APPENDIX A – USELF RENEWABLE ENERGY SCENARIOS

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Table A1 – USELF RENEWABLE ENERGY SCENARIOS

Resource scenario	Resource characteristics	Grouped Technologies or "Projects"	Technology characteristics	Areas with good potential	Technical Exclusions	Construction Activities	Development Scenario Scale?
Wind	Wind resources with wind density above 300 W/m^2.	Comprised of modern wind turbines of 2.0-3.0 MW each. • Small farms (<20 MW or 7-10 turbines) • Medium farms (20-100 MW or 10-50 turbines) • Large farms (>100 MW or 50 plus turbines)	Components: -turbines (7 to10 for <20MW, 10 to 50 for 20-100MW, 50+ for >100MW). Turbine towers are up to 100m high, blades are 100m diameter, and foundations are under 20m diameter and 4m deep). -meteorological towers (10 or less, 50-135m high). -collection and interconnection system – larger projects will require substations and overhead lines to connect to transmission system Land take: 18-48ha per MW. Effected areas are 2-8% of overall project. Higher density of turbines possible on ridge lines, but higher percentage of impacted land areas. Other land uses possible during operation e.g. animal grazing. Maintenance: Annual maintenance required. May need to bring in cranes for major repairs and replacements. Lifespan: 20-25 years. Life can be extended by replacement of turbine components and blades, but keep towers and foundations. Emissions: N/A Water requirement: N/A Waste: N/A Availability of components: Limited availability in Ukraine at present for wind turbines and steel towers, but the balance of plant can likely be sourced from general construction companies.	Crimea, Southern Coastal Ukraine, Donbass region (Luhansk, Donetsk), Western Ukraine-foothills of the Carpathians (Lviv and Ivano-Frankivsk) being best wind resources in Ukraine, and Central Ukraine (Dnieper River).	-Power density <300 W/m^2 -Slope >20% -Urban Areas -Major Waterbodies	Construction of a wind energy project is likely to involve the following major actions: • erection of meteorological towers (to gather data) • establishing site access • performing site grading • constructing lay-down areas and an on-site road system • removing vegetation from construction and lay-down areas (primarily for fire safety) • excavating for tower foundations • installing tower foundations • erecting towers with cranes • installing nacelles and rotors • installing permanent meteorological towers (as necessary) • for large farms, constructing the central control building and a weatherproof equipment and parts storage area (which may be separate or combined with the control building) • constructing electrical substations • interconnecting towers, the control building, meteorological towers, and substations with power-conducting cables and signal cables Additional activities may also be necessary at very remote locations or for very large wind energy projects; they can include constructing temporary offices, sanitary facilities, or a concrete batching plant.	Total Wind Only Development Scenario is 14 400MW across country. Combined Wind and Solar Development Scenario is 13 300 MW of wind and 2 600 MW of solar across the country.
Solar (PV)	Solar Insolation for Optimal Tilt and Tracking PV	Utility-scale, ground-mounted projects. • Small (1-5 MW) • Medium (5-20 MW) • Large (>20 MW) Rooftop installations are not included in this resource scenario.	Components: PV modules (can be on fixed tilt or tracking axes), inverters (converting DC to AC current), racking, and interconnection infrastructure, as well as measurement and monitoring devices. Land take: 2.3 to 4.5 ha per MW depending on type and axis tracking. Maintenance: Limited maintenance required. Remote monitoring and occasional panel washing. Lifespan: Approximately 20-30 years. Life can be extended by replacing panels but keeping racking system. Inverters and cabling may also need to be replaced or refurbished.	Southern Ukraine (Crimea and Odessa) has highest insolation, though Green Tariff may allow for projects to be economic in most areas in Ukraine (with the exception of the westernmost oblasts and mountainous terrain areas)	-Low solar insolation areas -Slope >5% -Major Waterbodies -Forested land .	Construction of any solar energy development project is likely to involve the following major actions: • establishing site access • performing limited site grading, sites with no grading required are preferred • constructing laydown areas and an on-site road system • removing vegetation from the solar field, construction, and laydown areas (primarily for fire safety) • constructing the solar field	Total Solar Only Development Scenario is 9 900 MW across country. Combined Wind and Solar Development Scenario is 13 300 MW of wind and 2 600 MW of solar across the country.

