)	South Africa	5
DE BEERS INDUSTRIAL DIAMOND DIVISION	South Africa	5
HYDROX HOLDINGS	South Africa	5
HUMAN JAN PETRUS	South Africa	4
MERLIN GERIN	South Africa	4
BHP BILLITON	South Africa	4
MEYER THOMAS JOHN	South Africa	3
O CONNOR GAVIN PAUL	South Africa	3
NASS HELMUT KARL	South Africa	3
EVANS BRIAN ANTHONY	South Africa	3
ELEMENT SIX	South Africa	3
AZAR JOHN	Burundi	3
HIHI BACHIR	Algeria	3
BRITS GAVIN JOHN	South Africa	3
Grand total (with known applicant country)		512

Note: Applicant names have been standardized and cleaned manually. (The HAN concordance does not cover African applicants.) Applicant's country is only indicative.

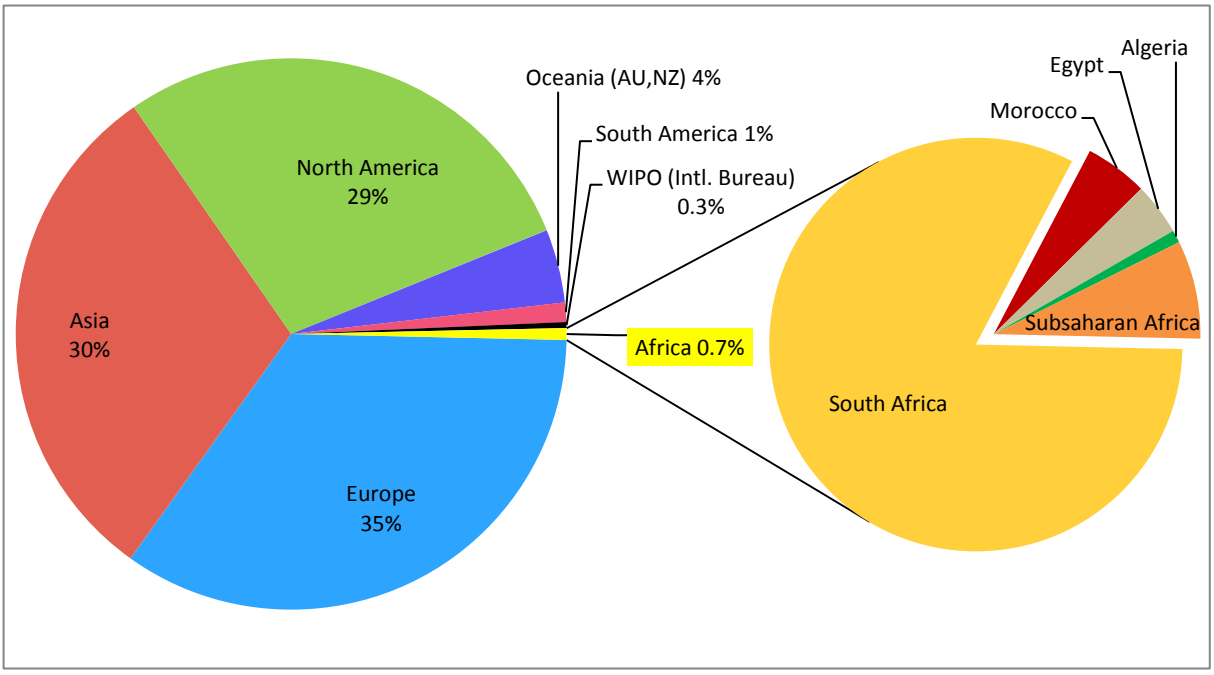
3.2. Africa as a market for technology

Figure 4 above shows inventive activity worldwide in selected mitigation technologies. This section examines to what extent innovators seek protection for these inventions in Africa. Overall, less than 1% of Y02 patenting activity worldwide targets African countries, of which South Africa is the dominant market. Other major markets include Morocco and Egypt (Figure 11). However, while the available data indicate a very low propensity to protect inventions in Africa, this conclusion must be qualified in the light of PATSTAT's coverage (see Section 2.4).

Nevertheless, while 0.7% of world's patent applications in mitigation technologies (Y02) registered at one of African patent offices is low, it is higher than the propensity to patent in Africa for all technologies overall (TOTAL) which is less than 0.5%.

Figure 11. Patenting Activity across Different Continents (1980-2009)

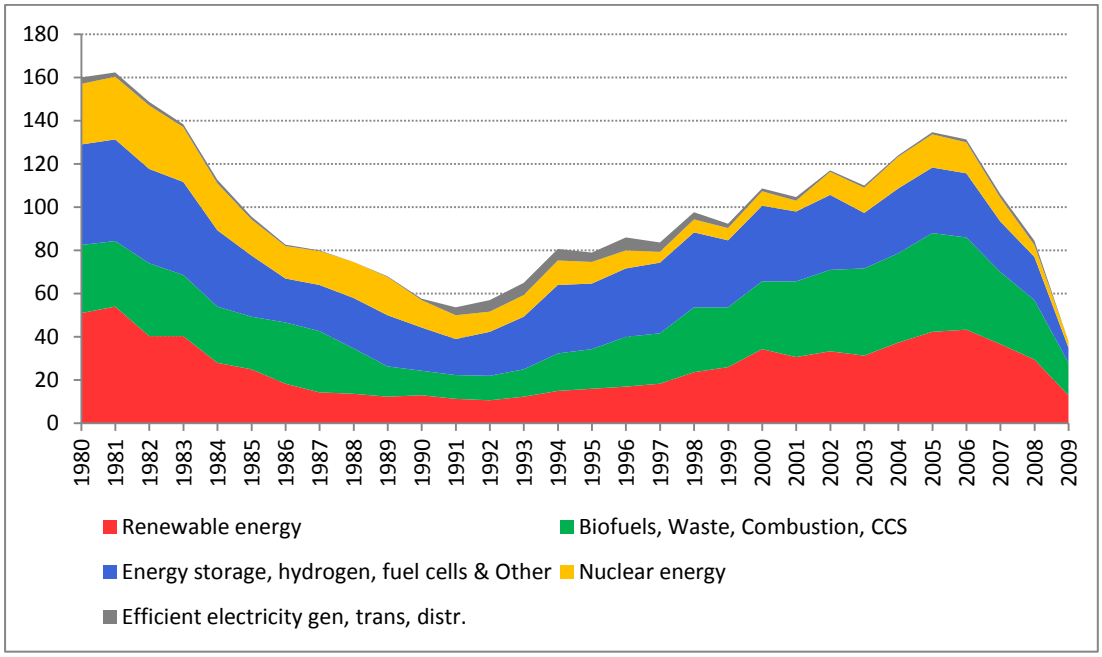
(Selected mitigation technologies – Y02, by application authority)



During the last 30 years, there has been a considerable variation in Y02 patenting activity in Africa, starting from a high of 166 patent applications in 1982 to a low of 45 applications only ten years later in 1992. Since then patenting has increased again. Interestingly, these variations seem to have little to do with a specific technological field, and rather seem to be a general phenomenon (Figure 12).

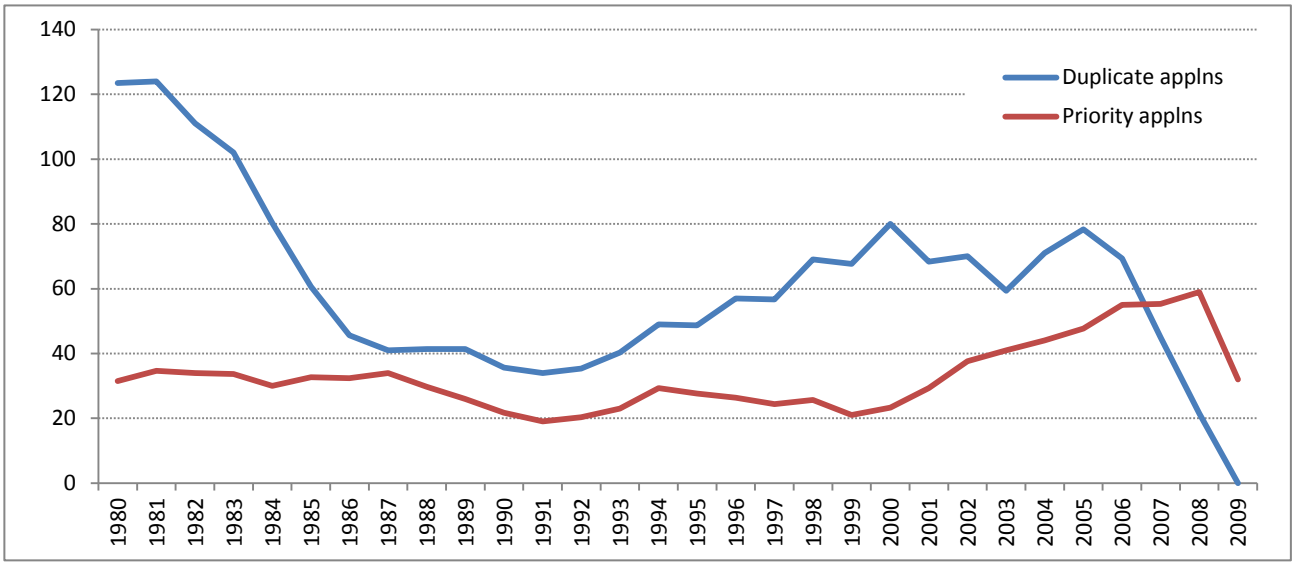
Figure 12. Patenting Activity in Africa (1980-2009)

(African application authorities, 3-year moving average)



In fact, a closer look at the data indicates that the large variations are due to changes in duplication patterns – i.e. duplicate applications in Africa for inventions originally protected elsewhere. In contrast, priority patenting in Africa has remained rather stable over time, and has even increased after year 2000 (Figure 13). The ratio of duplicates to priorities has been particularly high in Africa (but similar to the proportion found in South America). Almost all priorities are singulars, with protection sought at only one office.

Figure 13. Priority versus Duplicate Filings in Africa

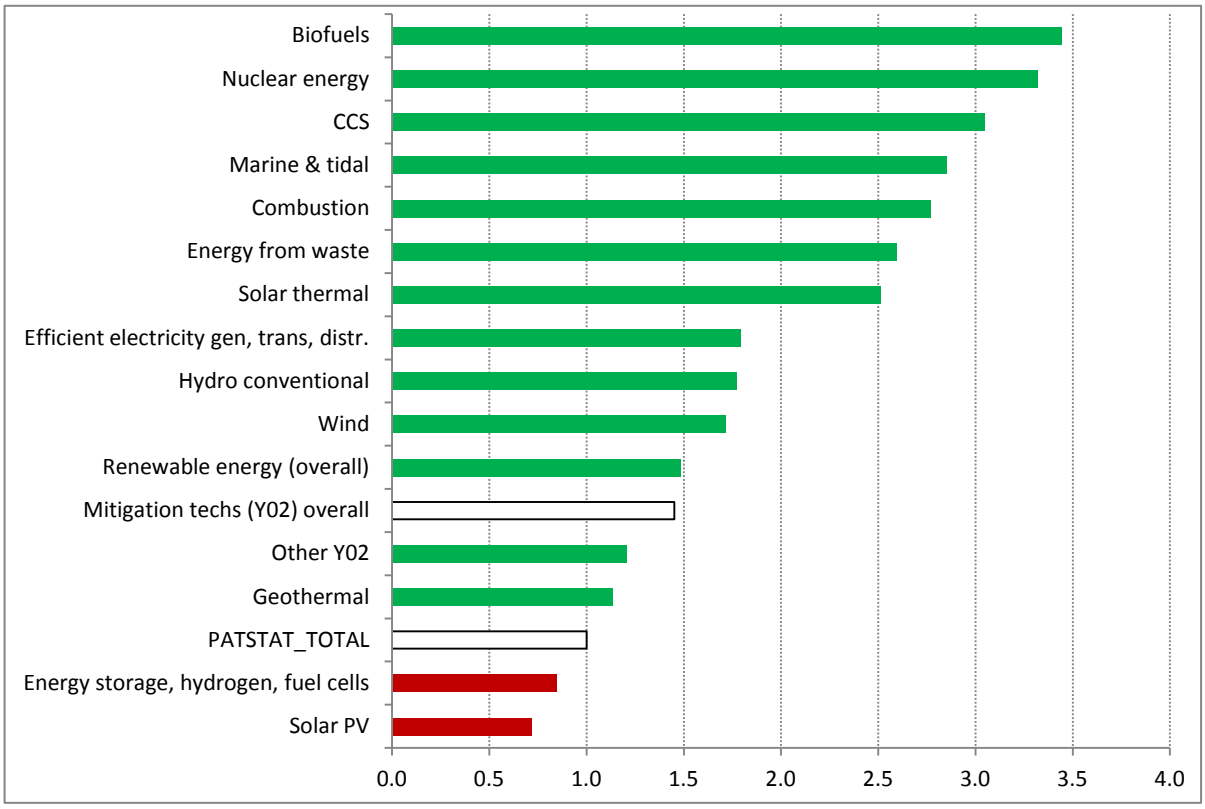


To put these figures in context, while in Africa about 0.14% of all patents are in biofuels, worldwide this is only 0.04%. Other Y02 mitigation technologies that are relatively frequently patented in Africa are

nuclear, CCS, marine & tidal, and combustion. On the other hand, energy storage/hydrogen/fuel cells and solar PV are relatively less frequently protected Y02 technologies in Africa than they are in the rest of the world. Overall, the propensity to protect mitigation technologies (Y02) is greater in Africa than what we observe worldwide. While Y02 technologies account for 1.7% of overall patenting in Africa, they account for only 1.2% worldwide. In Figure 14 this is shown as 1.7/1.2=1.4.

