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UKRAINE SUSTAINABLE ENERGY LENDING FACILITY (USELF)

Renewable Energy in Ukraine Technical Report: Biomass

One of five technical reports on Renewable Energy for the USELF Strategic Environmental Review

September 2011

USELF RENEWABLE ENERGY IN UKRAINE PROJECT SCENARIOS: BIOMASS

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Details of document preparation and issue:

Version Nº	Prepared by	Reviewed by	Authorised for issue	Issue date	Issue status
v1	Mon Hong (others to be added)	Mon Hong	Jay Abbott	May 11 2011	EBRD Bank Draft
v2	Mon Hong Trevor Curry	Mon Hong	Jay Abbott	September 1, 2011	EBRD Bank Draft
v3					

B&V project no. 167767 Client's reference no. TCS ID 29098

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USELF RENEWABLE ENERGY IN UKRAINE PROJECT SCENARIOS: BIOMASS

1. INTRODUCTION

The purpose of this technical report is to provide the USELF Strategic Environmental (SER) team with a representative scenario for biomass development in Ukraine as the team develops the SER report. The analysis examines potential locations, technologies and operating conditions for the biomass scenario. It focuses on the technical constraints associated with the availability of the resource and the technologies that employ the resource, but does not address environmental and socioeconomic constraints that will be discussed in the SER separately. This is not intended to preclude or limit the future development of other technologies that have not been identified here for review.

The report is organized into two sections:

- Resource and Potential
- Technology Characteristics

Section 2 (Resource and Potential) of the report provides the SER process with country-wide background on the availability and quantity of the biomass resource, as well as potential locations or higher concentrations of biomass resources in Ukraine.

Section 3 (Technology Characterstics) describes the technologies that employ the resource for electricity production and details the performance characteristics, emissions, interconnection and operations and maintenance needs of the technology, as well as the availability of the technology components in Ukraine. The section also examines typical site considerations and construction activities associated with biogas projects as inputs to the SER report.

The two primary categories of biomass fuel sources examined herein are wood residue[1] and agricultural residue[2] resources.

2. RESOURCE AREAS AND POTENTIAL

2.1 Current Projects

In 2008, energy production from biomass in Ukraine in 2008 was c.38PJ/year corresponding to 0.65% of the total primary energy consumption of the country. [3] The same report details that most of this bioenergy is produced from wood residues used in biomass boilers for the generation of heat. Biomass is used also for cooking and space heating by residential and commercial sectors, and for heat and steam production by industry and district heating. Electricity generation from biomass combined heat and power is insignificant.

During the past five years, a small number of modern biomass boilers have begun operating such as the 5 MW steam wood-fired boiler at the Odek Ukraine plywood factory in the town of Orzhiv. However, no biomass plants are yet operating in Ukraine to produce power for the electrical grid or large district energy systems.

[1] Wood residues include material of primary and secondary wood processing (and firewood) from cutting areas.
[2] Agricultural residues include wheat, barley and other grains such as straw, rapeseed straw, and residues of corn and sunflower
[3] Dutch Ministry of Agriculture, Nature Food Quality, 2009. Market Scan Bioenergy Ukraine.

2.2 Resource Areas

Areas of available wood residue and agricultural residue resources are identified in this report section. Estimates of maximum power capacity that the fuels can support are based on a representative biomass power plant. While there appears to be a significant amount of biomass potential from wood and agricultural waste, the quantities available for power generation are highly dependent on the cost of harvesting and transporting the fuel, as well as competing options for the use of the fuel. Ukraine is developing its biomass energy sector for a number of purposes including: heating fuel, export fuel, and power generation (and cogeneration). Agricultural residue can also be used as fertilizer in fields and feed for animals. Therefore, 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. Additionally, to manage transportation costs, the sources of the fuels should be in close proximity to the power plant, typically within 100 kilometres (km).

The area covered by a 100 km radius approximates the area of many of the oblasts in Ukraine. Thus, the biomass potential in Table 2-1 is summarized by oblast. When assessing the fuel availability for developing a project in a specific area, it is prudent to have about 3 to 4 times the fuel requirement available within a 100 km radius so there is assurance of sufficient fuel supply. Therefore, even if the total potential development capacity may appear high, the reasonable development in an oblast requires 3 to 4 times the estimated resource needed to be viable.

Table 2-1. Maximum Biomass Potential for Power Projects

Electrical System	Region	Wood Biomass				Primary Agricultural Waste				Total Max MW*	Total Scenario MW**
		Mtce	PJ	Max * (MW)	Scenario (MW)	Mtce	PJ	Max * (MW)	Scenario (MW)		
Central	Cherkasy	0.04	1.1	10	3	0.90	26.4	253	63	263	66
	Chernihiv	0.12	3.7	35	9	0.45	13.2	127	32	162	40 (BR)
	Kyiv	0.17	4.9	47	12	0.61	17.9	172	43	219	55
	Zhytomyr	0.22	6.5	62	16	0.20	5.9	56	14	119	30
Crimea	Crimea	0.02	0.5	5	1	0.19	5.6	53	13	58	15 (CHP)
Dnipro	Dnipropetrovsk	0.02	0.6	6	1	1.21	35.5	340	85	346	87
	Kirovohrad	0.03	0.8	8	2	1.14	33.4	321	80	328	82
	Zaporizhia	0.01	0.3	3	1	0.90	26.4	253	63	256	64
Donbass	Donetsk	0.03	0.8	7	2	0.84	24.6	236	59	244	61 (BR)
	Luhansk	0.04	1.1	10	3	0.52	15.2	146	37	156	39 (BR)
Northern	Kharkiv	0.06	1.8	17	4	0.97	28.4	273	68	290	72
	Poltava	0.03	0.9	8	2	1.30	38.1	366	91	374	93
	Sumy	0.08	2.4	23	6	0.51	14.9	143	36	166	42
Southern	Kherson	0.03	0.9	9	2	0.59	17.3	166	41	175	44
	Mykolaiv	0.01	0.3	3	1	0.76	22.3	214	53	216	54 (BR)
	Odessa	0.02	0.5	5	1	0.88	25.8	247	62	253	63
South western	Chernivtsi	0.10	3.0	29	7	0.14	4.1	39	10	68	17 (CHP)
	Khmelnytskyi	0.04	1.2	11	3	0.40	11.7	112	28	124	31
	Ternopil	0.02	0.6	6	1	0.32	9.4	90	22	96	24
	Vinnytsia	0.07	2.1	20	5	0.91	26.7	256	64	276	69
Western	Ivano-Frankivsk	0.07	2.0	19	5	0.08	2.3	22	6	42	10(CHP)
	L'viv	0.12	3.5	34	8	0.12	3.5	34	8	67	17(CHP)
	Rivne	0.10	2.9	28	7	0.11	3.2	31	8	59	15 (CHP)
	Volyn	0.06	1.9	18	5	0.06	1.8	17	4	35	9 (CHP)
	Zakarpattia	0.17	5.1	49	12	0.07	2.1	20	5	68	17 (CHP)
	Total	**1.67**	**49.1**	**471**	**118**	**14.18**	**415.6**	**3,987**	**997**	**4,458**	**1,114**

