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Opportunities for coupling wind and coal based generation in the electricity sector

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List of Abbreviations

CAES: Compressed Air Energy Storage

CCS: Carbon Capture and Storage

H_2: Hydrogen

IGCC: Internal Combustion Combined Cycle

NG: Natural Gas

NREL: National Renewable Energy Laboratory

NETL: National Energy Technology Laboratory

O_2: Oxygen

PC: Pulverized Coal

Contents

Executive Summary

About this report

This report assesses opportunities to deploy new technologies coupling wind and coal-based electricity in regions with high wind power potential and heavy dependence on coal-based electricity. It summarizes current scientific models and procedures conjugating the operation of wind and coal-based generation, and performs an assessment of prospects for industrial scale deployment from a technical and economic perspective.

Technology to build wind-coal hybrid units

A survey of the current research on hybrid systems combining wind and coal-based electricity indicated that the following two technologies showed promise and could be successfully used to generate wind-coal hybrid units:

Water Electrolytic Hydrogen Production

Wind-based electricity is used to electrolyze water to generate hydrogen gas, which is then used to generate syngas fuel for running IGCC plants. This technology provides an effective solution to intermittency of wind power and transmission constraints on transmitting wind power from remote locations. Stand-alone wind farms isolated from the grid may be used to generate the hydrogen gas that can then be stored and transferred to IGCC plants.

Flexible operation of Carbon Capture and Storage (CCS) units in coal plants

The energy penalty of CCS operation is one of primary barriers to its widespread implementation. To compensate for losses in revenue due to reduced power output resulting from CCS energy penalty, optimized operation of flexible CCS in coal plants could be used to utilize excess wind power in the system that cannot be dispatched due to transmission constraints or insufficient demand.

Cost Estimates

Conceptual modelling of power plants used to compute the levelized cost of electricity (LCOE) produced by coupling wind with IGCC plants using water electrolytic hydrogenation indicates values in the range of 15-35 cents/kWh. However, studies indicate that considerable reductions in cost of production in the range of 3.1-3.45 $/MmBtu (which corresponds to reduction in LCOE values in the range of 11.20-12.50 cents/kWh) when the by-products of electricity production in IGCC plant are used to produce ammonia in co-located chemical plants. A study by the National Renewable Energy Laboratory (NREL) [20] indicates an LCOE value of ~7.2 cents/kWh for a system consisting of a 3000 MW IGCC plant equipped with flexible CCS and syngas storage, and a 1500 MW wind farm.

Scope of Implementation

An assessment of remaining coal reserves, current dependence of coal based electricity, wind power resources and government policies available to encourage wind-based electricity generation was performed, for the countries in the UNECE region. The assessment indicates that while only twelve out of the 12 out of 57 member countries in the UNECE region were selected based on this region, about 87% of total coal-based electricity in UNECE was attributed to these twelve countries in 2012, indicating that incorporation of wind-coal hybrid units could lead to significant reductions in CO_2 emissions in this region.

Why couple coal with wind?

Despite best efforts to integrate high levels of low-carbon renewable power (such as wind and solar) into the existing grid, the fact remains that current installed renewable power accounts for only about 22% [1] of the global electricity demand. Intermittency of wind and solar power is a primary deterrent to assimilation of wind and solar power with the existing power system in large quantities. Conventional coal-fired plants, on the other hand, are widely considered to be a reliable source of continuous electricity. A typical coal plant emits 3.5 million tons of CO_2 per year [2] making coal-fired plants the largest contributors of CO_2 emissions from the electricity sector. Current advances in technology indicate that it may be possible to find a middle ground of sorts by coupling wind and coal based electricity generation, providing substantial reductions in CO_2 emissions from coal plants and muting the variability of intermittent wind power.

Technologies coupling wind and coal

Two main technologies found to have potential for effective coupling of coal and wind based power:

Water Electrolytic Hydrogen Production

The total wind-based electricity available at a given time instant is not always dispatched to the grid because of constraints on availability of transmission lines or insufficient demand.