Figure 14. Propensity to Protect Mitigation Technologies in Africa Relative to World Totals

(Share of Y02 priorities to TOTAL priorities in Africa versus worldwide, 1980-2009)



During the period 1980-2009, the number of Y02 patents registered with African patent offices has been constant, while patenting overall went down by 2.2% (Table 8).

Table 8. Average Annual Growth Rate in Patenting Activity: 1980-2008

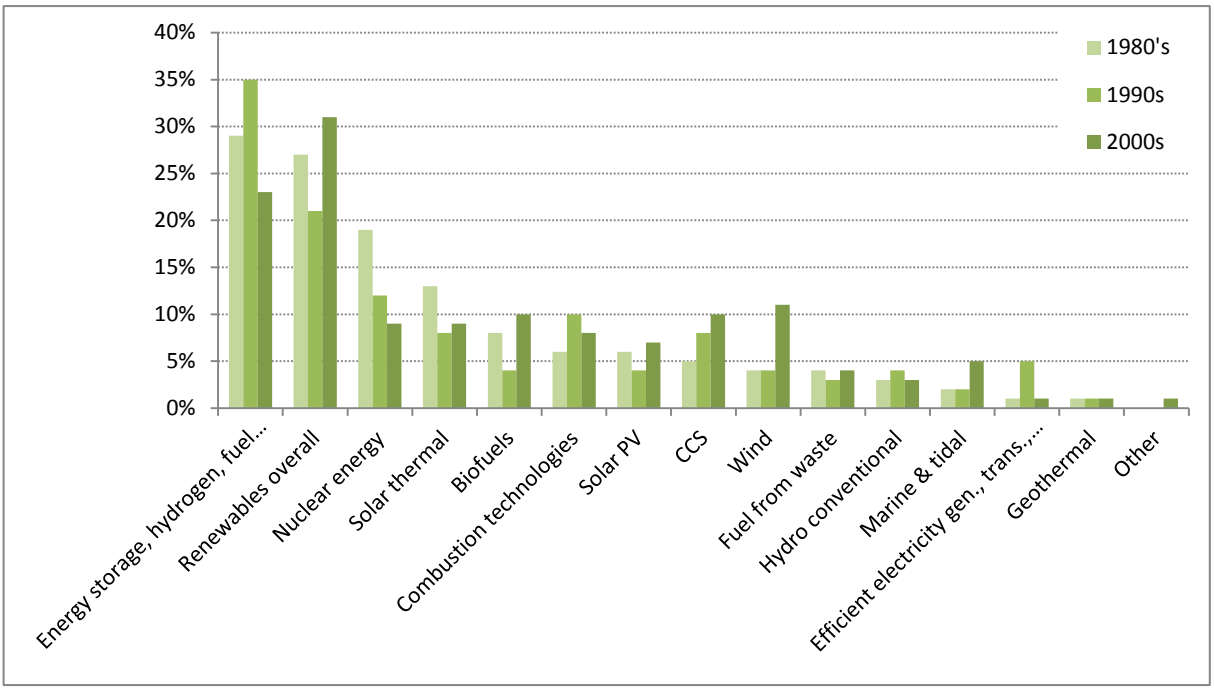
(Number of patent applications registered)

	African offices	World
Mitigation technologies (Y02)	0.0%	3.8%
All technologies (PATSTAT_TOTAL)	-2.2%	3.1%

Despite the general pattern, there are differences across fields – with inventions in wind, CCS and biofuels becoming relatively more frequently protected, while patenting in energy storage/hydrogen/fuel cells, nuclear and solar thermal energy have decreased in importance (Figure 15).

Figure 15. Patenting Activity in Africa: 1980-2009

(Share of a field on all Y02 patents)



Are particular countries more attractive for patent protection of Y02 technologies than others? To answer this question we examine the propensity to patent at different African authorities. We first calculate the shares of world's inventions that seek protection in Africa, for Y02 technologies and overall (Table 9). These figures suggest that on average an inventor is almost twice as likely to patent a mitigation technology in South Africa as s/he is to patent an 'average' technology there.

Table 9. The share of world's inventions for which protection has been sought in Africa: 1980-2009

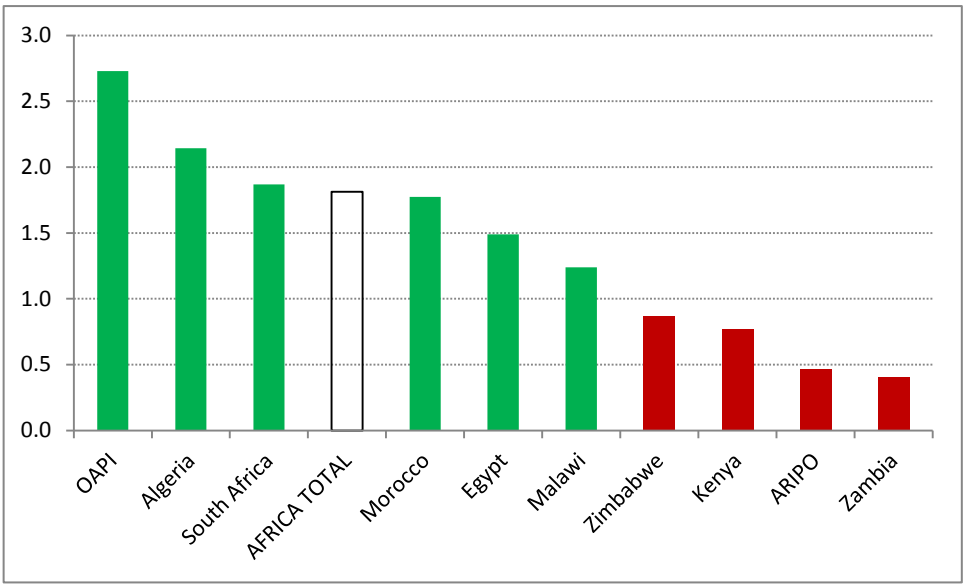
(Number of applications registered at African patent offices divided by number of priorities worldwide)

Application authority (patent office)	Y02 priorities	TOTAL priorities
South Africa	1.00%	0.53%
African Intellectual Property Org. (OAPI)	0.07%	0.03%
Morocco	0.06%	0.03%
Egypt	0.05%	0.03%
Algeria	0.01%	0.01%
African Regional Industrial Property Org. (ARIPO)	0.01%	0.02%
Zimbabwe	0.01%	0.01%

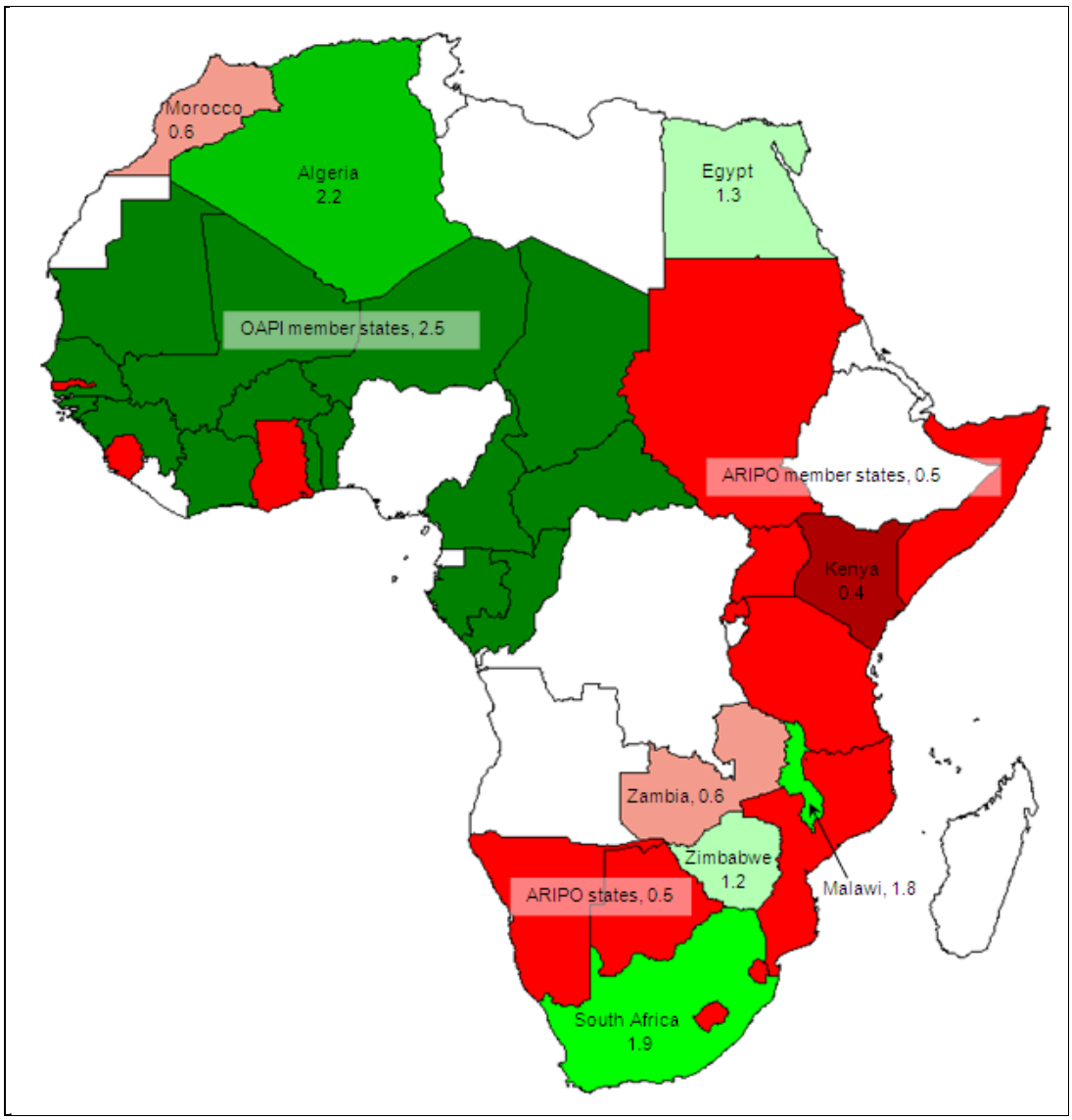
Next, we take the ratio of these shares and interpret them as "propensities to patent". A propensity equal to one indicates that a Y02 invention is as likely to be patented in the country as is an 'average' invention. Taking the example of South Africa, the propensity to patent a Y02 invention there is 1.00/0.53=1.89 relative to an 'average' invention (Figure 16). This data is also shown in Map 2.

Figure 16. Relative Propensity to Protect Mitigation Technologies in Africa versus Worldwide

(Country's share of Y02 patents worldwide compared to its share of TOTAL patents, 1980-2009)



Map 2. Relative Propensity to Protect Mitigation Technologies in Africa



Note: The map shows countries with a reasonable coverage in PATSTAT. This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries.

In order to get some idea whether this matches the size of different African markets for the relevant technologies we extracted data from the UN Comtrade database on commodity imports. Unfortunately there are few commodity classifications that can be mapped directly on environmental/climate-related technologies. Figure 17 gives the import shares of wind power generating equipment[13] for different African economies over the period 1990-2009. Egypt dominates, followed by Morocco and Sudan. The main differences to note with respect to the patent protection data are the high share of Sudan and the low share of South Africa. However, as noted above (Table 4) South Africa is itself a significant inventor of wind power technologies, which may explain its low import share of wind power generating equipment.

[13] HS 850231 - wind-powered generating equipment.

Figure 18 plots the patents registered in Africa against imports of wind power technologies for countries for which both patent data and trade data are available.