Source: IET, NAS, 2010. The Energy Potential of Biomass in Ukraine and B&V Calculations.

*Capacity potential estimate assumes power conversion factor 14 GJ/MWh and 85% capacity factor for plan operation.
**Potential scenario development potential assumes biomass fuel availability must be 3-4 times what is needed for a project to support the project.
CHP = Combined Heat and Power Plants and BR = Boiler Replacements.

(a) Wood Residue

Based on analysis developed by the NAS, the estimated amount of economic wood residue potential by oblast can hypothetically support about 470 MW of biomass power generation. However, since 3 to 4 times the fuel amount should be available for a project to be developed, the resulting potential is much less than is first perceived and restricts the development of larger wood-only biomass plants.

Projects relying on wood residue alone may be able to develop smaller projects of about 20 MW in Zhytomyr and perhaps Zakarpattia. Figure 2-1 shows density of wood residue available in each oblast, with darker colors representing higher densitiy for biomass development. Some of the remaining oblasts, such as in the western, southwestern, and northern oblasts, may be able to support one or two 5 MW CHP projects per oblast, if fueled by wood residue alone. Crimea, the Dnipro oblasts, the Donbass oblasts, and the southern oblasts do not have sufficient wood residue fuel to support even a 5 MW CHP system. These areas would need to use blended biomass fuel that would consist of both wood residue and agricultural residue.

(b) Agricultural Residue

The agricultural residue potential in Ukraine is substantially higher than available wood residue. However, agricultural residue, due to the variation of the sources of the material, can be challenging to use for power generation. Systems that utilize agricultural residue need to be properly designed to address the issues associated with handling and firing agricultural residue.

Like wood residue, it is more cost effective to obtain fuel from within 100 km of the project location which covers the area of individual oblasts in Ukraine. Figure 2-2 shows density of wood residue available in each oblast, with darker colors representing higher densitiy for biomass development. Using the same metric as wood residue, where 3 to 4 times the fuel requirement should be available in a given area, Crimea and the western oblasts would have very limited biomass fuel available for even a single 20 MW project per oblast, so CHP applications are preferred. The remaining oblasts could support one or two projects of 20-50 MW in capacity, but most of the projects would need to be designed to utilize large amounts of agricultural residue, since there would not be sufficient amount of wood residue alone.

(c) Boiler Replacement Potential

As discussed later, boiler replacements of coal units to fire 100% biomass may be possible at select coal plants and may be more cost effective than building new projects. Black & Veatch has identified some candidate coal units based on size of units that are 100 MW or smaller. These units are located in Chernihiv, Luhansk, Donetsk and Mykolaiv, shown in Table 2-2.

Based on the biomass fuel potential for wood residue and agricultural residue within each oblast, which falls within about a 100 km radius, there is limited wood residue available in these oblasts (Figure 2-3). Therefore, agricultural residue would need to be the primary fuel used. Each of these oblasts can support one boiler replacement of 50-75 MW only (Figure 2-4). Not all of the units can be replaced with boilers specifically for biomass due to availability of biomass fuel in the area. These coal plants will need to ensure there is adequate space at the facility to handle the larger volumes of agricultural residue being proposed.

Table 2-2. Candidate Coal Units for Biomass Boiler Replacement

UNIT	CITY	STATE	MW	YEAR
	In Commercial Operation			
CHERNIHIV 1	Chernihiv City	Chernihiv	50	1961
CHERNIHIV 2	Chernihiv City	Chernihiv	50	1961
CHERNIHIV 3	Chernihiv City	Chernihiv	100	1974
KRAMATORSKAYA (B)	Kramatorsk	Donetsk	55	NA
KRAMATORSKAYA 1	Kramatorsk	Donetsk	25	1955
LUGANSK 04	Schastye Village	Luhansk	100	1957
NIKOLAEV 1	Nikolaev	Mykolayiv	25	1958
SLAVYANSK 4	Slavyansk	Donetsk	100	1957
SLAVYANSK 5	Slavyansk	Donetsk	100	1957
	Retired Units			
LUGANSK 01	Schastye Village	Luhansk	100	1956
LUGANSK 02	Schastye Village	Luhansk	100	1956
LUGANSK 03	Schastye Village	Lugansk	100	1957
SLAVYANSK 1	Slavyansk	Donetsk	100	1951
SLAVYANSK 2	Slavyansk	Donetsk	100	NA
SLAVYANSK 3	Slavyansk	Donetsk	100	1957

3. TECHNOLOGY CHARACTERISTICS

This report section provides an overview of the technologies that have been identified in the scoping report as feasible for biomass projects in Ukraine. These technologies are for the direct combustion of biomass (chiefly wood residue and agricultural residue) using small combined heat and power facilities, stoker boiler, or bubbling fluidized bed technologies, as well as the replacement of boilers at existing coal plants to utilize biomass.