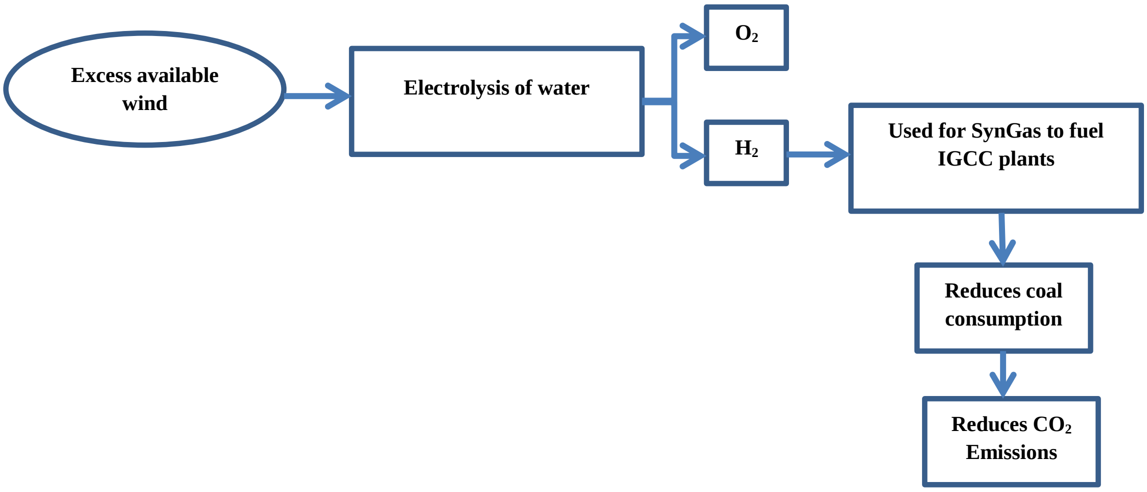

Figure 1 Schematic diagram outlining the basic operation of water electrolytic hydrogen production as a means to couple wind with coal

While solar power may also be used to perform electrolysis of water to obtain H_2 gas, a recent study [3] indicates that the cost of generating H_2 from water electrolysis using solar PV is about 23.27 $/kg, which is much higher than the cost of generating electricity from water electrolysis using wind power (estimated at about $4/kg on average [4])

Traditionally IGCC plants use a coal-based chemical reaction (or a mixture of coal and biomass) to generate hydrogen to be used in its combustion turbines. However current research [5] [6] indicates that up to 49% of the coal requirements for producing hydrogen could be reduced by using wind power for water electrolytic hydrogen production, thereby causing reductions in CO_2 emissions from the IGCC plant by up to 57% [6]. In addition, the IGCC plant may also be designed to incorporate Carbon Capture and Storage, resulting in further reduction in CO_2 emissions by 98-99% [7].

The oxygen generated as a byproduct of electrolysis may be sold to chemical factories or be used in the IGCC plant to generate remaining required hydrogen gas from coal [5]. Note that a similar procedure could be performed with biomass as the only source of carbon [1], however such technologies are not within the scope of this analysis and hence have not been described here.

Table 1 reports pilot projects being implemented by different organizations to demonstrate this technology:

Table 1 Pilot projects for water electrolytic hydrogen production to couple wind with IGCC plant operation