Figure 17. Import Shares of Wind-Power Technologies to Africa (1990-2009)

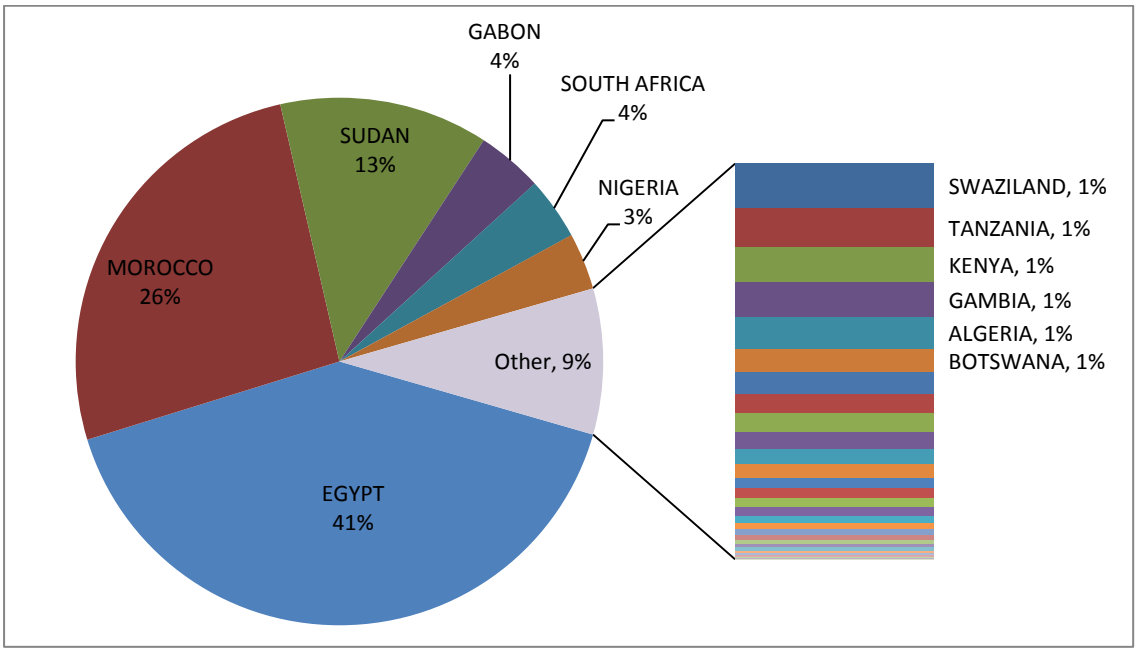
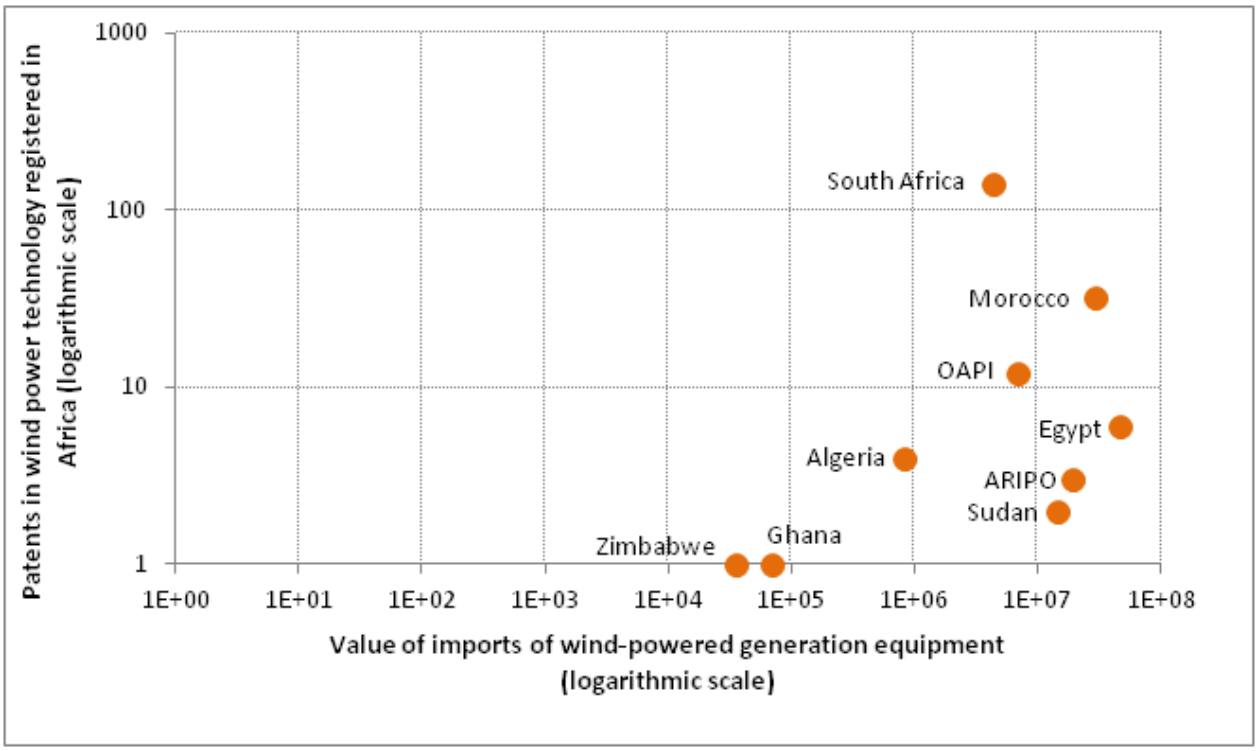


Figure 18. Imports versus Patenting in Wind-Power Technologies in Africa



The HS classification includes a separate code which is relevant for solar PV equipment.[14] The data suggests that the most important importers of solar PV equipment are South Africa, Morocco, Algeria and Kenya (Figure 19). Similarly as above, we then plot these data against the corresponding patent registrations for countries where both data sources are available (Figure 20). The correlation is positive and surprisingly high (0.98).

Figure 19. Import Shares of Solar PV Technologies to Africa (1990-2009)

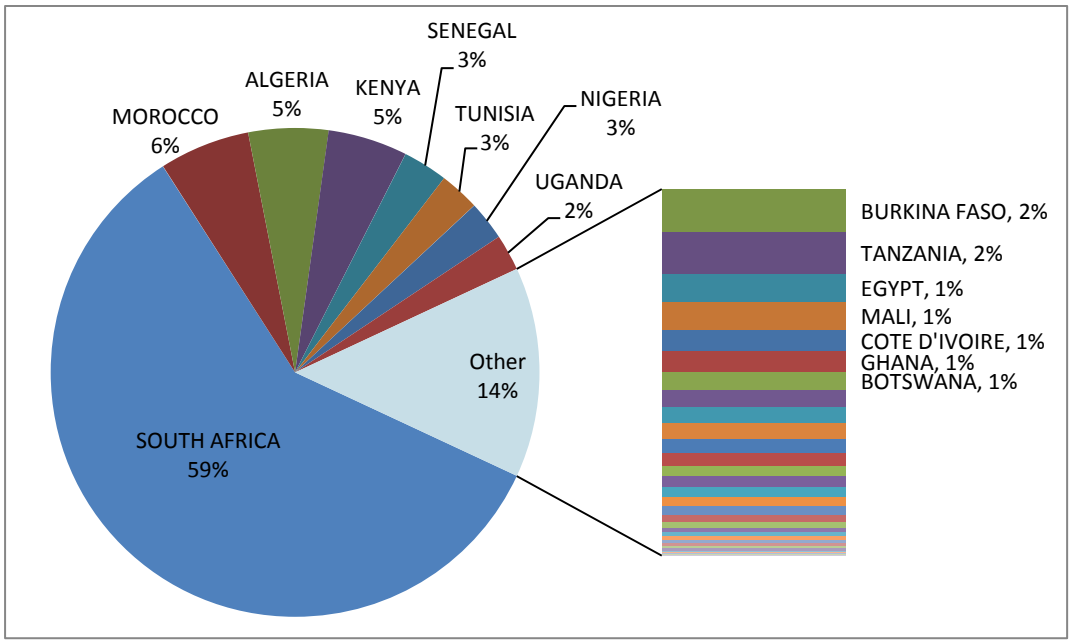
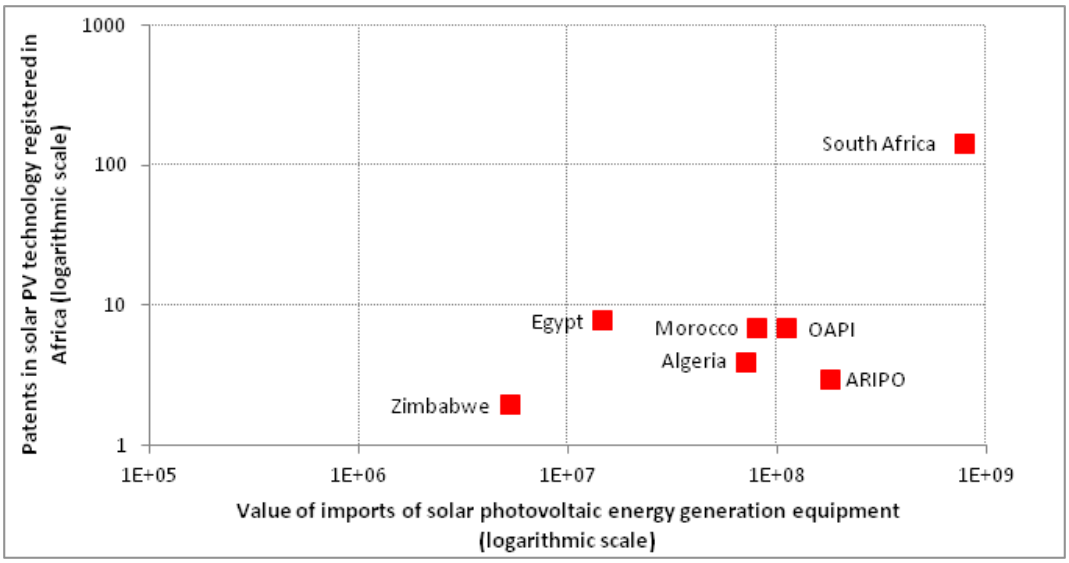


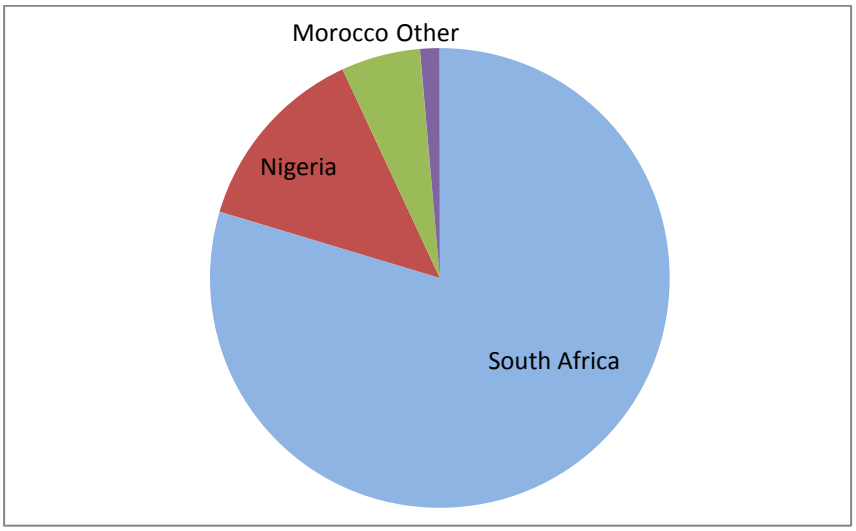
Figure 20. Imports versus Patenting in Solar PV Technologies in Africa



[14] HS 854140 - Photosensitive/photovoltaic/LED semiconductor devices

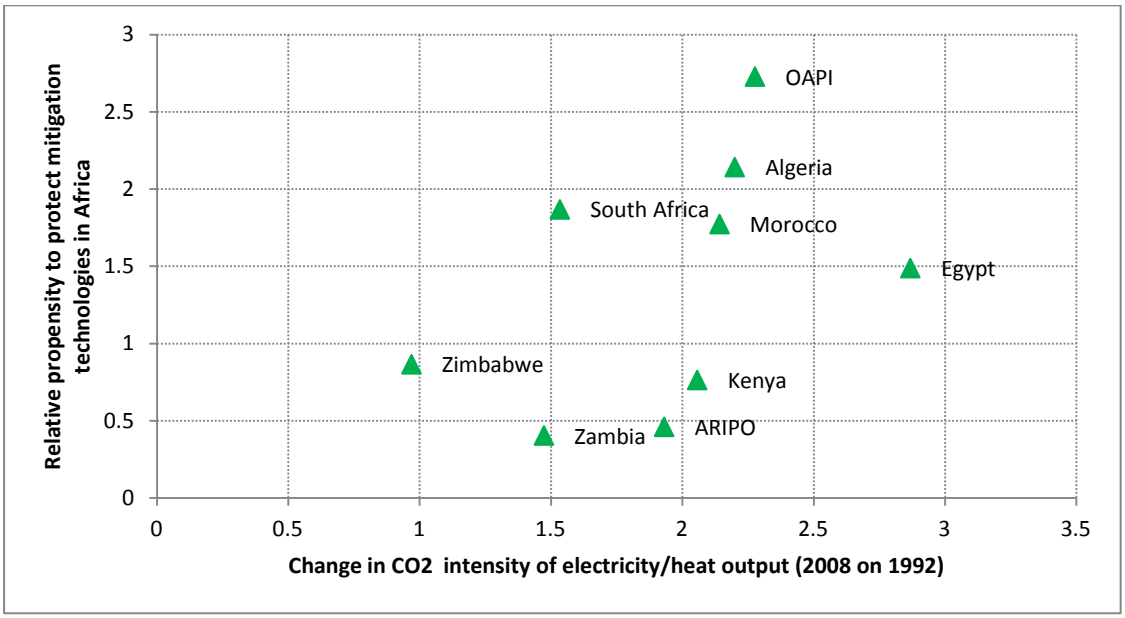
Finally, in the case of import shares of nuclear power equipment[15] South Africa dominates followed by Nigeria and Morocco (see Figure 21).

Figure 21. Import Shares of Nuclear Power Technologies to Africa (2005-2009)



We also examine the relationship between CO_2 emissions intensity of energy production and patenting of mitigation technologies in Africa. Figure 22 plots the change in CO_2-emission intensity of electricity and heat generation between 1980 and 2009 against the relative propensity to protect in Africa. The correlation is positive (0.43) and unlike some of the correlations/scatter plots presented above it is rather robust to outliers.