3.1 Components and Configurations

There are many components of biomass systems which are common to most facilities and are common among all three technologies identified for the SER: stoker boiler, bubbling fluidized bed (BFB), and small combined heat and power (CHP) facilities. Such components include:

- **Fuel Handling/Preparation** subsystems include all equipment associated with the receipt of biomass, fuel storage, material sizing and conveyance of biomass to the inlet of metered feeding bins. This equipment includes truck scales, conveyors, stacking equipment, reclaiming systems, and metering bins. This subsystem can be either in an enclosed building or occur in the open.
- **Boiler and Air Quality Control** subsystems include the equipment associated with the boiler island and the emission control equipment. Emission control equipment typically includes an ash handling system, a fabric filter baghouse for particulate control, a Selective Non-Catalytic Removal system for NOx control, and continuous emission monitoring (CEM) equipment.
- **Steam Turbine and Auxiliaries** subsystems include the equipment associated with the turbine island and the facility’s water systems. This equipment includes the steam turbine generator, steam piping, condenser, feedwater pumps, feedwater heaters, and a wet cooling system using a cooling tower.
- **Balance of Plant** includes all other buildings and equipment required for the operation of the facility that are not included in the previous subsystems. Electrical equipment, including step-up transformers, switchgear, and other electrical equipment, is the most significant portion of the Balance of Plant systems.

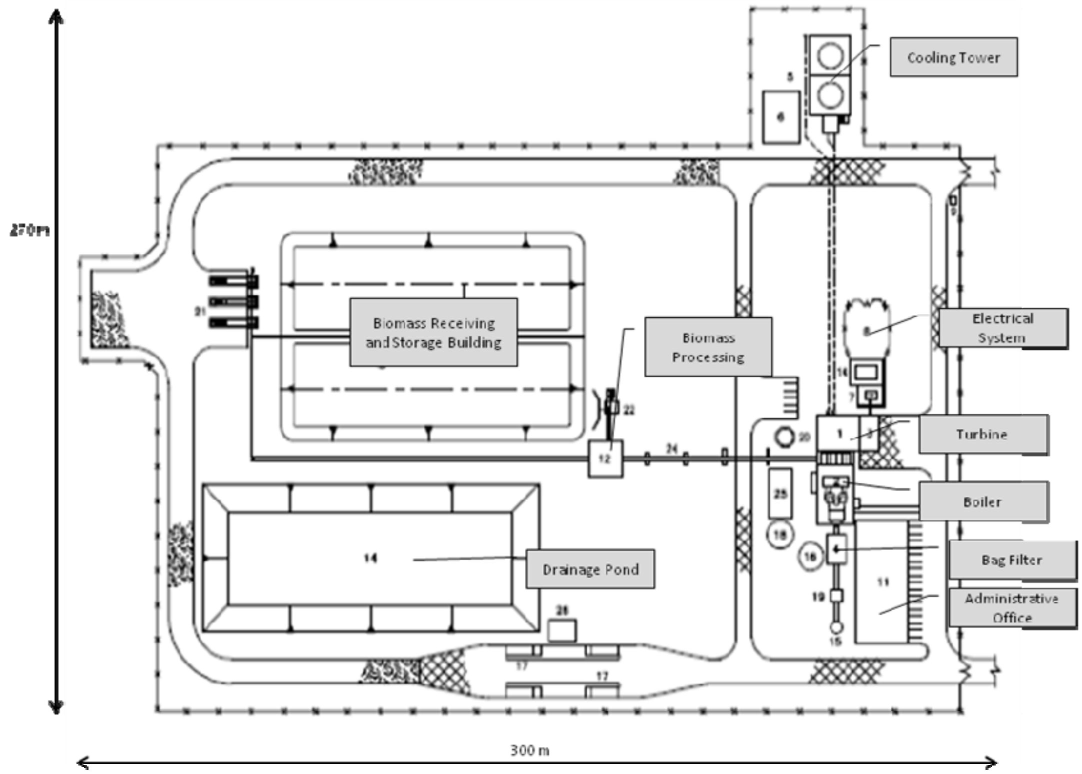


Figure 3-1. Representative Layout of 50 MW Biomass Facility.

One key difference in the utilization of woody biomass versus agricultural residue is in material handling.

- **Woody Biomass Receipt:** On an equivalent energy basis, the space required to store biomass is approximately four times that of coal. For repowering and standalone biomass-fired projects where biomass is the primary fuel, a biomass pile capacity sufficient for 28 days of supply would be needed. Woody biomass is delivered in dump trucks that operate during typical working hours, about 8-10 hours per day.

Source: National Renewable Energy Laboratory, Photographic Information Exchange

- **Agricultural Residues Receipt:** Agricultural residues are typically delivered by truck in square bales, with approximately 30 bales per truck. The bales would need to be removed by crane and either be stacked in an enclosed storage building or immediately placed on the processing line.

Source: Courtesy of http://www.inforse.org/europe/dieret/Biomass/biomass.html

(a) Stoker Boiler Systems

Stoker combustion is a proven technology that has been successfully used with biomass fuels (primarily wood) for many years. Figure 3-2 depicts a stoker boiler utilizing a vibrating grate; other configurations are also available.