Brief Description of Project	Country	Organization	Status of Project
Water electrolytic hydrogen production by wind power applied to IGCC plants with CCS, co-fired by coal and biomass [8]	USA	National Energy Technology Laboratory (NETL)	Research and Development Phase
Water electrolytic hydrogen production by wind power applied to IGCC plants fired by coal. The oxygen produced as by-product is used as an input of a co-located fertilizer plant synthesizing ammonia [9].	USA	Leighty Foundation	Conceptual models and simulations
Water electrolytic hydrogen production by wind power applied to IGCC plants co-fired by coal and biomass. The oxygen produced as by-product is used as an input of a co-located fertilizer plant synthesizing ammonia [10]	New Zealand	CRL Energy	Small pilot scale system exists for co-fired IGCC with coal and biomass. Future steps outlined in the report indicated the need to build and study the performance of co-fired IGCC and hydrogen obtained from electrolysis of water by wind power
Water electrolytic hydrogen production by wind power applied to IGCC plants co-fired by coal [11]	Germany	Siemens	Development of a pilot project is one of the primary goals. As of now, projects on water electrolytic hydrogen with high efficiency has been developed.
Water electrolytic hydrogen production by wind or solar power applied to IGCC plants co-fired by coal [12]	China	Siemens	Ongoing work on use of H_2 obtained from electrolysis of water by wind or solar, in IGCC plant operation

The primary advantages of this system may be enumerated as follows:

- This technology provides an effective solution to intermittency of wind power and transmission constraints on transmitting wind power from remote locations. Stand-alone wind farms isolated from the grid may be used to generate the hydrogen gas that can then be stored and transferred to IGCC plants
- This could also be a means to avoid cycling costs and mechanical damage to base-load coal plants that are sometimes forced to rapidly ramp up and down their net power output to offset the variability of wind power in the system
- Additional revenues may be earned by selling the oxygen produced as a by-product of electrolysis to chemical industries

The primary barriers to widespread deployment of water electrolytic hydrogen production to couple wind and coal include:

- High capital costs: Current capital costs of installation of such systems are much higher than that of conventional power plants indicating the need for further improvements in efficiency to lower costs
- Low efficiency of the electrolysis procedure: The efficiency of utilizing wind power to electrolyze water is still quite low and further improvements in technology would be beneficial.
- Lack of financing and sufficient financial incentives to cut-down CO_2 emissions: One of the primary reasons why the deployment of low carbon technologies such as these are difficult is because of insufficient financial incentives to invest in reduction of CO_2 emissions from existing power plants. Policy mechanisms such as carbon taxes and tax credits for investing in plants with lower emissions may be recommended to attract investors interested in this technology.

Cost considerations

At present, conceptual models of power plants used to compute the levelized cost of electricity (LCOE) produced by coupling wind with IGCC plants using water electrolytic hydrogenation indicates values in the range of 15-35 cents/kWh [4]. This is relatively high compared to LCOE for conventional IGCC plants at ~7.72 cents/kWh [13]. The increase in LCOE value relative to Pulverized Coal (PC) (~5.92 cents/kWh) and NGCC plants (~5.89 cents/kWh) is even higher. However, studies indicate that considerable reductions in cost of production in the range of 3.1-3.45 $/MmBtu [14] (which corresponds to reduction in LCOE values in the range of 11.20-12.50 cents/kWh) when the by-products of electricity production in IGCC plant are used to produce ammonia in co-located chemical plants.

The H_2 produced from wind-based electrolysis of water can be stored for use during peak load or periods of high electricity demand. Thus, this technology may also be considered as a storage device rather than a conventional source of electricity. Under such considerations, an NETL study indicates that the levelized cost of generating electricity in IGCC from hydrogen produced by wind-based water electrolysis is much lower than that of Ni-Cd, NaS and Vanadium redox batteries and only slightly higher than pumped hydro or compressed air energy storage (CAES) systems [4].

It is to be kept in mind that most of these cost estimates are based on conceptual modelling rather than industrial scale units, so there may be additional reductions in cost obtained from economies of scale. Large scale deployment of such systems would also lead to a better understanding of the risks associated with financing such technologies.

Flexible operation of Carbon Capture and Storage (CCS) units in coal plants

Current state of the art CCS technology can capture up to 90% of total CO_2 emissions from coal plants. However, the use of CCS technology in coal plants may lead to as much as 40% reduction in net power output [15]. This energy penalty of CCS operation is one of primary barriers to its widespread implementation. To compensate for losses in revenue due to reduced power output resulting from CCS energy penalty, optimized operation of flexible CCS in coal plants have been proposed [15] [16] [17] [18] [19] to utilize excess wind power in the system that cannot be dispatched due to transmission constraints or insufficient demand.