Figure 22. Patenting of Mitigation Technologies and Trends in CO2 Emissions (1980-2009)



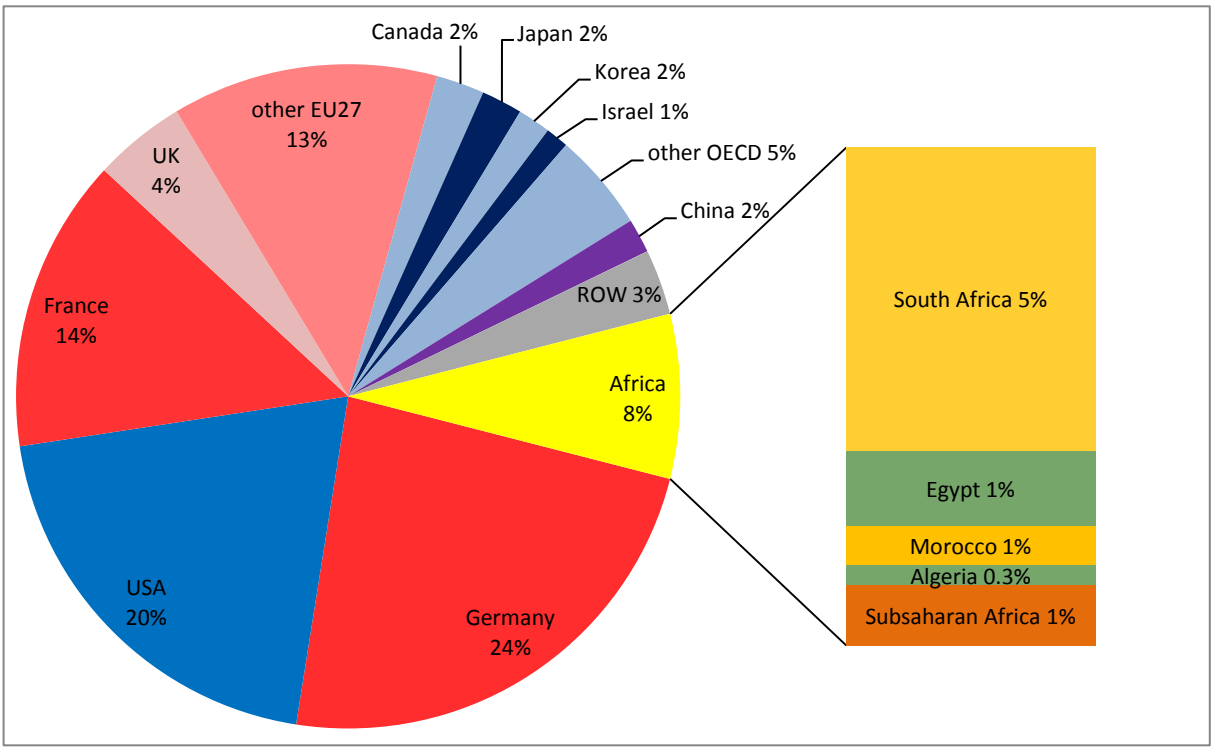
What is the 'origin' of the inventions that are protected in Africa? Overwhelmingly, Y02 inventions have been invented in OECD countries and this fact has changed little over time. While in the 1980s over a

[15] HS 8401 – Nuclear reactors, fuel elements, isotope separators

half of all inventions patented in Africa originated in only two countries (United States and France), their share has come down significantly in the last decade as Germany has become the most important 'origin' (Figure 23). At the same time, the share of African countries has increased from less than 1% to over 8%.

Figure 23. Patenting in Africa by Inventor Country: 2000-2009

(Patent applications registered at African patent offices, by country of the inventor)



Note: The Figure shows data for the period 2000-2009. There were very few African inventions patented in Africa prior to this period.

Who are the 'owners' of the inventions that seek protection in Africa? While applicant data are often missing (see the counts of "unknown" in Table 10), the available evidence suggests that overwhelmingly they are European, followed by US patentees (Table 11).[16]

Table 10. Invention & ownership of inventions protected in Africa (1980-2009)

(Inventor and applicant country of applications deposited at African patent offices)

Applicant countries / Inventor countries	*unknown*	France	Germany	United States	South Africa	United Kingdom	Australia	Switzerland	Spain	Netherlands	Canada	Egypt	Austria	Grand Total
unknown	836	13	3	14	2	10	8	1		6				902
United States	524			47							0.5			571
France	362	82		0.5				2						447
Germany	276		57		0.3			3				0.3	1	341
United Kingdom	54			0.5		7				0.5				62
Canada	38	1			0.5						7			46
South Africa	3		0.3		31	0.5					0.5			35
Italy	28	1												33
Japan	26	1												29
Sweden	27													28
Spain	17					1			9					27
Netherlands	22									3				25
Israel	20		1											25
Switzerland	20							4						24
Belgium	18					1								23
Austria	15		1										6	22
Australia	4						8							13
China	12			0.3										13
Norway	8													12
Korea	11		0.5											12
India	11													11
Brazil	7													9
Finland	8													9
Denmark	8													8
Egypt	0		0.3									7		8
Morocco	2	1												7
Grand Total	2390	99	64	63	34	20	16	10	9	9	8	8	7	2804

[16] Due to the large proportion of missing data, caution should be taken to interpret these statistics.

Table 11. Top Applicants Protecting in Africa: 1980-2009

(Selected mitigation technologies - Y02)

Standardized name	Country	Nb. of applications
FRAMATOME	France	158
WESTINGHOUSE ELECTRIC	USA	70
DURACELL	USA	42
ALOYS WOBBEN	Germany	38
SHELL INTERNATIONAL RESEARCH SOCIETY	Netherlands	33
AREVA NC	France	33
UNITED TECHN CORP	USA	32
CHLORIDE GROUP	United Kingdom	29
AIR LIQUIDE	France	29
ENERGY CONVERSION DEVICE	USA	28
LILLIWYTE SOCIETE ANONYME		23
UNION CARBIDE	USA	22
SIEMENS	Germany	21
THE BOC GROUP	USA	21
LES PILES WONDER	France	18
COMMUNAUTE EUROPEENNE DE L'ENERGIE ATOMIQUE (EURATOM)		18
VARTA	Germany	18
AIR PROD & CHEM	USA	18
KRAFTWERK UNION	Germany	17
IMPERIAL CHEM IND	United Kingdom	17
PRAXAIR TECHNOLOGY	USA	15
COMMISSARIAT A L'ENERGIE ATOMIQUE (CEA)	France	15
OWENS ILLINOIS	USA	14
KAWASAKI JUKOGYO	Japan	14
AGENCE NATIONALE DE VALORISATION DE LA RECHERCHE (ANVAR)	France	13
Grand total (with known applicant country)		3074

Note: Applicant names have been standardized using a two-stage procedure – first using the HAN concordance, followed by additional manual cleaning. Applicant's country is only indicative.

3.3. International collaboration in technology development

International collaboration is of particular relevance in the field of climate change mitigation. In this respect, patent data can be used to develop indicators of co-invention – that is counts of priorities that involve inventors from more than one country (see OECD 2012b).

Overall, 23% of African inventions in mitigation technologies involve co-invention. This contrasts with 12% of Y02 inventions co-invented worldwide, and 9% of inventions overall (in all fields) co-invented worldwide. Hence, Y02 technologies have a generally greater rate of co-invention, but this is particularly the case in Africa!

Biofuels and efficient combustion technologies tend to involve most co-invention, with nuclear energy and energy from waste having the least co-invention (Table 12). As a point of comparison, it is interesting to note that the rate of co-invention is lower worldwide than in Africa in every Y02 field except for solar thermal, nuclear energy, and waste-to-energy.

Table 12. Co-invention in Africa (1980-2009)

(Y02 mitigation technologies, 1980-2009)

	Co-invention rate in Africa	Co-invention rate worldwide
Biofuels	47%	20%
Efficient combustion	42%	15%
Wind	37%	12%
Hydro conventional	35%	9%
Energy storage, hydrogen, fuel cells	29%	12%
CCS	25%	19%
Renewable energy (overall)	20%	11%
Solar PV	15%	14%
Marine & tidal	9%	6%
Solar thermal	5%	8%
Nuclear energy	**1%**	**6%**
Energy from waste	0%	11%
Y02 (overall)	23%	12%

Note: Co-invention rate refers to the share of priorities that involve inventors from more than one country. This could be a country in Africa or elsewhere in the world.

Interestingly South Africa, while ranking as the major inventor in Africa, is less likely to co-invent with others in developing mitigation technologies. Countries that are most likely to co-invent include Tunisia, Morocco, Egypt, Kenya and Mali – all of whom co-invent at least 50% of their inventions with inventors in other countries (Table 13).

Table 13. Top African co-inventors

(Y02 mitigation technologies, 1980-2009)

	Co-invention rate
Tunisia	67%
Morocco	61%
Egypt	56%
Kenya	55%
Mali	50%
Algeria	21%
South Africa	16%
Ghana	14%
Africa (all countries)	23%

The most frequent partner countries include the US, UK, Belgium, Germany and Sweden (for whom South Africa is the primary co-inventor partner in Africa) as well as France and Canada (for whom other African countries are equally important co-invention partners) (Table 14). Finally, it is important to point out that there is very little evidence of intra-Africa co-invention, with a single documented case (Kenya-Egypt), suggesting that every African country is an "island". The most important co-invention relations are summarized in Map 3.

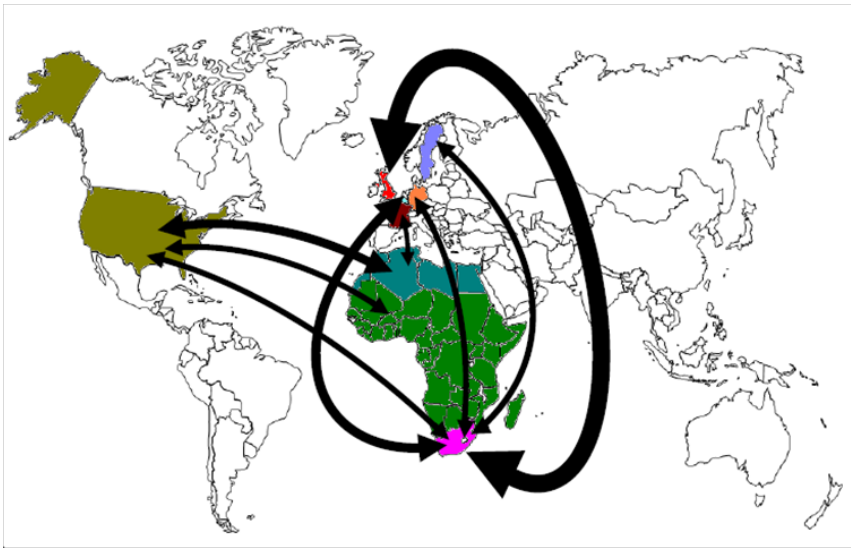
Table 14. Bilateral co-invention cooperation between African countries and the world

(Selected mitigation technologies Y02, 1980-2009)

	United States	United Kingdom	Belgium	Germany	France	Sweden	Canada	Spain	China	Japan	Israel	Switzerland	Netherlands	Korea	ROW	This total
South Africa	11	34	18	11	1	12	3	2	2		5	1	3		3	106
Egypt	9		5	1	1		2								1	19
Morocco	2		1	2	4			3	2						2	16
Kenya	4													2	2	8
Nigeria	3	1		1			1		1	1						8
Algeria	3	1			1											5
Gabon		1					4									5
Tunisia				1	3							1				5
Chad										4						4
Cameroon								1				1			1	3
Ghana	1								1						1	3
Libya	3															3
Mali					3											3
Mauritius	1	1													1	3
other Africa	2		1	1				2	1			1		1	4	13
This total	39	38	25	17	13	12	10	8	7	5	5	4	3	3	15	204

Note: The only case of intra-African co-invention is Kenya-Egypt (2 priorities).

Map 3. International Co-invention between African Countries and the World



Note: The map shows co-invention between South Africa and the UK, USA, Belgium, Germany and Sweden, between Maghreb countries and US, between Maghreb and France, and between, countries of Sub-Saharan Africa and the USA. This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries.

4. Patenting activity in selected adaptation technologies (Z-tags)[17]

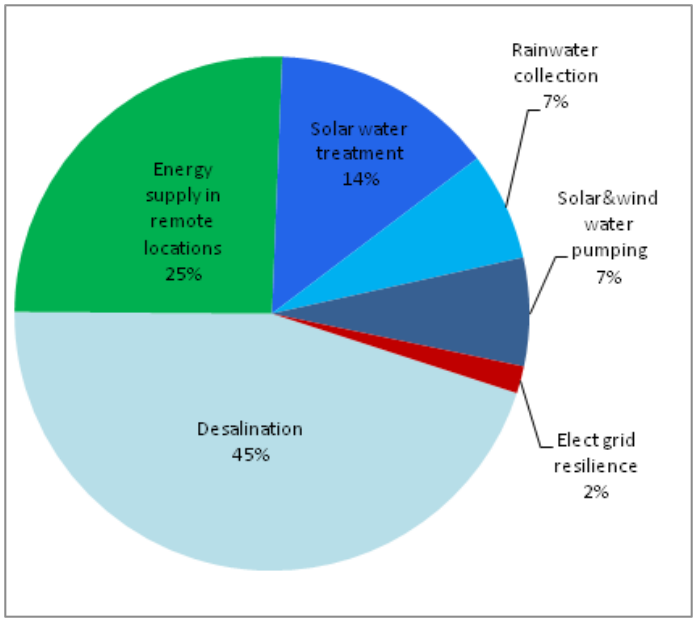
4.1. The place of Africa in technology development

In terms of adaptation technologies, Figure 24 gives the breakdown of inventive activity in Africa during 1980-2009. For presentational purposes, we aggregate the 11 technological fields (Annex B1) into somewhat broader five major categories. Overall, there are only 56 priorities invented by African inventors, with almost half of them in desalination (45%), followed by energy supply for remote areas (25%). Surprisingly, there are no African inventions in solar cooking. For detailed data see Annex B3.