Resource scenario	Resource characteristics	Grouped Technologies or "Projects"	Technology characteristics	Areas with good potential	Technical Exclusions	Construction Activities	Development Scenario Scale?
			Emissions: N/A Water requirement: N/A Waste: N/A Availability of components: limited production in Ukraine at present. Largest supplier produces 12MW of cells annually. (need to be verified) Aside from solar panels, remaining balance of plant can likely be sourced from general construction companies and steel producers in the country.			• central control building • a weatherproof area for minor maintenance and for storage of equipment and parts (which may be separate or combined with the control building) • electrical substations • meteorological stations (if not done during site characterisation) Additional activities may also be necessary at some facilities, including, constructing sanitary facilities, temporary offices, and landscaping. On-site construction activities of a 30 MW PV plant could be completed in 15 weeks with 3 crews working in parallel (10 MW blocks each), excluding commissioning.	
Small Hydro	River Flow and Existing Hydro Project Sites	Hydro projects are constrained by Green Tariff definition of Small hydropower (<10 MW of capacity) • Small hydropower with Impoundment • Hydro Retrofit/Rehab at retired/existing hydro sites (presumed at existing impoundments)	Components: includes impoundment (dam, weir, or diversion structure), turbines, generator, powerhouse, penstock, intake, draft tube and control systems. Land take: typically very small footprint for powerhouse and tailrace; could be long narrow linear area for penstock/pipeline. More detail is available for different sized projects in report. -Example of typical 1 MW Mini Hydro facility with impoundment would have this approximate footprint: • Dam (with impoundments): <25 m • Reservoir (optional): 7-10 ha • Powerhouse: 100 m2 • Penstock: 100-1 000 m length (1.0 m diameter) • Tailrace: <75 m length Sizing varies due to site conditions, river flow, etc and does not scale linearly. Operations: May be operated as run-of-river where inflow is equal to flow in the river system at all times. Alternatively, may be controlled (storage or non run-of-river) operations may adjust inflow as needed or have some kind of storage/reservoir to shift timing and volume of flow. Maintenance: requires regular maintenance and inspection, but may not need on-site staffing. Lifespan: >50 years with proper maintenance Emissions: All types of hydro projects will cause some decomposition of inundated plant matter, releasing CO^2.	Carpathian area (Dniester, Tissa River Basins) and Central Ukraine area (larger tributaries of Dnieper).	-Areas away from existing watercourses -very low head -low to intermittent stream flow -Exclusionary areas (for example, parks and recreational areas) - Very steep terrain	<u>New Small Hydro (<10MW)</u> Major on-site construction activities will likely include: • Geotechnical investigations and drilling • Construction of access roads • Installation of river diversion • Mobilisation of cranes and other major equipment • Excavation works for temporary and permanent civil structures (dam, waterway, powerhouse) • Construction of concrete or earthen dam, including vibration and compaction of material • Installation of hydraulic steel structures • Placement and installation of major equipment, valves, turbines, generator • Installation of electrical work (conduits, station power, transformer, transmission lines) <u>Retrofit / Rehab at Existing/Retired sites</u> Major on-site construction activities will likely include: • Installation of hydraulic steel structures • Placement and installation of major equipment, valves, turbines, generator • Installation of electrical work (conduits,	Total potential is 50-100 MW in Carpathian region.