Modelling and analysis of flexible CCS operation of coal-based plants (both IGCC and conventional thermal plants) indicated reduction of CO_2 emissions of up to 90%, a 20% improvements in profits relative to inflexible CCS operation [18] and considerable quantities of wind power integration within the range of 18-32% of the system nameplate capacity, depending upon the quality of wind power in the region [15] [16].

The following types of flexible CCS operation have primarily been studied in academic journals and reports by research organizations:

- Flexible operation of post-combustion amine based CCS unit through partial capture: This technology may be applied to base-load thermal power plants fuelled by coal. This involves the use of amine solution to capture CO_2 from flue gas generated by the plant. During periods of high electricity prices, when it is specially unprofitable to sell low amounts of net power due to CCS energy penalty, a portion or all of the flue gas is diverted away from the CCS unit thereby reducing the CCS energy penalty
- Flexible operation of post-combustion amine based CCS unit through solvent storage: This technology may be applied to base-load thermal power plants fuelled by coal. This also involves the use of amine solution to capture CO_2 from flue gas generated by the plant. The two primary steps of carbon capture in such systems include: capture of CO_2 and regeneration of CO_2 from the amine solution and subsequent compression and transfer of the compressed CO_2 to sequestration sites. The regeneration process accounts for 90% of the CCS energy penalty. During periods of high electricity prices, when it is especially unprofitable to sell low amounts of net power due to CCS energy penalty, we postpone the regeneration operation of the post-combustion amine based CCS unit. This means that the resulting CO_2 rich amine solution after the flue gas is passed over the original 'lean' amine solution is stored in tanks to avoid about 90% of the total CCS energy penalty.
- CCS in IGCC plants: A chemical process is used to convert the gasified coal to a pure stream of hydrogen thereby avoiding CO_2 generation when the combustion turbine generates electricity.

To date, no physical pilot projects have been attempted to demonstrate flexible CCS operation in conjunction with coal. However, there exists a vast body of literature in scientific journals that model the behaviour of optimized operation of flexible CCS units of coal plants in conjunction with wind power and are summarized in **Error! Not a valid bookmark self-reference.**.

Table 2 Summary of primary types of models studied by researchers to assess the potential of coupling flexible CCS operation in coal plants with wind farms

Brief Description of Project	Country	Organization	Status of Project
Analysis of advanced coal-wind hybrid system with flexible CCS operation in Wyoming that would supply power to load centers in California, Arizona or Nevada. The system consists of a 3000 MW IGCC plant equipped with flexible CCS and syngas storage, and a 1500 MW wind farm [20].	USA	NREL	Conceptual modeling
Model of flexible operation of post-combustion amine based CCS system either through partial capture or solvent storage technology in a base-load coal plant with an auxiliary NG plant and co-located wind farm [18]	USA	Stanford University	Conceptual modeling
Model of flexible operation of post-combustion amine based CCS retrofit in existing coal plant either through partial	USA	Duke University	Conceptual modeling

capture or solvent storage technology and a co-located wind farm [15] [16]			
System wide analysis of the benefits of having flexible CCS operation to offset the intermittency of renewable power [17]	Germany	Brandenburg University of Technology	Conceptual modeling

The primary advantages of this system may be enumerated as follows:

- This technology (especially flexible operation of CCS retrofits for existing coal plants) provides a way to keep existing coal plants online while drastically cutting down CO_2 emissions. This is important because the popular alternative of replacing majority of existing coal plants with NGCC plants would make the power system vulnerable to NG prices which are generally much more volatile than coal prices. Also, this technology could potentially be of interest in developing nations with high percentages of sub-critical coal plants that still have several years of operational life remaining.
- Similar to water electrolytic hydrogen production using wind, this avoids increased expenses for transmission lines and mutes the variability of wind power

The main barriers to implementation of this technology include:

- Lack of sufficient incentives and financing to cut down CO_2 emissions leads to fewer number of investors interested in financing such projects
- High Capital Costs: Current capital costs of CCS retrofits are estimated to be much higher than that of existing coal plants and further research is essential to bring improve efficiency, cut down energy penalty and reduce costs of installation of CCS
- Lack of pilot projects to give a sense of challenges that would be faced during industrial-scale deployment of this technology, such as mechanical wear and increased energy usage due to cycling of coal plants and CCs units to offset variable wind power. Although recent publications modelling flexible operation of CCS using Aspen software seems to indicate minimal damage to the CCS unit [21], physical systems for such units do not exist yet.