[17] More precisely, "in technologies suitable for addressing specific environmental needs of African countries". (See also Section 2.2.)

Figure 24. Inventive Activity in Africa: 1980-2009

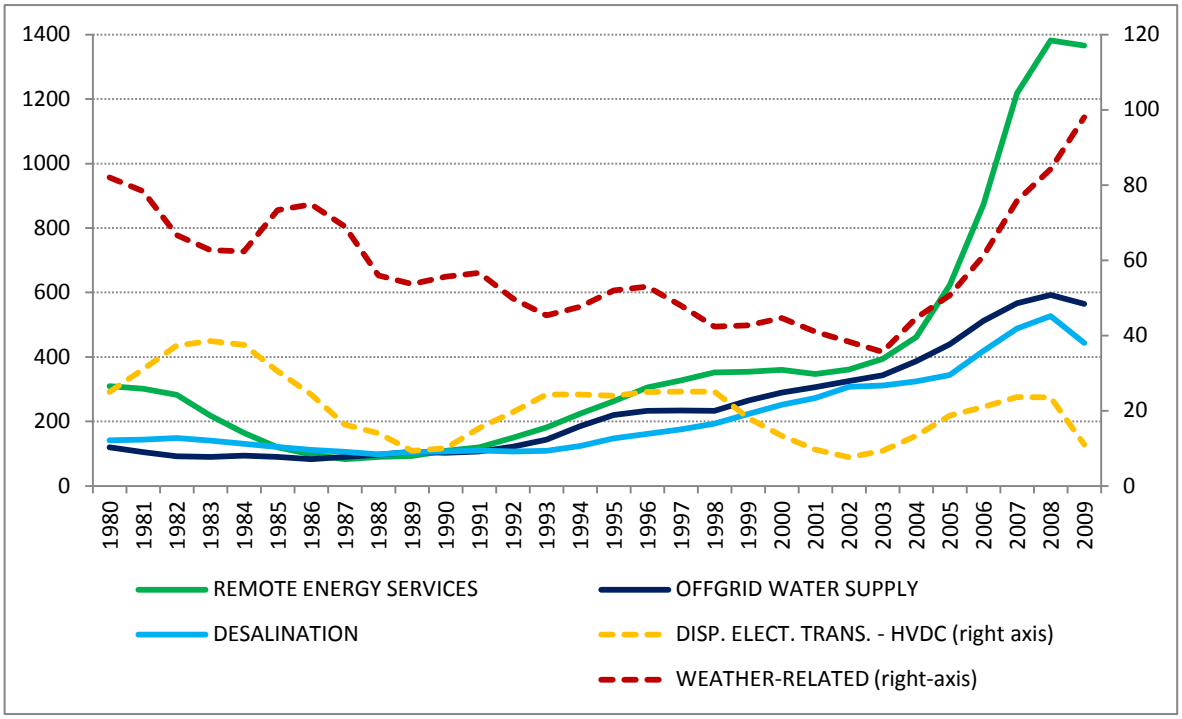
(Number of priorities in selected adaptation technologies, Z-tagged)



Given the low numbers, it is not very illuminating to show trends over time. As a consequence we do so only for inventive activity worldwide in order to give an indication of temporal trends (Figure 25).

Figure 25. Inventive Activity in Adaptation Techs Worldwide

(Number of priorities in selected adaptation technologies (Z-tags), 3-year moving average)



Historically, the share of African inventors has been very low most of the time. Since 2000, this share has stabilized at around 0.26% (Figure 26). However, the share is much higher in desalination technologies (0.41%) (Figure 27).

Figure 26. Share of World's Inventions with African Inventor

(Selected adaptation technologies (Z-tags), number of priorities, 3-year moving average)

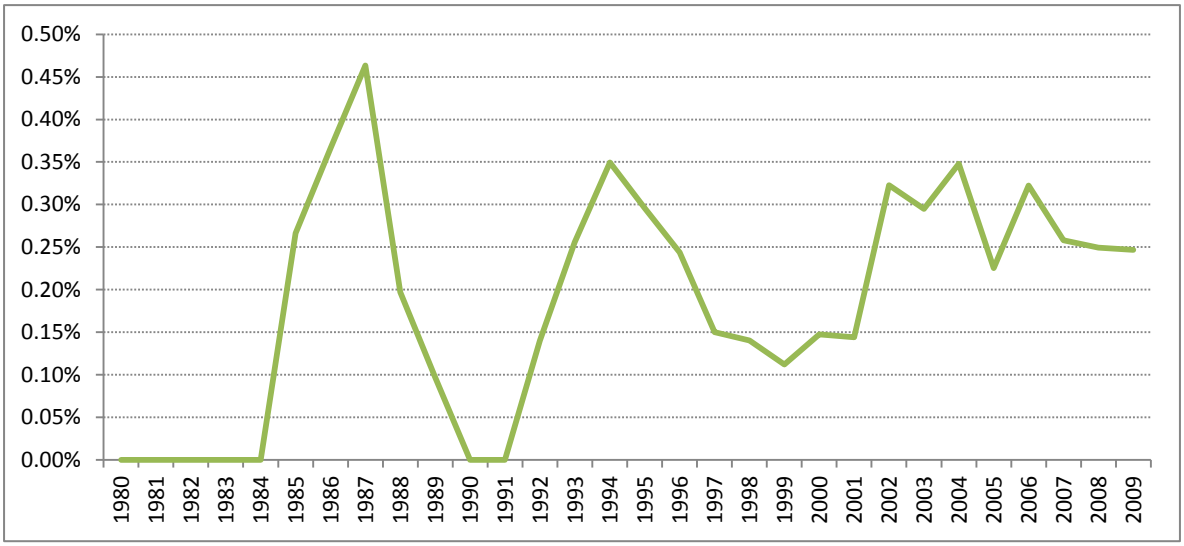
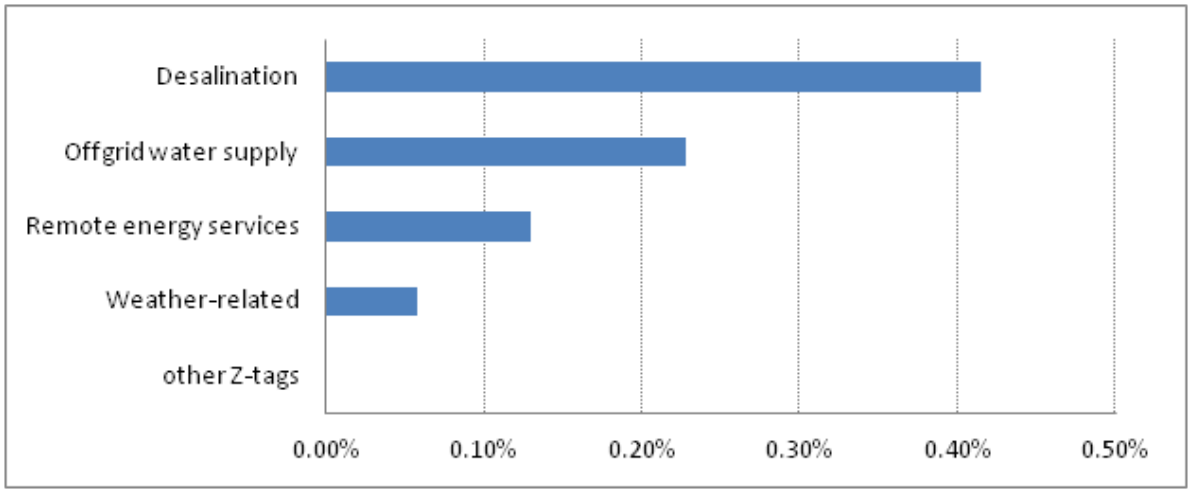


Figure 27. Share of World's Inventions with African Inventor: 1980-2009



South Africa is the most important inventor country (53% of inventions) but its dominance is much less than is the case in mitigation technologies.

Table 15. Major African Inventor Countries: 1980-2009

(Selected adaptation technologies - Z tags, number of priorities)

	Count	%	Invention portfolio
South Africa	30	53%	Desalination (26%), Energy supply in remote locations (21%)
Morocco	8	13%	Desalination (26%)
Egypt	7	12%	Desalination (58%)
Africa Total	56	100%	

The proportion of African adaptation inventions for which protection is sought in Africa is 81% – a much greater share than is the case for mitigation technologies. In South Africa alone, as much as 47% of African adaptation-related inventions seek protection, compared with only 1% of worldwide adaptation priorities. African inventors are also more likely to use the PCT (WIPO) route to protect their inventions, and they are more likely to protect elsewhere in Africa as well as in Australia and Norway (Table 16 and Annex B4).

There is very little information on ownership of African adaptation-related inventions – in fact, there are only 20 African priorities during 1980-2009 for which applicant data is available.

Table 16. Markets where protection is sought for African inventions: 1980-2009

(Selected adaptation technologies – Z tags)

Application authority (patent office)	African Priorities	Worldwide priorities
South Africa	47%	1%
United States	26%	20%
International Bureau of the World Intellectual Property Organization (WIPO)	**22%**	**0.4%**
European Patent Office (EPO)	**18%**	**12%**
Australia	16%	8%
United Kingdom	13%	3%
Canada	12%	4%
Germany	10%	16%
African Intellectual Property Organization (OAPI)	**10%**	**0.2%**
Morocco	10%	0.2%
Egypt	9%	0.2%
Norway	8%	1%
China	7%	23%
Spain	5%	3%
Brazil	4%	2%
Czech Republic	4%	0.3%
Israel	4%	1%
Hungary	4%	0.2%
Eurasian Patent Organization (EAPO)	**4%**	**0.2%**
Austria	4%	3%
Japan	4%	34%
Korea	4%	4%
Portugal	4%	0.5%
Hong Kong, China	4%	0.2%
Chinese Taipei	4%	0.3%
Slovak Republic	4%	0.1%
New Zealand	4%	1%
Iceland	4%	0.1%
Bulgaria	4%	0.2%
African Regional Industrial Property Organisation (ARIPO)	**4%**	**0.2%**
Algeria	1%	0%
Zimbabwe	0%	0.01%
Tunisia	2%	0.0%
ROW	19.3%	14.0%
At least one patent office in Africa	**81%**	**1%**

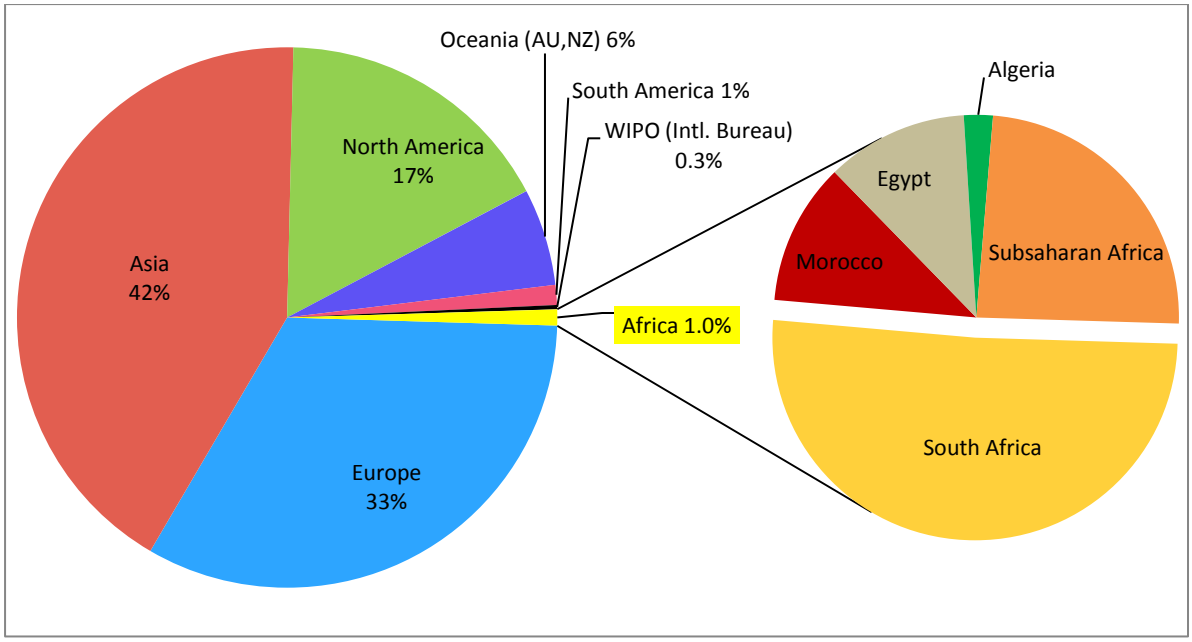
Note: The values sum here to more than 100% because an invention may seek protection in more than one jurisdiction, or through alternative routes (e.g. regional or international route).

4.2. Africa as a market for technology

While for mitigation technologies Europe is the principal market (see Section 3.2 above), the most important market for the selected adaptation technologies is Asia (Figure 28). The share of Africa is low, with only about 1% of world's patents for adaptation technologies registered with African patent offices. And while South Africa is, again, the major African country where patent protection is sought, its share is much lower than was the case for mitigation techs. Conversely, the share of Sub-Saharan countries is greater (mostly through OAPI and ARIPO). (For detailed data see Annex B5.)