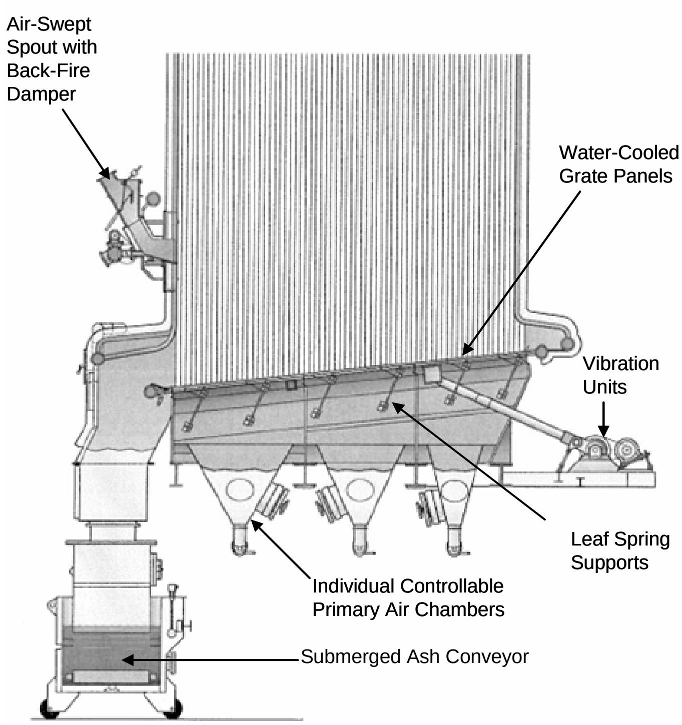


Figure 3-2. Vibrating Grate Stoker (Source: Steam, 41st ed., Babcock & Wilcox).

For the SER, stoker boiler systems sized in the range of 20 – 50 MW are being considered. In the stoker boiler, fuel feeders ("stokers") regulate the flow of fuel down chutes that penetrate the front wall of the boiler above a grate. Mechanical devices or jets of high-pressure air throw the fuel into the furnace section and onto the grate. Because biomass fuel readily de-volatilizes, much of the biomass burns in suspension. Therefore, a significant portion of the total combustion air is introduced as over-fire air. The unburned char settles on the grate surface, and char burnout is completed by preheated primary air introduced below the grate. The speed of the feeders is modulated to maintain output with changing fuel conditions or to respond to load changes.

The stoker boiler requires the biomass fuel to be sized. Depending on the manufacturer, the top size of the fuel may range from 7.5 to 15 cm. However, the stoker boiler has some flexibility to handle larger pieces. It is likely that the stoker will be able to handle up to 5 percent of the total fuel feed as strips or stringers up to 30 cm in length. Also, small fuel tends to burn more completely in suspension, and its contribution to the overall fuel mix also needs to be limited.

In Europe and Asia, there are small, stoker boiler plants with slagging superheaters that are firing 100 percent straw or other agricultural waste type materials.

Figure 3-3. Modern 20 MW Stoker Biomass Power Plant, Lünen, Germany

Nitrogen oxide emissions from a new stoker boiler burning biomass waste can vary significantly because of factors such as the type of biomass being burned, moisture content of the biomass, temperature on the grate, and quantity of primary air. Although some plants report lower emissions, NO_x emissions from biomass fired stoker boilers typically range of 1.0-2.0 g/MJ. Selective non-catalytic reduction (SNCR) systems have been used in stoker boilers to reduce NO_x emissions. In a SNCR system, a reagent (ammonia or urea) is injected into the flue gas to reduce NO_x emissions levels by approximately 50 to 60 percent. Some facilities have reported higher reductions. Biomass fuels typically have minimal amounts of sulfur and only trace amounts of mercury, so emissions controls for SO2 and mercury are not generally a major concern with biomass combustion. As noted earlier, use of baghouse filtration for control of particulate emissions is generally an effective approach for addressing particulate matter emissions resulting from biomass combustion.

Other operations and maintenance requirements for boilers include annual boiler overhaul. For agricultural residue, more frequent cleaning of heat transfer surfaces is needed to the slagging issue described previously. Turbine and generators need to be inspected every 6 years.

(b) Bubbling Fluidized Bed Boiler Systems

Combustion of biomass in bubbling fluidized bed boilers (BFB) has been practiced for more than 30 years. BFBs traditionally range from 20 to 75 MW, but for the purposes of the SER BFB boiler systems sized at 20 – 50 MW are being considered. An illustration of a BFB is shown on Figure 3-4.

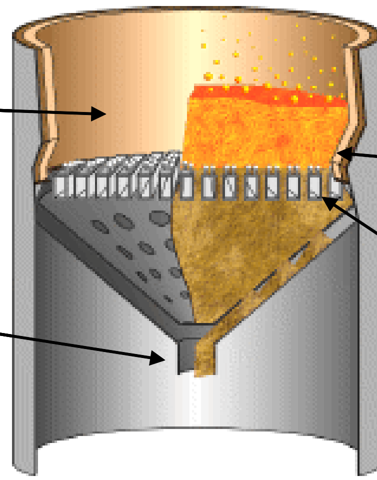


Figure 3-4. Typical Bubbling Fluidized Bed (Source: Energy Products of Idaho).

In BFB boilers, fuel feeders discharge either to chutes that drop the fuel into the bed or to fuel conveyors that distribute the fuel to feed points around the boiler. The speed of the feeders is modulated to maintain output when fuel conditions or loads change. The fluidized bed consists of fuel, ash from the fuel, inert material (e.g., sand), and possibly a sorbent (e.g., limestone) to reduce sulfur emissions. In most biomass fired applications the fuel typically has very little sulfur, so limestone sorbent is not typically required.[4] The fluidized state of the bed is maintained by hot primary air flowing upward through the bed. The air is introduced through a grid to evenly distribute the air.