Cost considerations

To the best of our knowledge only one attempt to perform conceptual modelling for industrial scale deployment of such systems has been made. A study by the National Renewable Energy Laboratory (NREL) [20] indicates an LCOE value of ~7.2 cents/kWh for a system consisting of a 3000 MW IGCC plant equipped with flexible CCS and syngas storage, and a 1500 MW wind farm. The cost models of academic papers [15] [18] [21] [17] indicate higher revenues relative to plants with inflexible CCS operation but do not include factors such as cost of procuring additional land to install wind farms and the costs of transporting compressed CO_2 to sequestration sites.

Comparison of Costs of Wind-Coal Hybrid technologies with conventional sources of electricity

Table 3 compares the cost of wind-coal hybrid technologies with that of other existing power generation units. Please refer to appendix 1 for details on how these costs were calculated.

Table 3 Cost Comparison of Wind-Coal Hybrid technologies with other existing technologies in 2014 US Dollars

Technology	Conversion Factor	Cost	Source
System coupling wind with IGCC plants using water electrolytic hydrogenation	0.92302	Range: 13.85-32.31 cents/kWh	[22]
Conventional IGCC plant	1.01742	Average: 7.85 cents/kWh	[23]
Pulverized Coal (PC) plant	1.01742	Average: 6.02 cents/kWh	[23]
NGCC Plant	1.01742	Average: 5.99 cents/kWh	[23]
Reductions in LCOE of IGCC plants by sale of ammonia as a by product	1.01742	Range: 11.39-12.75 cents/kWh	[24]
Ni-Cd Battery	0.92302	Median: 76.61 cents/kWh Range: 41.53-92.30 cents/kWh	[22]
Na-S Battery	0.92302	Median: 23.07 cents/kWh Range: 20.31-27.69 cents/kWh	[22]
Vanadium Redox Batteries	0.92302	Median: 25.84 cents/kWh Range: 20.31-46.15 cents/kWh	[22]
Pumped Hydro	0.92302	Median: 11.99 cents/kWh (9.21-16.61 cents/kWh)	[22]
CAES	0.92302	Median: 9.23 cents/kWh (7.38-13.85 cents/kWh)	[22]
IGCC plant equipped with flexible CCS and syngas storage co-located with wind farm	1.01742	7.32 cents/kWh (approx.)	[25]
Flexible CCS operation with solvent storage to incorporate more wind in the power system in the Netherlands (Includes capital Cost of Coal Plant)	0.97389	54.53 eurocents/kWh[1] (69.46 cents/kWh)	[26]
Flexible CCS retrofit with solvent storage and co-located wind farm	0.97389	Range: 9.60-12.91 cents/kWh	[27]

Scope of Implementation of coal-wind hybrid technologies within the UNECE region

UNECE Member States

The UNECE region consists of the countries in Europe, United States, Canada, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, and Israel [28] [29].

Scope of Implementation

An assessment of remaining coal reserves, current dependence of coal based electricity, wind power resources and government policies available to encourage wind-based electricity generation was performed in this section.

The criteria for selection were as follows:

1. The country was among the top 30 nations worldwide with highest coal reserves
2. At least ~10% of annual generation in the region is coal based
3. The energy policy in the region encouraged integration of wind power by either:
    a. Assigning national targeted MWs of installed wind power capacity within the next 15 years

[1] Currency exchange rate from IRS (http://www.irs.gov/Individuals/International-Taxpayers/Yearly-Average-Currency-Exchange-Rates) @ 0.785 Euro/USD in 2010

b. Provided financial support in the form of tax deductions, feed-in-tariffs etc.