Resource scenario	Resource characteristics	Grouped Technologies or "Projects"	Technology characteristics	Areas with good potential	Technical Exclusions	Construction Activities	Development Scenario Scale?
			Water requirement: Water passes through for generation. All water for turbine/generator is returned to the adjacent stream. Waste: N/A Availability of components: Generally available in-country due to large hydro construction experience, but most advanced turbines and generators for small hydro applications may not be readily available.			station power, transformer, transmission lines) • In cases, where the civil works need refurbishment as well certain existing structures are rehabilitated	
Biogas	Landfill Gas (LFG)	Minimum size will be limited by available LFG at site. • Microturbines (30 – 250 kW) • Internal combustion engines (ICE) (500 kW–3 MW) (most common) • Single-cycle gas turbines (>3 MW) ** Pending Green Tariff rule change to qualify LFG for tariff.	Components: LFG collection system to extract trapped gases (multiple wellheads connected to lateral piping), gas cleaning, power generation turbines / engines, and sometimes a boiler to utilise waste heat. Land take: Require entire landfills, ranging from 10-35 ha, although it is noted that these would already be in existence. Maintenance: Periodic maintenance required for engine and generator parts, as well as gas cleaning equipment. Major overhauls every 20 000-72 000 hours of operation, depending on technology. Lifespan: LFG projects are typically 15 years due to decline in gas in the landfill, Emissions: Methane, CO^2, NOx, SOx, VOCs, CO, and PM10s Water requirement: Minimal water requirements Waste: n/a Availability of components: Small generator sets are potentially available in the country as they are standard equipment. Collection system is also fairly standard equipment.	Landfills near high population centres with sufficient size Top sites and footprints are identified in map and Appendix.	Landfill sites that are too small for economic development are excluded. In general, LFG is more economically feasible at sites with >1 million tonnes waste, >10ha available for gas recovery, waste depth >12 meters and >60cm precipitation annually, but conditions may vary -Landfills that are not capped or covered; it is not standard practice to cap landfills in Ukraine, but they would need to be capped for effective LFG capture	The specific requirements of construction are project specific and dependent on the biogas source (LFG, animal manure and substrate type) and the size of the project. The following list covers typical expected construction activities: • construction of access roads, securing site (e.g. fences, gates) • clearing and grubbing of the site, removal of vegetation • performing site grading and excavation (shallow), • construction of underground utilities,(water, drainage) • construction of gas collection facilities (LFG) 1. construction of wells 2. installation of gas collection system 3. installation of lining / cover • construction of manure / substrate collection system (animal manure) 4. site specific, dependent on amount and type of substrate and proximity of animals to anaerobic digestion facility 5. may include activities such as installation of trenched piping and pumps • erection of steel and reinforced concrete structures, 6. foundations for gas cleaning equipment, mechanical power generation facilities, AD tanks, 7. construction of formwork 8. pouring, compacting concrete, curing and stripping of formwork 9. erection of steel members • installation of mechanical equipment 10. gas cleaning equipment (foam/sediment,	Total development scenario at the sites identified total 48 MW across country.
	Animal Waste	Anaerobic digester coupled with ICE. (250 kW to 5 MW). Power only or CHP. ** Pending Green Tariff rule change to qualify biogas for tariff.	Components: Anaerobic digester, gas cleaning, power generation turbines / engines, and sometimes a boiler to utilise waste heat. Landtake: About 1-5 ha (does not include land for animals to produce the waste) Maintenance: Periodic maintenance required for engine and generator parts, as well as gas cleaning equipment. Major overhauls every 30 000-72 000 hours of operation, depending on technology. Anaerobic digester requires constant monitoring and cycling of waste material. Lifespan: Biogas projects can continue as long as there is animal waste production and equipment is repaired/overhauled according to schedule. Generator sets last about 20-25 years.	Where larger cattle, pig, and poultry farming operations exist. Higher density of animal population in north central and northwest part of country, as well as Dnipropetrovk. Anaerobic digester may also have mixed wastes if different animal operations are in close proximity.	Less than 1 000 m3 of methane per day : Small to medium cattle operations (less than 2 000 adults in one location) Small to medium sized pig operation (less than 6 000-8 000 heads in one location))). Small to medium sized poultry operation (less than 100 000 heads in one location).		Total development scenario is 160 MW across country.