Management of tramp material and agglomerates in the bed is very important for reliable long-term operation. For example, some BFB boilers utilize a bed recycle system that withdraws material from the bottom of the fluidized bed. The removed bed material is screened to separate the tramp materials (dirt and other non-combustibles) from the inert bed material, and the reclaimed inert material is then recycled back to the bed. The high heat transfer of the fluid bed medium also helps assure that complete combustion of the biomass fuel is achieved.

BFB boilers have the potential to accommodate fuels with a wider range of heating value and moisture content than the stoker boiler allows for a diverse mix of fuels to be processed simultaneously (e.g., a mixture of wood waste, agricultural residues, and biosolids). This allows projects flexibility in sourcing fuel inputs and in managing cost. However, fuel must be properly sized. This may require more screening and sizing operations beforehand to ensure that no dimension of the fuel exceeds the recommended upper limit.

[4] There are some cases where biomass fuels can have higher sulfur content. For example, the sulfur content of pulping process residues, such as spent sulfite liquor, is somewhat higher which may necessitate sorbent injection to control emissions.

A disadvantage of BFBs compared to stokers is the large auxiliary power requirement for the fluidizing air fan. The added energy penalty associated with fluidizing the bed is generally offset by the improved effectiveness of BFBs in completely converting the biomass fuel to useable energy. The typical boiler efficiency for bubbling bed combustion units firing biomass is approximately 70 to 75 percent. Depending on the moisture content of the biomass fuel, the typical net heat rate is generally in the range of 14-15 MJ/kWh – with higher heat rates (i.e., lower efficiency) associated with higher moisture fuels or small-scale biomass power systems.

NO_x control is required regardless of the fuel, and the prevailing technology for NO_x control is SNCR. Because of the low combustion temperatures, NO_x emissions from a BFB boiler that burns biomass will be generally less than 0.1 g/MJ of fuel input. In addition, the operating temperature of a BFB is usually within the temperature range that allows a SNCR system to be more effective. Like stoker technology, particulate matter is controlled with baghouse filtration, while SO2 and mercury are not of concern for biomass fuels.

There are numerous technical concerns with biomass fuels that can affect plant design and operation including alkali, moisture, and chlorine. Common biomass fuels with the highest alkali contents are typically crop residues (such as rice and grain straws), grasses (including switchgrass), and animal manure. Woody biomass can provide lower alkalinity levels, depending on the blend being burned.

Woody biomass fuels tend to have an ash content in the range of 1.5 to 4 percent of the fuel (by weight), where-as agricultural residues may have ash content that ranges from 2 to 8 percent. The ash from biomass fuels can have high levels of alkali components and agricultural residues would have higher alkali. The alkali components of ash, particularly potassium and sodium compounds such as potassium oxide (K_2O) and sodium oxide (Na_2O), cause the ash to remain sticky at a much lower temperature than coal ash. This increased stickiness creates the potential for serious slagging and fouling problems. In fluidized bed technologies, high alkali content can also lead to bed agglomeration. To remove the sticky material from the boiler surfaces, it is required to perform soot blowing, implement operational procedures such as slag shedding, or have regularly scheduled outages to manually clean the unit. Slagging presents significant maintenance and availability burdens that need to be accounted for. The addition of limestone or other additives (such as magnesium oxide) to the fuel feed can help reduce agglomeration in the fluidized bed. Increased maintenance/cleaning of boiler surfaces may be an option to address this challenge, but likely will add to operating/maintenance costs.

Other operations and maintenance requirements for boilers include annual boiler overhaul. For agricultural residue, more frequent cleaning of heat transfer surfaces is needed to the slagging issue described previously. Turbine and generators need to be inspected every 6 years.

(c) Combined Heat and Power Systems

Biomass projects with a demand for both electrical generation and thermal energy employ combined heat and power (CHP) systems. These systems typically have a moderately high pressure biomass-fueled stoker boiler coupled to a conventional steam turbine that drives a generator. The thermal energy produced in CHP systems is usually provided in the form of process steam or hot water, which is piped directly to the end user. The greatly improves the overall efficiency of the biomass system, as the excess heat is being utilized, potentially displacing fossil fuels for heating. The primary differences between CHP facilities and traditional electricity-only facilities lie in the design of the steam turbine. The system can be designed to maximize electricity production or maximize heat production. The biomass handling and combustion subsystems of CHP systems are conceptually identical to those of facilities which produce only electricity.

Small CHP systems sized at or below 5 MW are being considered for the SER. For small-scale CHP systems, a back pressure (non-condensing) steam turbine is often employed. The back pressure turbine exhausts the entire steam flow at a relatively high pressure (typically 690 kPa or greater). The entire turbine exhaust stream is directed to the end user as process steam, and the end user generally returns condensate to the CHP system. The boiler and turbine equipment needed for these systems are widely available, however (not surprisingly) the cost per unit of output for these systems tends to be notably higher than for larger-scale installations (e.g., 25 to 50 MW).

The most attractive smaller-scale biomass CHP applications are typically found at locations where biomass residues are produced (e.g., wood products industries, or crop processing sites), where there are also significant year-round thermal/process energy demands. These location generally have low-cost biomass fuel available, plus they also have staff available that are familiar with the issues and equipment needed for solid fuel handling and who can spread their labor costs between CHP operation and biomass processing facility operation.

Source: Courtesy of http://www.rsbiomass.com/urbas_chp.html

Figure 3-5. Stora Enso - Ybbs, Austria (5 MW Electric, 18.5 MW Thermal).