Although only 12 out of 57 member countries in the UNECE region were selected based on this region, about 87% of total coal-based electricity in UNECE was attributed to these twelve countries in 2012.

Table 4 lists the twelve countries in the UNECE region that could benefit from installation of wind-coal hybrid technology, and the amount of electricity generated from coal units expressed as a percentage of the annual coal-based generation in the UNECE region in 2012:

Table 4 Countries that could benefit from installation of wind-coal hybrid units

Country	Percentage of coal-based generation relative to coal-based generation in the entire UNECE Region (2012)
Bulgaria	1%
Canada	2%
Czech Republic	2%
Germany	9%
Greece	1%
Kazakhstan	2%
Poland	4%
Russian Federation	5%
Spain	2%
Turkey	2%
Ukraine	3%
United States of America	53%
Total	87%

Table 5 summarizes the wind power potential, existing coal reserves as well as estimates of coal and wind based generation expressed as a percentage of total annual generation in order to give an indication of the scope of implementation of coal-wind hybrid technologies in the UNECE region.

Table 5 Scope of Implementation of coal-wind hybrid technologies in the UNECE region

Member Countries of the UNECE	Coal reserves (Million tonnes)	% of annual generation currently attributed to coal (2012)	Wind Energy potential, Targets and Policy Support for Wind power development	% of Annual Generation currently attributed to Wind Power (2012)	Comments
Albania	794.0000355	0%	Low wind power potential (Average WP density is 100 W/sq. meters at 75 meters)	0%	Country reports indicated that coal mining not profitable in this region
Andorra	NA	0%	NA	NA	No information found on coal or wind resources in this region

Armenia	163.0000057	0%	302 MW (or ~7% of total generation by 2020). Total Wind Power Potential: 11050 MW	0%	
Austria	333.0000122	9%	No set targets or policy in place specifically for wind. Wind resource potential at 3544 MW	4%	
Azerbaijan	NA	0%		0%	No information found on coal (probably no resources in this region)
Belarus	100.0000081	0%	Feed in tariffs available for wind power. Wind resource potential at 1600 MW	0%	
Belgium	NA	7%	Wind Power Potential in the region: 4320. Green certificate scheme in force for renewable energy including wind power	4%	No information found (probably no resources in this region)
Bosnia and Herzegovina	2853.000127	70%	Wind Power Potential in the region: ~2000. Benefits such as feed-in tariffs, preferntial dispatch available for renewable power including wind power.	0%	
Bulgaria	2366.000107	49%	Wind Power Potential in the region: 2200-3400. Feed-in-tariffs available	3%	Among top 30 nations with highest coal reserves
Canada	6582.000292	10%	Wind power potential estimated to satisfy 200% of current energy demand in Canada not considering reliability requirements. Funding for industrial research available for wind power. Feed-in-tariffs provided certain raw materials come from Ontario	2%	Among top 30 nations with highest coal reserves
Croatia	4.000004315	22%	Feed in tariffs available for wind power. Wind resources indicated to be favourable in 2014 report by European Wind Energy Association	3%	
Cyprus	NA	0%		4%	
Czech Republic	1052.000046	54%	Wind Power Potential in the region: 12500. Strict environmental planning regulations make only 15-20% of favourable wind power locations available	1%	Among top 30 nations with highest coal reserves
Denmark	NA	34%		36%	
Estonia	NA	4%		4%	
Finland	NA	11%		1%	
France	NA	4%		3%	
Georgia	201.0000059	0%	Wind Power Potential in the region: 4 billion kWh (2283 GW at 20% capacity factor). Favourable regulatory structure, government offers guaranteed purchase price for renewable power during winter months	0%	
Germany	40548.00179	46%	10 GW onshore installations targeted by 2020. Guaranteed purchase price available. As of now, wind power installations cannot be contested.	9%	Among top 30 nations with highest coal reserves