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			Emissions: CO^2, NOx, SOx, VOCs, CO, and PM10s Water requirement: TBD Waste: Solid and liquid digestates. The solids can be used directly or composted. The liquid fraction may either be recycled for dilution of fresh waste, applied to land as a liquid fertiliser (frequently requires licensing), or sent to a wastewater treatment plant (often following some separation of solids). Availability of components: Small generator sets are potentially available in the country as they are standard equipment. Anaerobic digestion components may need to be imported or custom built.			CO2 removal, H2S removal, dewatering, siloxane removal equipment) 11. power generation equipment (ICE), • start-up, testing, and acceptance Additional activities may also be necessary at very remote locations or for very large facilities; they can include constructing temporary offices, sanitary facilities, or a concrete batching plant.	
Biomass[1]	Wood Residue	Direct-fire in power-only or CHP configurations. • Small Stoker CHP (<5 MW) • Stoker (20-50 MW) • Bubbling fluidised bed (20-50 MW) • Replacement boiler (50 MW)	Components: fuel handling/ preparation, boiler and air control, steam turbine and auxiliaries, other plant, woody biomass receipt (for a 50MW plant, approximately 70 truckloads of material required each day). Height: Boiler building is approximately 40-65m with stack height of approximately 75-120m (dependent on emissions regulations). Land take: 50MW stoker and bubbling fluidised bed schemes will be approximately 7-20ha (large fuel handling and storage areas required). Size of project and land take is proportional. New CHPs would be approx 1ha. Maintenance: Removal the sticky material from the boiler surfaces requires soot blowing, operational procedures such as slag shedding, or regularly scheduled outages to manually clean the unit. Annual boiler overhaul. Turbine and generators need to be inspected every 6 years. Coal plants with replacement boilers would employ existing staff, utilise existing transmission access, and other pre-existing site facilities. The continued operation and maintenance, compared to a coal plant, would need to be modified, primarily to address unique fuel handling requirements for biomass compared to coal. Fuel Requirement: 500 000 tons per year for 50 MW plant and 54 000 tons per year for 5 MW Life span: 25-30 years, but may be longer with proper maintenance and periodic major components overhauls Emissions: limited SO^2, NOx and PMs Water requirement: approx 4000 cu metres per day if water	Higher concentrations in northern Ukraine (Zhytomyr, Kiev, and Chernihiv, and Zakarpattia).	No technical exclusions except that biomass fuels for power generation will be competing with alternative uses for the biomass material, which will determine the availability and cost-effectiveness of the fuel for power generation. -Fuels should be sourced typically within 100km of site to be cost effective. Up to 300km away from high quality/ very economic fuel source.	Onsite Construction: • Civil / Site Development (roads, grading, fences, utilities) • Construction of Structures and Facilities • Major Equipment Installation • Instrumentation, Controls, and Communication • Switchyard Construction (electrical substations, etc) • Interconnection to Transmission Major Equipment: • Materials Handling System • Boiler • Steam Turbine Generator • Cooling Tower, Condenser & Circulating Water System • Pollution Control Systems • Ash Handling Equipment	Total development potential of **1 114** MW for wood and agricultural residue combined across country.

[1] Co-firing biomass with non-renewable fuels does not qualify for Green Tariff.

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			cooled and 750-1000 cu metres per day if air cooled (more prevalent in Europe). For 5 MW CHP, water is recycled so only need 40 cu. metres per day Waste: Ash content in wood residues is 1.5-4% of fuel (by weight) – 5 to 6 times less than coal. Some slag is produced. Availability of components: Boilers and fuel handling/ transportation equipment are potentially available in the country as they are standard equipment for coal power plants.				
	Agricultural Residue (wheat, barley, straw, rapeseed straw, corn and sunflower)	Direct-fire in power-only or CHP configurations. • Small Stoker CHP (<5 MW) • Stoker (20-50 MW) • Bubbling fluidised bed (20-50 MW) • Replacement boiler (50 MW)	High transportation levels required as fuel is roughly four times lower bulk density than coal. For a 50MW plant, 70 truckloads of material required each day. Components: fuel handling/ preparation, boiler and air control, steam turbine and auxiliaries, other plant, agricultural residues receipt (for a 50MW plant, approximately 70 truckloads of material required each day). Height: Boiler building is approximately 65m with stack height of approximately 75m for a 100MW plant. Landtake: 50MW stoker and Bubbling fluidised bed schemes will be approximately 7-25ha (large fuel handling and storage areas required). Size of project and landtake is proportional. New CHPs would be approx 1ha. Maintenance: Same as above. For agricultural residue, more frequent cleaning of heat transfer surfaces is needed to minimise slagging. Fuel Requirement: 380 000 tons per year for 50 MW plant and 41 000 tons per year for 5 MW CHP Lifespan: 25-30 years, but may be longer with proper maintenance and periodic major components overhauls Emissions: limited SO^2, NOx and PMs Water requirement: approx 4 000 cu meteres per day if water cooled and 750-1 000 cu me per day if air cooled (more prevalent in Europe) For 5 MW CHP, water is recycled so only need 40 cu. Meters per day Waste: Ash content in agricultural residues is 2-8% of fuel (by weight) – 5 to 6 times less than coal. The ash is also high in alkali, which has potential to be sticky and cause slagging and fouling. Slagging requires regular maintenance (potentially through the addition of limestone). Availability of components: Boilers and fuel handling/ transportation equipment are potentially available in the country as they are standard equipment for coal power plants.	Preliminary data shows good concentrations across most of Ukraine, and notably higher potential than wood residue (capacity for	Power generation will be competing with alternative uses for the biomass material, which will determine the availability and cost-effectiveness. For agricultural residue, additional competition for current uses of land application as fertiliser.		