(d) Replacement Boiler

A fourth option for utilizing biomass fuel is to replace the coal boilers at existing coal-fired facilities with biomass boilers. Repowering provides a direct replacement for coal generation capacity. However, there is the potential for unit derating to occur. Biomass repowering may be less expensive than building new capacity, because repowering makes use of existing equipment (e.g., steam turbine generator and air quality control systems). For purposes of the SER, replacement boilers of up to 50 MW are assumed for coal units that are 100 MW or less so there would be sufficient fuel available in the immediate area, as well as compatibility with the existing steam turbines. There appears to be a handful of existing coal units that may be able to be converted to utilize biomass. They are all subcritical steam units. Note that either stoker or BFB boilers may be viable options for replacement of coal boilers – stoker or BFB options are both potentially viable in the 25 to 40 MW range; above 40 MW of repowered capacity BFB is likely to be the preferred option. To replace existing boilers, many of the components described for new facilities would not be needed.

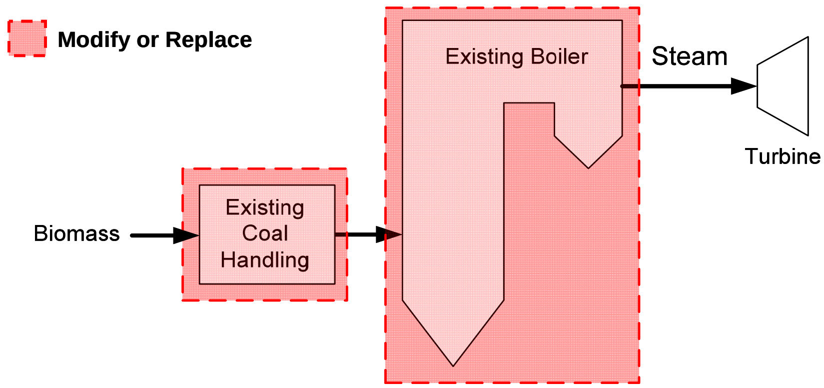


Figure 3-6. Biomass Repowering via Replacement

Repowering via boiler replacement will require modification of the existing fuel handling systems in most cases. The specific equipment required and the material handling strategies employed depend upon the level of automation desired in the biomass receiving/stockout systems and the biomass reclaiming systems. Since coal facilities already have a fuel receiving area with a scale, the increase in the number of truck deliveries for biomass requires at least one more scale to minimize delays due to scale congestion. Note that, on a cubic volume basis, roughly four times as much biomass is needed on volumetric basis as coal for each megawatt of power generated (considering that biomass often has 40 to 50 percent water, and also has a lower bulk density compared to coal).

For coal power plants that employ Selective Catalytic Reduction (SCR) systems for control of NO_x emissions, there is potential for increased SCR catalyst degradation due to catalyst poisoning and pluggage from constituents of woody biomass ash. There is a lack of consensus among catalyst suppliers regarding the extent of this concern. The repowered project may be able to utilize existing emissions control equipment available at the plant, but this will need to be evaluated in detail to make a plant-specific determination.

Repowered power plants would employ existing staffs, utilize 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.

3.2 Biomass Technology Summary

Table 3-1summarizes the performance and costs characteristics of the biomass power generation technologies described in this report section.

For continuous operation of a biomass power plant, the amount of biomass fuel needed is in the range of approximately 1.1 to 1.3 metric tons per hour of green (as-received) biomass fuel for each megawatt of electrical output. A typical dump truck can hold about 20 tons of wood material or 15 tons of agricultural residues. For a 50 MW biomass plant, this means about 70 truckloads are delivered per day, creating truck traffic of 140 trips per day near a facility.

Table 3-1. Performance and Cost Characteristics of Large Biomass Facilities.

Parameter	Units	50 MW Stoker		50-MW BFB	
Capacity Factor	%	85	85	85	85
Biomass Fuel					
Fuel Type		Woody Biomass	Ag Residue	Woody Biomass	Ag Residue
Heating Value (dry)	MJ/kG	20	17	20	17
Moisture Content	%	45	15	45	15
Net Heat Rate (Full Load)	MJ/kWh	14.7	14.9	14.7	14.9
Consumption	ktpy (wet)	499	384	499	384
	tpd (wet)	1366	1052	1366	1052
	Truckloads/ day	68	70	68	70
Ash Content	% (wet wt)	2%	6%	2%	6%
Ash Creation	ktpy	10	23	10	23
Water Requirement (dry cooling and wet cooling)	cu. m/day	750-4000	750-4000	750-4000	750-4000
Emissions					
SO2	g/MJ	negligible	negligible	negligible	negligible
NOX	g/MJ	0.09-0.17	0.09-0.17	0.06-0.11	0.06-0.11
PM total	g/MJ	0.01	0.02	0.01	0.02
Project Footprint	Ha	7-25	7-25	7-25	7-25
Building Height	Meters	40-65	40-65	40-65	40-65
Smoke Stack Height	Meters	75-120	75-120	75-120	75-120
Typical Project Cost	$/kW	$3500-$5000	$3500-$5000	$3700-$5200	$3700-$5200
Typical Project O&M	$/kW	$120-$150	$120-$150	$120-$150	$120-$150
Fuel Cost	$/ton (wet)	$10-$50	$10-$50	$10-$50	$10-$50

Source: Black & Veatch calculations.
Notes:

Water consumption for stand alone biomass power plants that produce only electricity can be fairly high, if these plants use cooling towers to maximize power output and efficiency – water consumption can be in the range of 65 to 70 liters per day per megawatt of capacity at full load output. Most of this water (over 90 percent) is used as make-up water for evaporation in the cooling tower. The majority of this water consumption can be avoided by the use of somewhat more expensive, and less efficient air-cooled condensers, or via the use of river water or lake water as a cooling medium. The water consumption presented in Table 3-1 reflects the range of water consumption from dry cooling, which is more prevalent in European plants, and wet cooling. CHP systems often have the thermal demand serve in lieu of a cooling tower, and the water may simply be recirculated in the system if heat exchangers are used to deliver process heat. This would greatly reduce the consumption of water on-site, perhaps up to 90 percent.

Table 3-2. Performance and Cost Characteristics of Boiler Replacements and CHP.