Figure 28. Patenting Activity across Different Continents: 1980-2009

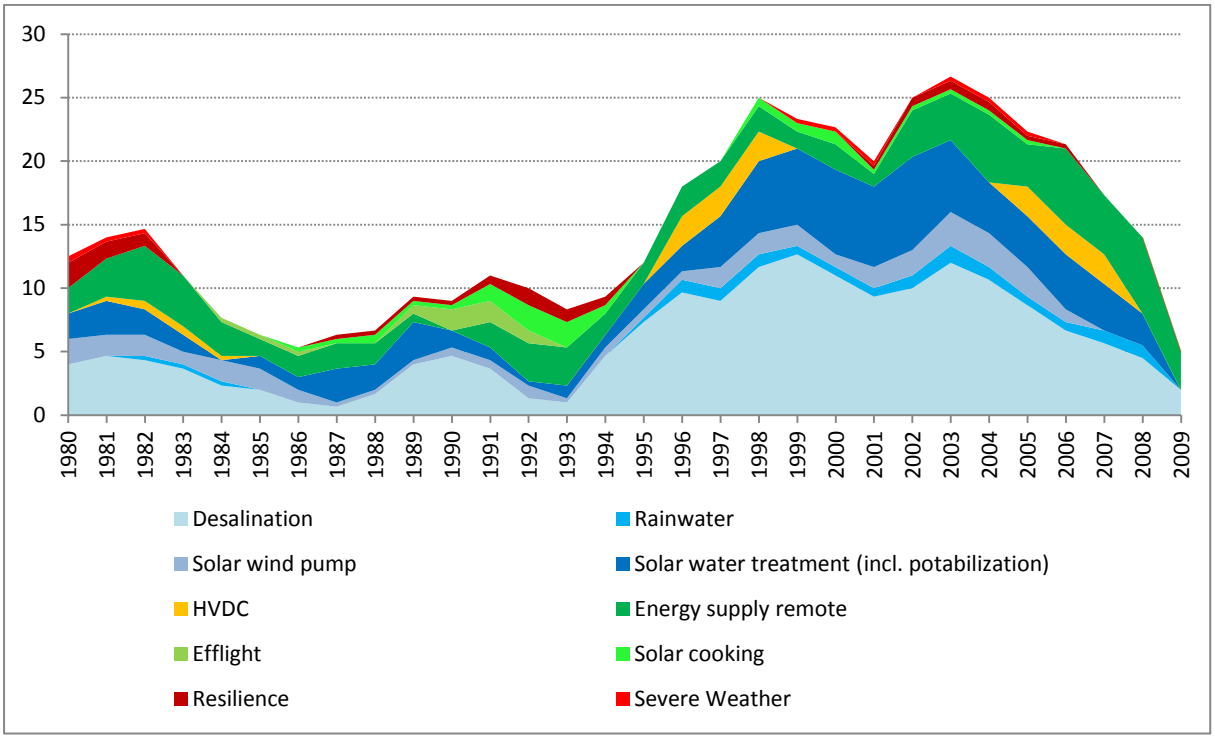
(Selected adaptation technologies – Z, by application authority)



Among the adaptation technologies examined, desalination is by far the most important technology protected in Africa. This is followed by solar water treatment (incl. potabilization) and energy supply in remote locations. This pattern has changed little over time (Figure 29). It is noteworthy that there have been very few patents in fields that would seem highly relevant for addressing some of the Africa's most pressing environmental needs, such as solar cooking and rainwater collection. However, this may be a consequence of the 'narrowness' of these technological fields – that is, the low volume of inventions in these technologies more generally. We address this point next.

Figure 29. Patenting Activity in Africa: 1980-2009

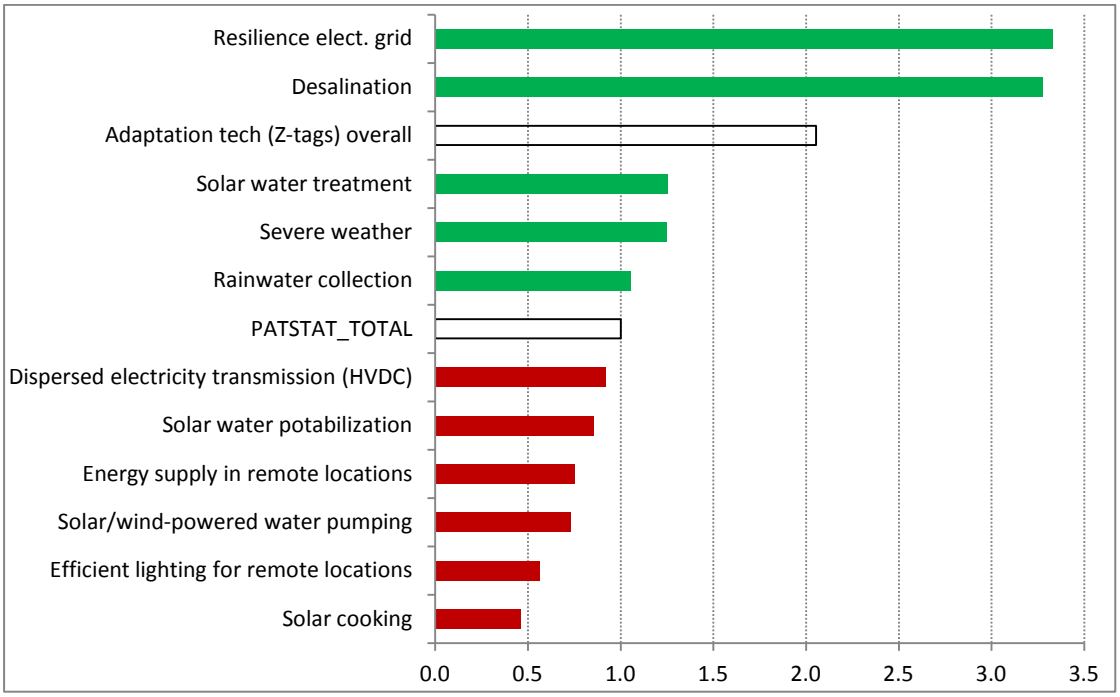
(African Z- application authorities, 3-year moving average)



Indeed, when we control for the overall volume of patents in a given field and their propensity to be patented widely, we conclude that many adaptation technologies tend to be protected relatively more often in Africa than elsewhere in the world. This is true especially for grid resilience and desalination, and to a lesser extent for solar water treatment and severe weather prediction (Figure 30). Conversely, solar cooking and efficient lighting for remote locations are relatively less frequently protected in Africa than elsewhere. Again, this is rather surprising.

Figure 30. Relative Propensity to Protect Adaptation Technologies in Africa

(Africa's share of Z-tagged patents worldwide compared to its share of TOTAL patents, 1980-2009)



During the period 1980-2009, the number of adaptation-related patents registered with African patent offices increased every year by as much as 17% on average, while patenting in general actually decreased (Table 17).

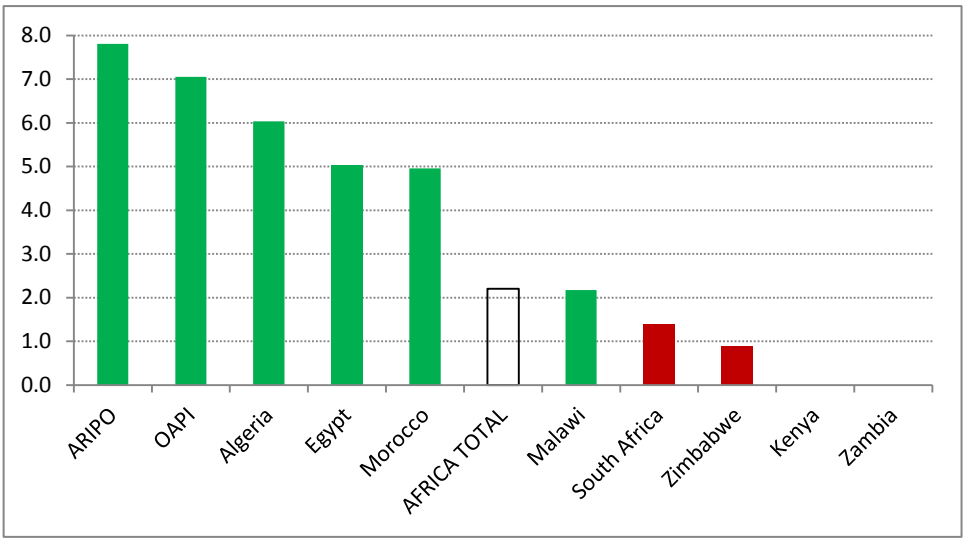
Table 17. Average Annual Growth Rate in Patenting Activity: 1980-2008

	African offices	World
Adaptation technologies (Z-tags)	17%	5%
All technologies (PATSTAT_TOTAL)	-2%	3%

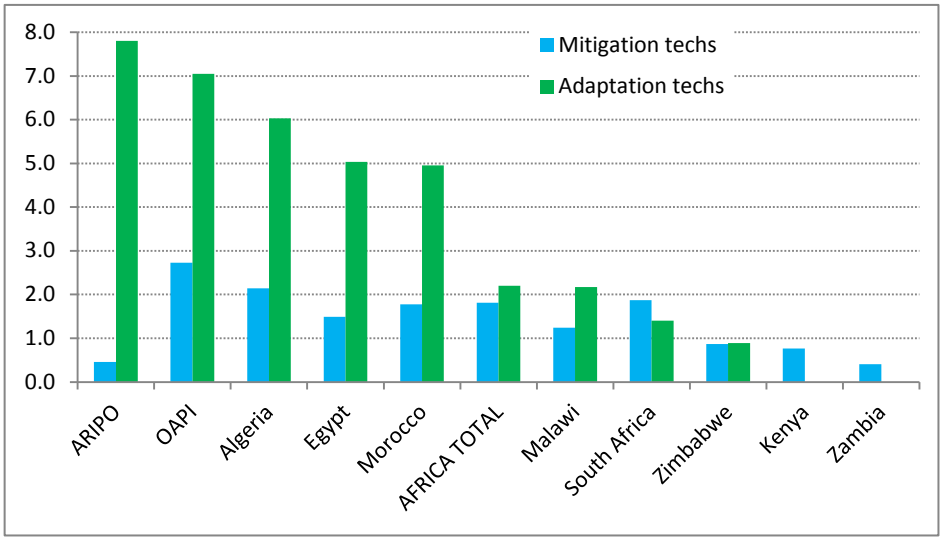
Interestingly, adaptation technologies are much more likely to be protected in northern Africa and sub-Saharan Africa than in South Africa. For example, compared with an 'average' technology, an adaptation technology is 7-times more likely to be protected at ARIPO and OAPI (Figure 31a). Overall, these figures suggest that adaptation technologies are significantly more likely to be protected in Africa than are mitigation technologies (Figure 31b).

Figure 31. Relative Propensity to Protect Adaptation Technologies in Africa

(Country's share of Z-tagged patents worldwide compared to its share of TOTAL patents, 1980-2009)



b.

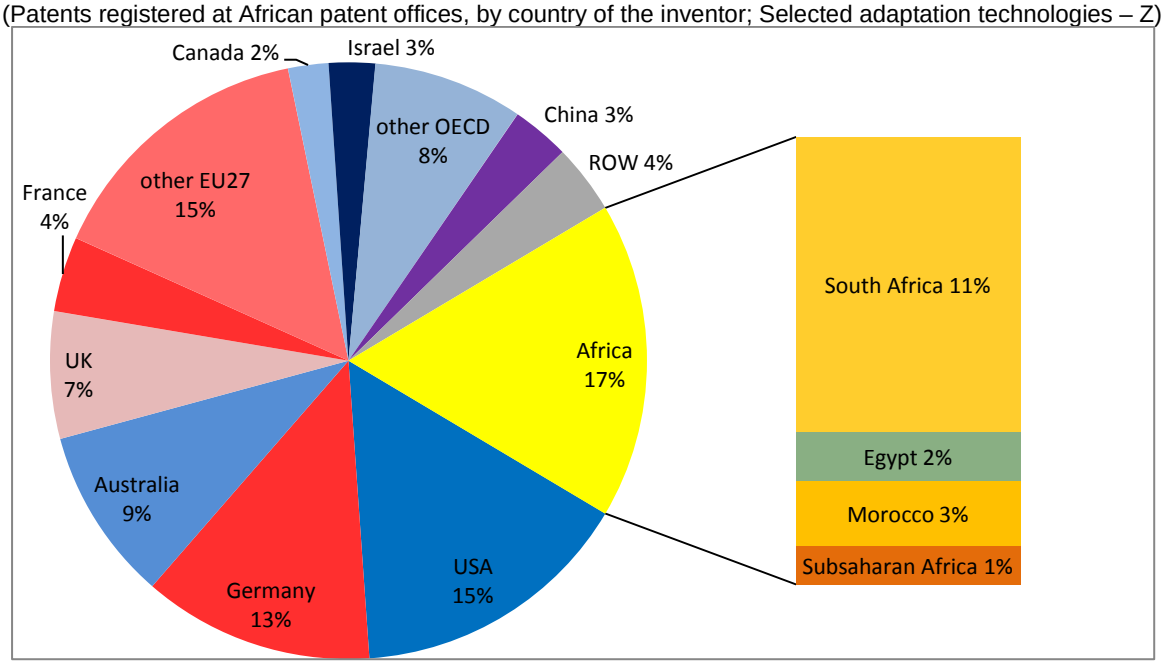


The adaptation technologies patented in Africa originate predominantly in OECD countries (76%). Similarly as with mitigation technologies, the US and Germany are still the major inventors. They are followed by Australia with an unusually high share of 9%. Conversely, the shares of Japan and Korea are extremely low. The proportion of Africa's own inventions is as much as 17% - a much higher share than for mitigation (Figure 32).