Greece	3020.000137	51%	Estimated 10 GW of wind power potential. Feed-in-tariffs available	7%	Among top 30 nations with highest coal reserves
Hungary	1660.000076	19%	330 MW ceiling for wind power enforced to maintain reliability of grid. Exemption from Environmental Impact Assessment for all renewable power sources	2%	
Iceland	NA	0%		0%	
Ireland	14.00000149	20%	Wind power target of 6000-7000 MW by 2020. Feed-in tariffs available. Grants and subsidies available for micro-generation	16%	
Israel	NA	61%		0%	
Italy	50.00000404	18%	Onshore wind power target of 12 GW by 2020. Feed-in tariffs available.	5%	
Kazakhstan	33600.00148	76%	Solar and wind power targeted to be >3% of total generation by 2020	0%	Among top 30 nations with highest coal reserves
Kyrgyzstan	812.0000322	5%	Limited Data available about Wind resources. No wind farms in this region.	0%	
Latvia	NA	0%		2%	
Liechtenstein	NA	0%		NA	
Lithuania	NA	0%		14%	
Luxembourg	NA	0%		4%	
Malta	NA	0%		0%	
Moldova	NA	0%		0%	
Monaco	NA	0%		NA	
Montenegro	142.0000035	48%	Approximate wind energy potential: 400 MW. Feed-in-tariffs available for wind power	0%	
Netherlands	NA	27%		5%	
Norway	5.000003126	0%	Addition of 5,800-7,150 MWs of wind power possible by 2025	1%	
Poland	5465.000241	84%	Wind power target of 6.65 GW of Energy by 2020.Market based mechanism called Green certificates in place to ensure purchase of renewable electric power	3%	Among top 30 nations with highest coal reserves
Portugal	36.00000255	29%	No estimates of specific targets or potential for wind energy found, but current growth rate of wind energy is ~10% annually	24%	
Romania	291.0000168	39%	Wind Power Potential of 14000-15000 MW	5%	
Russian Federation	157,007	16%	Estimated Wind Power Potential 700 GW	0%	Among top 30 nations with highest coal reserves
San Marino	NA	0%		NA	
Serbia	13411.00059	73%	Currently 2.6 GW of wind power installation planned but projects have been stalled due to siting and permit requirements. Feed-in tariffs available	0%	

Slovakia	262.000015	14%	Targeted wind farm installations of 1000 MW. Current regulatory threshold for wind power set at 450 MW. Feed-in-tariffs available	0%	
Slovenia	223.000007	33%	Targeted wind farm installations of > 100MW between 2010-2020	0%	
Spain	530.0000229	19%	Currently there is overcapacity of wind based generation in Spain	18%	Among top 30 nations with highest coal reserves
Sweden	NA	1%		4%	
Switzerland	NA	0%		0%	
Tajikistan	375.0000167	0%	Wind Power potential of >25 TWh annually or 8153 GW (considering a 35% Capacity Factor)	0%	
The former Yugoslav	NA	NA		NA	
Republic of Macedonia	NA	NA		NA	
Turkey	8702.000383	28%	Wind power installed capacity target is 20,000 MW by 2023. Feed-in-tariffs available	3%	Among top 30 nations with highest coal reserves
Turkmenistan	NA	0%		0%	
Ukraine	33873.00149	41%	12 GW of onshore wind farm installations targeted by 2030. Feed-in-tariffs available	0%	Among top 30 nations with highest coal reserves
United Kingdom of Great Britain and Northern Ireland	231	40%	28 GW of wind power installation targeted by 2020. Feed in tariffs available	6%	Among top 30 nations with highest coal reserves
United States of America	237,292	38%	11000 GW onshore wind power potential. Renewable Energy Portfolio Standards enforced by some states and funding for renewable energy projects available	3%	Among top 30 nations with highest coal reserves
Uzbekistan	1900.000081	4%	520 GW of wind power potential	0%	

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