Parameter	**Units**	**50 MW Boiler Replacement**		**5 MW CHP**	
Capacity Factor	%	85	85	80	80
Biomass Properties					
Fuel Type		Woody Biomass	Ag Residue	Woody Biomass	Ag Residue
Heating Value (dry)	MJ/kG	20	17	20	17
Moisture Content	%	45	15	45	15
Net Heat Rate (Full Load)	MJ/kWh	13.3	13.3	17	17
Consumption	ktpy (wet)	450	343	54	41
	tpd (wet)	1233	938	148	113
	Truckloads per day	62	63	10	8
Ash Content	% (wt)	2%	6%	2%	6%
Ash Creation	ktpy	9.0	20.6	1	2
Water Requirement (dry cooling and wet cooling)	cu. m/day	750-4000	750-4000	40	40
Emission Limits					
SO2	g/MJ	0.011	0.011	negligible	negligible
NOX	g/MJ	0.043	0.043	0.09-0.21	0.09-0.21
PM	g/MJ	0.005	0.005	0.01	0.02
Project Footprint	ha	existing	existing	1	1
Typical Project Cost	$/kW	$1500-$2000	$1500-$2000	$4000-$5000	$4000-$5000
Typical Project O&M	$/kW	$100-$150	$100-$150	$150	$150
Fuel Cost	$/MJ	$10-$50	$10-$50	80	80
Source: Black & Veatch calculations					
Notes:					

In general, agricultural residues tend to be distinctly less attractive as a boiler fuel than wood fuel, since agricultural residues tend to have lower energy density per unit of weight, lower bulk density per unit of volume (raising transport costs), poorer storage characteristics (e.g., greater propensity to deteriorate), higher ash content, and greater propensity to cause boiler slagging and fouling (due to typically higher alkali metal content in the ash, particularly compounds with sodium or potassium). It is important to note that there are approaches that can accommodate the challenges associated with the use of agricultural residues as fuel – these entail selection of proper boiler equipment and maintenance approaches that address the specific challenges of a particular crop or agricultural residue.

Biomass fuels typically have much less ash per ton of fuel than coal – in the range of five to six times less ash than coal. Since much less ash is generally produced with biomass fuel, disposal of ash residues are typically not a major problem – either in landfills or via spreading the ash back on the land as a soil amendment/nutrient to produce more biomass.

(a) Interconnection Requirements and Components

The technology described in this report for utilization of biomass is based on steam turbines. Steam turbines are typically induction generators that require reactive power, depending on the output power and power factor correction, which can cause self-excitation, thus increasing harmonic content. Increasing harmonic content can create stability concerns for an interconnection, especially within weaker power systems (e.g. radial distribution lines). Induction generators also have subtransient reactance inherent to the machine, which contributes to high fault current at lower voltages. Different padmount transformer configurations can also increase or decrease the amount of fault current onto the system, so it is important to design the system to keep the zero sequence impedance to a minimum, but still have a ground reference (so no overvoltage scenarios occur). Series neutral reactors or resistors can be added to the neutral connections of the collection system to increase the zero sequence impedance, thus decreasing the fault current. Biomass plants have a distinct operational advantage, as they can be used as a base load plant, since the fuel source can be controlled and scheduled. This allows for load following and the reduction of voltage imbalances to the system which cause stability issues like flicker. Biomass projects of different sizes have different interconnection concerns. For additional background on interconnection issues, see Appendix B.

Biomass projects less than 10 MW should typically be interconnected at distribution voltages. It is usually too costly to facilitate an interconnection at a higher voltage; however, there are no technical constraints to doing so. At distribution voltages, it is more reliable to interconnect directly to a substation, not tap a line, due to the fault contribution to the system. This type of interconnection would require a generation tie line from the project site to the substation. The minimum load size requirement should be able to separate the biomass systems that are too large for the lower distribution voltages; however, load flow, short circuit, and stability studies should be completed to ensure reliability.

Biomass projects greater than 20 MW typically should be interconnected at the subtransmission voltages. Interconnecting these projects at the distribution level can cause serious loading issues, and may cause stability issues. As the Ukraine may only have a 110 kV subtransmission system, larger projects may consider transmission (220 kV or higher) interconnections, but detailed studies into available transfer capacities should be completed. Limiting fault current is still important, but the fault current will be less due to the higher voltage interconnection.

(b) Availability of Components in Ukraine

Most boilers are purchased from foreign manufacturers. One firm "Zhitomirrempischemash" in the town of Zhitomir, though, is producing hot water wood-fired boilers in the range of 40-820 kW that are much lower cost than similar boilers of foreign producers, but may be too small for larger biomass installations. Overall, with a strong industrial base, Ukraine is well positioned to manufacture biomass power plant components as many are standard thermal power components.

3.3 Site Considerations

To be economically feasible, direct fired biomass plants are located either at the source of a fuel supply (such as a sawmill), within 100 kilometers of disperse suppliers, or up to a maximum of 300 kilometers for a very high quantity, low cost supplier. Wood and wood waste are often the primary biomass fuel resources and are typically concentrated in areas of high forest product industry activity. In rural areas, agricultural production can often yield fuel resources that can be collected and burned in biomass plants.

The siting for the biomass fired BFB Combustion facilities requires close proximity to a variety of commodities, utilities and services. Fuel supply, water supply and electrical interconnection may be the more critical items.