The list of the most frequent applicants is composed of European and US firms (Table 18). (The usual caveat about availability of applicant data applies.)

Figure 32. Patenting in Africa by Inventor Country: 2000-2009

(Patents registered at African patent offices, by country of the inventor; Selected adaptation technologies – Z)



Note: The Figure shows data for the period 2000-2009. There are few African adaptation inventions patented in Africa prior to this period.

Table 18. Top Applicants Protecting in Africa: 1980-2009

(Adaptation technologies, Z-tags)

Standardized name	Country	Nb. of applications
ABB	Sweden	14
SNAM PROGETTI SPA	Italy	11
DOW CORNING CORPORATION	USA	6
AGENCE NATIONALE DE VALORISATION DE LA RECHERCHE (ANVAR)	France	4
WATER STANDARD COMPANY LLC	United Kingdom	4
OWENS ILLINOIS INC	USA	4
SOLAR SOLUTIONS LLC	USA	3
ROHM AND HAAS COMPANY	USA	3
COMMISSARIAT A L'ENERGIE ATOMIQUE (CEA)	France	3
AKZO NOBEL	Netherlands	3
D.D.C. PLANUNGS- ENTWICKLUNGS- UND MANAGEMENT	Germany	3
PRESTIDGE D. JOSHUA	USA	3
GARFIELD INTERNATIONAL INVESTMENTS LIMITED	United Kingdom	3
BARRETO AVERO MANUEL	Spain	3
IND PIRELLI SPA	Italy	3
SOCIETE D'ETUDES ET DE RECHERCHES DE L'ECOLE NATIONALE SUPERIEURE D'ARTS ET METIERS	France	3
MANUEL BARRETO AVERO	Spain	3
ARCELOR MITTAL - STAINLESS & NICKEL ALOYS	France	3
Grand total (with known applicant country)		405

Note: Applicant names have been standardized and cleaned manually. Applicant's country is only indicative.

4.3. International collaboration in technology development

There is very little co-invention activity, mostly in desalination (Table 19), and primarily with South Africa (Table 20).

Table 19. Co-invention in Africa: 1980-2009

(Adaptation technologies, Z-tags)

	Co-invention rate in Africa	Co-invention rate worldwide
Desalination	31%	10%
Solar water treatment	30%	8%
Remote energy supply	0%	6%
Other Z-tags	0%	7%
Adaptation techs (Z-tags) overall	21%	7%

Note: Co-invention rate refers to the share of priorities that involve inventors from more than one country. This could be a country in Africa or elsewhere in the world.

Table 20. Bilateral co-invention between African countries and the world: 1980-2009

(Adaptation technologies, Z-tags)

	Virgin Islands (British)	Singapore	United States	Japan	Saudi Arabia	Belgium	Germany	Switzerland	This total
South Africa	3	2	2						7
Sudan				2	2				4
Morocco						1			1
Niger							1		1
Cameroon								1	1
This total	3	2	2	2	2	1	1	1	14

5. Conclusions

In this paper we have presented data on the invention and protection of climate change mitigation and adaptation technologies in Africa. We find that:

- Despite Africa's generally low volume of inventive activity, it is disproportionately directed towards climate mitigation technologies, and to a lesser extent toward adaptation technologies. In addition, the rate of growth is high relative to the rest of the world.
- With respect to mitigation, and in comparison with specialisation in the rest of the world, inventive activity is relatively low in Africa in the solar PV sector, whereas in the sectors of biofuels, carbon capture and storage, solar thermal, and waste-to-energy it is relatively high.
- Among adaptation technologies, African inventors have a particular focus on desalination, off-grid water supply and remote energy service technologies.
- In terms of protection, although the absolute numbers are very low, there is a relatively high propensity to protect mitigation technologies in Africa relative to protection of other technologies. This is even more evident for adaptation technologies.
- Inventive activity is dominated by South Africa. To a slightly lesser extent, South Africa also dominates in terms of number of patents registered for protection. Countries in Sub-Saharan Africa seem to be a relatively frequent target for protecting adaptation technologies.
- It must be emphasized that in absolute terms a relatively small number of mitigation and adaptation inventions are protected in Africa, providing indirect evidence that IP is not a barrier to technology transfer and diffusion.
- There is relatively little evidence of patenting activity among BRIC countries, despite the increasingly important role played by countries such as China in a number of African economies. Europe is important but on a decreasing slope (at least in terms of ownership of patents.) The role of Japan and Korea is very limited.
- The rate of co-invention for most mitigation and adaptation technologies is much higher in Africa than in the rest of the world. However, there is very little evidence of intra-Africa co-invention and cross-border patenting – every country is an 'island' within the continent, with links outside the continent.

However, the reader should keep in mind that these results must be qualified due to problems of data availability from some offices in Africa. This is particularly important when assessing the likelihood of protection of inventions in different African countries.

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ANNEX A. SUPPLEMENTARY INFORMATION TO SECTION 3

Table A1. Patent search strategy for selected mitigation technologies [18]

Field	Description	ECLA Y-tag
WIND		
		Y02E10:7
	Wind energy	
	All subclasses, including: - Wind turbines with rotation axis in wind direction; including: Blades or rotors; Components or gearbox; Control of turbines; Generator or configuration; Nacelles; Offshore towers; Onshore towers - Wind turbines with rotation axis perpendicular to the wind direction - Power conversion electric or electronic aspects; including: for grid-connected applications; concerning power management inside the plant, e.g. battery charging/discharging, economical operation, hybridisation with other energy sources	
SOLAR PV		
		Y02E10:5
	Solar photovoltaic (PV) energy	
	All subclasses, including: - PV systems with concentrators - Material technologies, including: CuInSe2 material PV cells; Dye sensitized solar cells; Solar cells from Group II-VI materials; Solar cells from Group III-V materials; Microcrystalline silicon PV cells; Polycrystalline silicon PV cells; Amorphous silicon PV - Power conversion electric or electronic aspects, including: for grid-connected applications; concerning power management inside the plant , e.g. battery charging/discharging, economical operation, hybridisation with other energy sources - Power conversion electric or electronic aspects; Maximum power point tracking (MPPT)	
SOLAR THERMAL		
		Y02E10:4
	Solar thermal energy	
	All subclasses, including: - Tower concentrators; Dish collectors; Fresnel lenses; Heat exchange systems; Trough concentrators; Solar thermal plants for electricity generation, e.g. Rankine, Stirling solar thermal generators; Mountings or tracking; Mechanical power, e.g. thermal updraft	
	Thermal-PV hybrids	Y02E10:6
GEOTHERMAL		
		Y02E10:1
	Geothermal energy	
	All subclasses, including: - Earth coil heat exchangers, incl.: Compact tube assemblies, e.g. geothermal probes - Systems injecting medium directly into ground, e.g. hot dry rock system, underground water - Systems injecting medium into a closed well - Systems exchanging heat with fluids in pipes, e.g. fresh water or waste water	
MARINE & TIDAL		
		Y02E10:3
	Energy from sea	
	All subclasses, including: - Oscillating water column (OWC)	

[18] Based on http://v3.espacenet.com/eclasrch?classification=ecla&locale=en_EP&ECLA=y02

- Ocean thermal energy conversion (OTEC) - Salinity gradient - Wave energy or tidal swell, e.g. Pelamis-type **Hydro energy** - Tidal stream or damless hydropower, e.g. sea flood and ebb, river, stream	Y02E10:28
HYDRO CONVENTIONAL	
Hydro energy - Conventional, e.g. with dams, turbines and waterwheels, including: Turbines or waterwheels, e.g. details of the rotor; Other parts or details	Y02E10:20-22
BIOFUELS	
Energy generation using biofuels All subclasses, including: - CHP turbines for biofeed; Gas turbines for biofeed; Bio-diesel; Bio-pyrolysis; Torrefaction of biomass; Cellulosic bio-ethanol; Grain bio-ethanol; Bio-alcohols produced by other means than fermentation	Y02E50:1
ENERGY FROM WASTE	
Energy generation using fuels from waste All subclasses, including: - Synthesis of alcohols or diesel from waste including a pyrolysis and/or gasification step - Methane, including: production by fermentation of organic by-products, e.g. sludge; from landfill gas	Y02E50:3
COMBUSTION	
Combustion technologies with mitigation potential All subclasses, including: Combined combustion: - Heat utilisation in combustion or incineration of waste - Combined heat and power generation (CHP) - Combined cycle power plant (CCPP), or combined cycle gas turbine (CCGT); including Integrated gasification combined cycle (IGCC); combined with carbon capture and storage (CCS) Technologies for a more efficient combustion or heat usage - Direct CO2 mitigation, including: Use of synair, i.e. a mixture of recycled CO2 and pure O2; Use of reactants before or during combustion; Segregation from fumes, including use of reactants downstream from combustion or deep cooling; Controls of combustion specifically inferring on CO2 emissions - Indirect CO2 mitigation, i.e. by acting on non CO2 directly related matters of the process, e.g. more efficient use of fuels, including: Cold flame; Oxyfuel combustion; Unmixed combustion; Air pre-heating - Heat recovery other than air pre-heating, including: at fumes level; at burner level	Y02E20
CCS	
Technologies specific to climate change mitigation All subclasses, including:	
CO2 capture or storage: - Capture by biological separation; by chemical separation; by absorption; by adsorption; by membranes or diffusion; by rectification and condensation. Subterranean or submarine CO2 storage.	Y02C:10
Capture or disposal of greenhouse gases (GHG) other than CO2: - of nitrous oxide (N2O); of methane; of perfluorocarbons (PFC), hydrofluorocarbons (HFC) or	Y02C:20

sulfur hexafluoride (SF6)

EFFICIENT ELECTRICITY GTD

Y02E40

Efficient electricity generation, transmission, distribution:

All subclasses, including:
- Flexible AC transmission systems (FACTS)
- Active power filtering (APF)
- Arrangements for reducing harmonics
- Arrangements for eliminating or reducing asymmetry in polyphase networks
- Superconducting electric elements and equipment
- Methods and systems for the efficient management or operation of electric power systems, e.g. dispatch aiming to losses minimisation or emissions reduction, coordination of generating units or of distributed resources, interaction with loads (e.g. smart grids)

ENERGY STORAGE, HYDROGEN, FUEL CELLS

Y02E60

Technologies with potential or indirect contribution to emissions mitigation

All subclasses, including:

Energy storage:
- Battery technology; Ultracapacitors, supercapacitors, double-layer capacitors; Thermal storage; Pressurised fluid storage; Mechanical energy storage; Pumped storage

Hydrogen technology:
- Hydrogen storage; Hydrogen distribution; Hydrogen production from non-carbon containing sources

Fuel cells:
- characterised by type or design, incl. Proton Exchange Membrane Fuel Cells (PEMFC), Solid Oxide Fuel Cells (SOFC), Molten Carbobate Fuel Cells (MCFC), Bio Fuel Cells, Regenerative or indirect fuel cells, e.g. redox flow type batteries
- specially adapted for a certain application, incl. stationary, transport, portable appl.
- integrally combined with other energy production systems

NUCLEAR

Y02E30

Nuclear energy generation

All subclasses, including:
- Fusion reactors: Magnetic plasma confinement (MPC), e.g. tokamaks, stellarators; Inertial plasma confinement; Low temperat²ure fusion, e.g. "cold fusion"
- Nuclear fission reactors: Boiling water reactors; Pressurized water reactors; Gas cooled reactors; Fast breeder reactors; Liquid metal reactors; Pebble bed reactors; Accelerator driven reactors; Fuel; Control of nuclear reactions; Other aspects relating to nuclear fission

OTHER Y02

Y02E70

Other energy conversion or management systems reducing green-house gas (GHG) emissions

All subclasses, including:
- Hydrogen from electrolysis with energy of non-fossil origin, e.g. PV, wind power, nuclear
- Systems combining fuel cells with production of fuel of non-fossil origin
- Systems combining energy storage with energy generation of non-fossil origin
- Batteries, ultra-capacitors, super-capacitors or double-layer capacitors, charging or discharging systems or methods for reducing GHG emissions, e.g. auxiliary power consumption reduction, resonant chargers or dischargers, resistive losses minimisation, including those specially adapted for vehicles, for portable applications, etc.

Table A2. Summary statistics for the selected mitigation technologies

Field	Appln_id's in PATSTAT Y02-tagged
Renewable energy	152347
WIND	31354
SOLAR PV	59762
SOLAR THERMAL	38147
GEOTHERMAL	5321
MARINE & TIDAL	10984
HYDRO CONVENTIONAL	19619
Combustion-related techs	
BIOFUELS	18037
ENERGY FROM WASTE	11473
COMBUSTION	20793
CCS	19479
EFFICIENT ELECTRICITY GEN., TRANS., DISTR.	11823
ENERGY STORAGE, HYDROGEN, FUEL CELLS	292911
NUCLEAR ENERGY	65625
OTHER Y02	2756
Y02-TAG TOTAL	580154

Table A3. Number of priorities invented in African countries: 1980-2009

(Selected mitigation technologies – Y02 tags)

Inventor country	Wind	Solar PV	Solar thermal	Geothermal	Marine & tidal	Hydro conv.	Renewable energy (overall)	Biofuels	Energy from waste	Combustion	CCS	Energy storage, hydr., fuel cells	Nuclear energy	Efficient elect. gen, trans, distr.	Other Y02	Y02 TAGS TOTAL	PATSTAT TOTAL
South Africa	22	41	28		14	10	105	32	13	24	27	222	137	4		553	18166
Egypt	1	3	3		4	3	13	0.3		0.3		4	1			18	970
Algeria		8	8				8				2	2				12	160
Morocco	3	2	4			2	6				1	6		1	2	12	906
Kenya								5	5		1	2				8	211
Burundi	6		6	5			6									6	21
Ghana	6				1		6	0.3								6	65
Mali			1				1	2	2			2				5	41
Zimbabwe	2	1	2				4									4	139
Senegal			4				4									4	63
Tunisia		1	2				3					1				4	258
Côte d'Ivoire			2	1			2	1	1							3	59
Cameroon		1				1	2					1				3	111
Libya				1			1					2				3	17
Mauritius					2		2				0.3					2	90
Chad												2				2	8
Saint Helena								2				1				2	19
Gabon												2				2	38
Nigeria											0.3	1				2	146
Sao Tome/Pr.												2				2	66
Eritrea								1								1	8
Sudan	1		1				1									1	61
Mauritania	1						1									1	23
Sierra Leone						1	1									0.5	80
Ethiopia												1				0.5	51
Liberia												1				0.5	10
Niger											1					0.5	33
Swaziland			0.3				0.3									0.3	29
Rwanda		0.3					0.3									0.3	3
Seychelles																	49
Madagascar																	38
Namibia																	35
Congo																	28
Uganda																	28

Tanzania																	25
Burkina Faso																	21
Guinea																	18
Zambia																	18
Benin																	16
Togo																	14
Botswana																	9
Angola																	9
Reunion																	8
Gambia																	8
Malawi																	7
DR Congo																	7
Somalia																	7
Central Afr. Rep.																	6
Cape Verde																	4
Lesotho																	4
Eq. Guinea																	3
Djibouti																	3
Mozambique																	1
Comoros																	1
Grand Total	42	57	61	7	21	17	167	43	21	24	31	249	138	5	2	657	22220

Table A4. African inventions patented worldwide: 1980-2009
(Selected mitigation technologies – Y02 tags)

Application authority	Wind	Solar PV	Solar thermal	Geothermal	Marine & tidal	Hydro conv.	Renewable energy (overall)	Biofuels	Energy from waste	Combustion	CCS	Energy storage, hydr., fuel cells	Nuclear energy	Efficient elect. gen, trans, distr.	Other Y02	Y02 TAGS TOTAL	PATSTAT TOTAL
United States	8	13	14	2	3	2	35	12	6	5	7	93	24	1		178	5797
WIPO	8	7	12		9	6	35	9	5	6	3	18	32		1	102	2714
EPO	9	10	9	1	1	1	25	6	2	4	4	33	20	1		95	4212
Germany	2	4	1				7	1		0	3	59	11	2		83	2138
Canada	2	5	2		1	1	8	5	2	3	2	32	17			67	2064
China	3	3	5	1		1	8	2		2	0	12	17			41	1298
South Africa	4	1	7		5	5	18	3	3	1	1	12				34	2092
Austria	2	4	1				6	1			2	12	11			32	1268
Korea		3	0			1	4	2		2	1	8	5			22	742
UK	2	1			2	1	6	2	2	2	4	6				18	940
Japan	1	1					2	1		1	2	10				17	785
OAPI	1	1	7	1		1	10	3	3			2				15	275
Australia	2	1	4				6	0		1	1	7				15	1011
Spain	1	1					2	2			2	7				13	692
Mexico	1	3	3	1			5	1		2		4				12	404
Egypt	1	0	1		3	2	7	1				1				9	302
Denmark	2	1					3	1			1	1				6	258
Norway		1	1				1	0		2	3					6	280
Morocco		2	3				3					2		1	1	5	634
Russia								1		1		4				5	338
France												4				4	298
Chinese Taipei											1	2	1			4	198
EAPO		2					2	1		1	1					4	89
ARIPO		2	1				2					1				3	309
Netherlands											2	1				3	73
Hong Kong, China		1	1				1					2				3	72
Portugal		1					1	1			1					3	216
Algeria		2	2				2									2	61
Belgium	2		1	1			2									2	37
Brazil			1				1			1						2	370
Indonesia		1					1				1					2	55
Poland																-	171
Israel																-	148
Zimbabwe																-	40
ROW	2		1		1		2	2		1	2	2				9	1492
Grand Total	52	71	78	7	24	19	204	53	23	31	45	336	138	5	2	811	31876

Table A5. Number of patent applications registered with African authorities: 1980-2009

(Selected mitigation technologies – Y02 tags)

Application authority	Wind	Solar PV	Solar thermal	Geothermal	Marine & tidal	Hydro conv.	Renewable energy (overall)	Biofuels	Energy from waste	Combustion	CCS	Energy storage, hydr., fuel cells	Nuclear energy	Efficient elect. gen, trans, distr.	Other Y02	Y02 TAGS TOTAL	PATSTAT TOTAL
South Africa	142	143	177	12	70	50	533	176	76	194	203	771	376	62	11	2309	131507
OAPI	12	7	49	7	11	14	86	24	21	6	6	31		1		161	6280
Morocco	32	7	38		7	7	86	8	6	10	3	25	5	1	1	138	8280
Egypt	6	8	20		6	8	45	8	4	11	8	24	20			114	8149
Algeria		4	9			4	14	1	1	4	5	4				28	1391
ARIPO	3	3	6	3	2	3	14	2	1	2	2	3			1	22	5077
Zimbabwe	1	2	2		1	3	8	4	1		2	3				17	2089
Malawi			1				1	2			2					5	429
Kenya			1	1			2	2	1							4	557
Zambia					1		1				2					3	788
Sudan	2		1				2									2	31
Ghana	1				1		1									1	6
Tunisia																	22
Liberia																	2
Lesotho																	1
Libya																	1
Grand Total	199	174	304	23	99	89	793	227	111	227	233	861	401	64	13	2804	164611

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ANNEX B. SUPPLEMENTARY INFORMATION TO SECTION 4

Table B1. Patent search strategy for selected adaptation technologies 19

Field	Description	Temporary (Z) tag
DESALINATION	Membranes especially made for desalination and desalination processes using membranes are included. Processes for producing membranes, potentially suitable for desalination, are not included.	A_desalination
RAINWATER COLLECTION	Methods or installations for obtaining or collecting drinking water or tap water from rain water.	A_rainwater
SOLAR/WIND WATER PUMPING	Solar- and wind-powered water pumping.	A_solarwind pump
SOLAR WATER TREATMENT	Water treatment using solar energy, include sewage treatment, wastewater treatment and drinking water treatment. (Remark: Does not include treatment of sludge. May include some instances of use of other local power sources such as wind.)	A_solarwater treatment
SOLAR WATER TREATMENT - POTABILIZATION	Potabilization of water by means of solar power. (Remark: This is a sub-group of the more general class SOLAR_WATER_TREATMENT)	A_solarwater potabilization
HVDC	High-voltage direct current (HVDC) electricity transmission, incl. associated power electronics.	A_HVDC
ENERGY SUPPLY - REMOTE	Solar energy for remote locations (off-grid solar power, solar home systems, solar water heating, solar drying, energy storage), and similar wind-powered applications. (Remark: in 95% related to solar and/or wind, but other renewables at "home" level are included as well. Includes also other "solar household devices" (e.g. air conditioning), home photovoltaics, some grid-connected PV applications characterised by being remote/dispersed/ /distributed, either because of being presented as both (off-grid and grid-connected) or simply because the concept "off-grid" sometimes is difficult to screen.	A_remote
EFFICIENT LIGHTING - REMOTE	Lighting systems specially adapted for remote locations wherein alternative power sources may be required.	A_efflight
SOLAR COOKING	Solar cooking devices, e.g. solar ovens. (Remark: Documents relating to solar water heating (for hygienic purposes etc.) are tagged in A_remote. Some double classification may occur.)	A_solar cooking
RESILIENCE	Resilience of electricity supply systems to extreme weather events: strengthening power-lines, (under)ground power cables, etc. (Remark: Documents dealing with power cables/line/wires that are resilient to water, moist and corrosion, independently whether they are underground or aerial.)	A_resil
SEVERE WEATHER	Prediction and early warning for extreme weather events, such as storms and floods (Remark: Tsunami-warning systems are in principle excluded as tsunamis originate from earthquakes, which are not weather events.)	A_severe weather

[19] Based on information provided by the European Patent Office (Konstantinos Karachalios, Victor Veefkind, Javier Hurtado-Albir, and colleagues).

Table B2. Summary statistics for the selected adaptation technologies

Field	Appln_id's in PATSTAT Z-tagged
DESALINATION	13595
Off-grid water supply	
RAINWATER_COLLECTION	3410
WATERPUMP_SOLAR_WIND	1726
SOLAR_WATERTREAT	6105
SOLAR_WATERTREAT_POTABILIZATION	939
Dispersed electricity transmission	
HVDC	2127
Remote energy services	
ENERGY_SUPPLY_REMOTE	15417
EFF_LIGHTING_REMOTE	1916
SOLAR_COOKING	674
Weather-related	
RESILIENCE_ELECT_GRID	3926
SEVERE_WEATHER	737
Z-TAGS TOTAL	47108

Table B3. Number of priorities invented in African countries: 1980-2009

(Selected adaptation technologies – Z tags)

Inventor country	Desalination	Energy supply remote	Solar water treatment	Rainwater collection	Solar/wind water pump	Resilience	Z-TAGS TOTAL	PATSTAT TOTAL
South Africa	13	10	4	2	1	1	30	18166
Morocco	4		1	2	2		8	906
Egypt	6	1	1				7	970
Tunisia	1	1	1				3	258
Senegal		1	1				2	63
Algeria	2						2	160
Côte d'Ivoire		1					1	59
Libya					1		1	17
Mali		1					1	41
Cape Verde	1						1	4
Sudan	0.7						0.7	61
Cameroon			0.3				0.3	111
Niger	0.3						0.3	33
Kenya								211
Nigeria								146
Zimbabwe								139
Mauritius								90
Sierra Leone								80
Sao Tome/ Pr.								66
Ghana								65
Ethiopia								51
Seychelles								49
Madagascar								38
Gabon								38
Namibia								35
Swaziland								29
Congo								28
Uganda								28
Tanzania								25
Mauritania								23
Burkina Faso								21
Burundi								21
Saint Helena								19
Guinea								18
Zambia								18

Benin								16
Togo								14
Liberia								10
Botswana								9
Angola								9
Reunion								8
Gambia								8
Eritrea								8
Chad								8
Malawi								7
DR Congo								7
Somalia								7
Central African R.								6
Lesotho								4
Rwanda								3
Equatorial Guinea								3
Djibouti								3
Mozambique								1
Comoros								1
Grand Total	26	15	8	4	4	1	56	22220

Table B4. African inventions patented worldwide: 1980-2009
(Selected adaptation technologies – Z tags)

Application authority	Desalination	Solar water treatment	Energy supply remote	Solar/wind water pump	Solar water potabilization	HVDC	Rainwater collection	Solar cooking	Resilience	Efficient lighting remote	Severe weather	Z-TAGS TOTAL	PATSTAT TOTAL
South Africa	11	3	9	1			2		1			26	2092
United States	7	3	2	2			1					15	5797
WIPO	6		5	2					1			13	2714
EPO	7	1	1				1					10	4212
Australia	6	1	1	2								9	1011
UK	6			1								7	940
Canada	5	1	1									7	2064
Germany	5	1	1									6	2138
OAPI	2	1	3									6	275
Morocco	3	1					2					6	634
Egypt	4	0.3	1									5	302
Norway	5											5	280
China	3	1					1					4	1298
Spain	3	0.3										3	692
Brazil	3											3	370
Czech Rep.	3											3	125
Israel	3											3	148
Hungary	3											3	104
EAPO	3											3	89
Austria	3											3	1268
Japan	2											2	785
Korea	2	1										2	742
Portugal	2											2	216
Hong Kong, China	1						1					2	72
Chinese Taipei	2											2	198
Slovakia	2											2	57
New Zealand	2											2	110
Iceland	2											2	14
Bulgaria	2											2	33
ARIPO	2											2	309
Mexico	2	0.3										2	404
Russia												-	338
France												-	298
Denmark												-	258
ROW	13											13	1486
Grand Total	115	12	24	8	-	-	8	-	2	-	-	166	31876

Table B5. Number of patent applications registered with African authorities: 1980-2009

(Selected adaptation technologies – Z tags)

Application authority	Desalination	Solar water treatment	Energy supply remote	Solar/wind water pump	Solar water potabilization	HVDC	Rainwater collection	Solar cooking	Resilience	Efficient lighting remote	Severe weather	Z-TAGS TOTAL	PATSTAT TOTAL
South Africa	80	35	52	14	6	10	7	4	11	2	3	198	131507
OAPI	18	13	11	5	5	2	2	2		2		48	6280
Morocco	25	10	2	7	3		3			2		44	8280
Egypt	27	13	3	3	4			2	1			44	8149
ARIPO	19	12	9	3	6	4	1	4				43	5077
Algeria	4	3	1	1	2							9	1391
Zimbabwe			1	1								2	2089
Tunisia	1											1	22
Malawi	1											1	429
Zambia													788
Kenya													557
Sudan													31
Ghana													6
Liberia													2
Lesotho													1
Libya													1
Grand Total	174	86	79	34	26	16	13	12	12	6	3	389	164611