Site specific constraints, such as requirements for additional buffers for adjacent residential areas or increased fuel storage, may increase the required acreage. This land requirement would include areas designated for the following purposes:

- Power block and other major equipment
- Maintenance and operations buildings
- Fuel delivery and long-term fuel storage
- Access roads
- Construction lay-down and parking
- Drainage requirements
- Underground utilities
- Noise mitigation
- Buffer between plant and neighboring lands

Based on the experience of the authors with solid fuel power generation facilities employing Rankine power cycle systems and wet cooling methods (i.e., mechanical draft cooling towers), a 50-MW facility operating at average ambient conditions would require 4,000 cubic meters per day (m^3 per day). This water requirement would include:

- Makeup water for steam power cycle, including allowances for steam losses and blow-down
- Makeup water for circulating (cooling) water systems
- Service water
- Potable water

Of these requirements, makeup requirements for the circulating water systems are the largest quantity.

3.4 Construction Activities

Typical construction activities for the development of biomass power production facilities are generally the same as would be expected for other major industrial construction projects. Required activities include clearing and grubbing, site grading and excavation, installation of process piping and underground utilities, construction of access roads, erection of steel and reinforced concrete structures, installation of mechanical equipment and power generation equipment, installation of electronic controls and monitoring, testing and acceptance.

Table 3-3identifies general activities that are required for the construction of biomass facilities described in this report section.

When a biomass boiler will completely replace the steam from an existing coal boiler, it is possible that the biomass-fired boiler could be constructed while the existing coal-fired boiler remains in operation. However, space constraints must be a consideration for any retrofit project. Construction of the biomass-fired boiler while the coal-fired boiler remains in operation requires that sufficient area be available within the site to allow erection of the biomass-fired boiler and the associated construction laydown.

Table 3-3. Biomass Facility Construction Activities.

Category	Activity
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

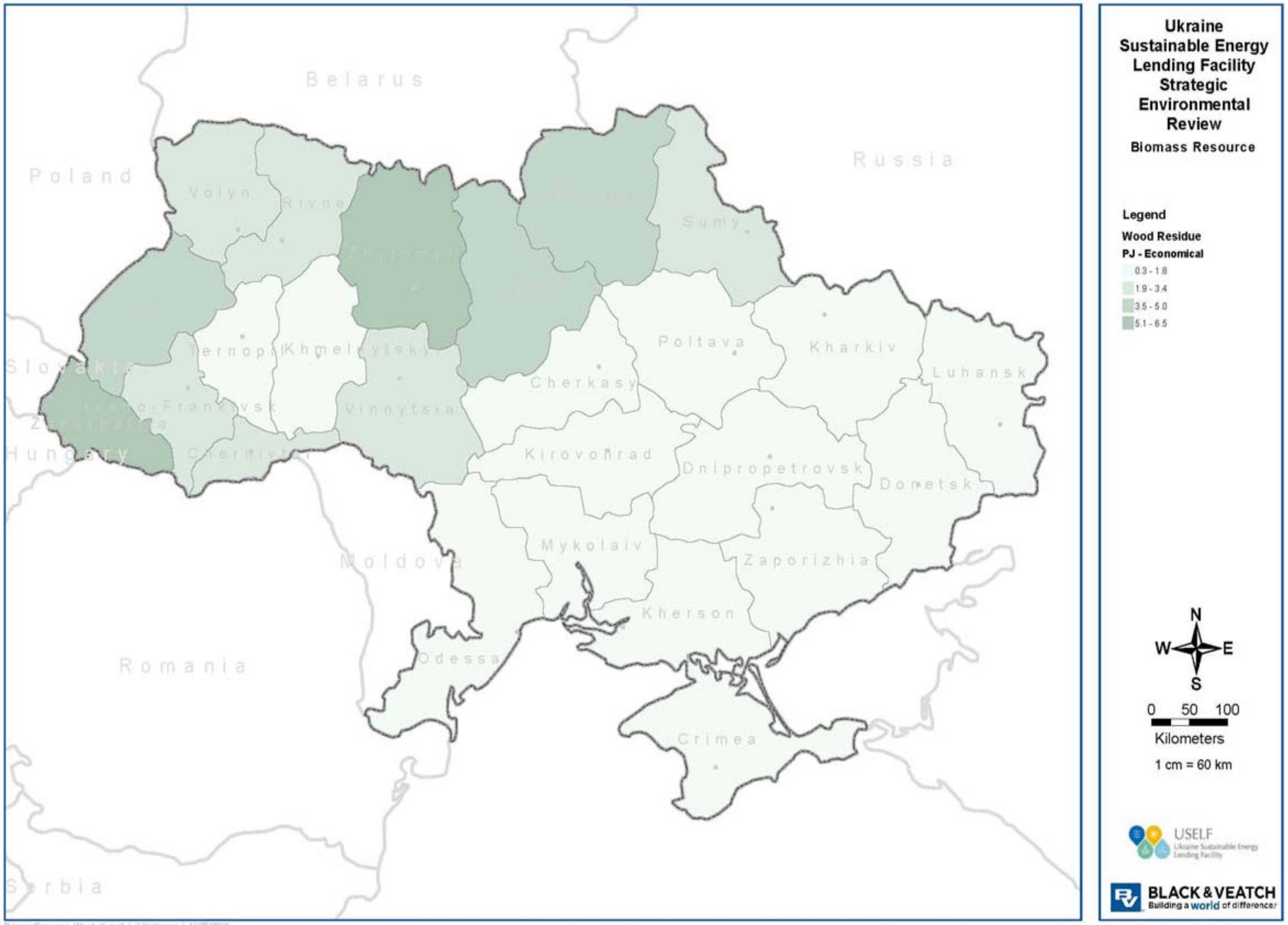
FIGURES

Figure 2-1. Map of Wood Residue

Figure 2-2. Map of Agricultural Residues

Figure 2-3. Potential Boiler Replacement Sites Using Woody Biomass

Figure 2-4. Potential Boiler Replacement Sites Using Agricultural Residues



Data source: ESRI; derived from Institute of Engineering Thermophysics, NASU, 2010. Assessment of biomass potential in Ukraine, Biomass Energy Europe Project, FP7.

Figure 2-1. Map of Wood Residue

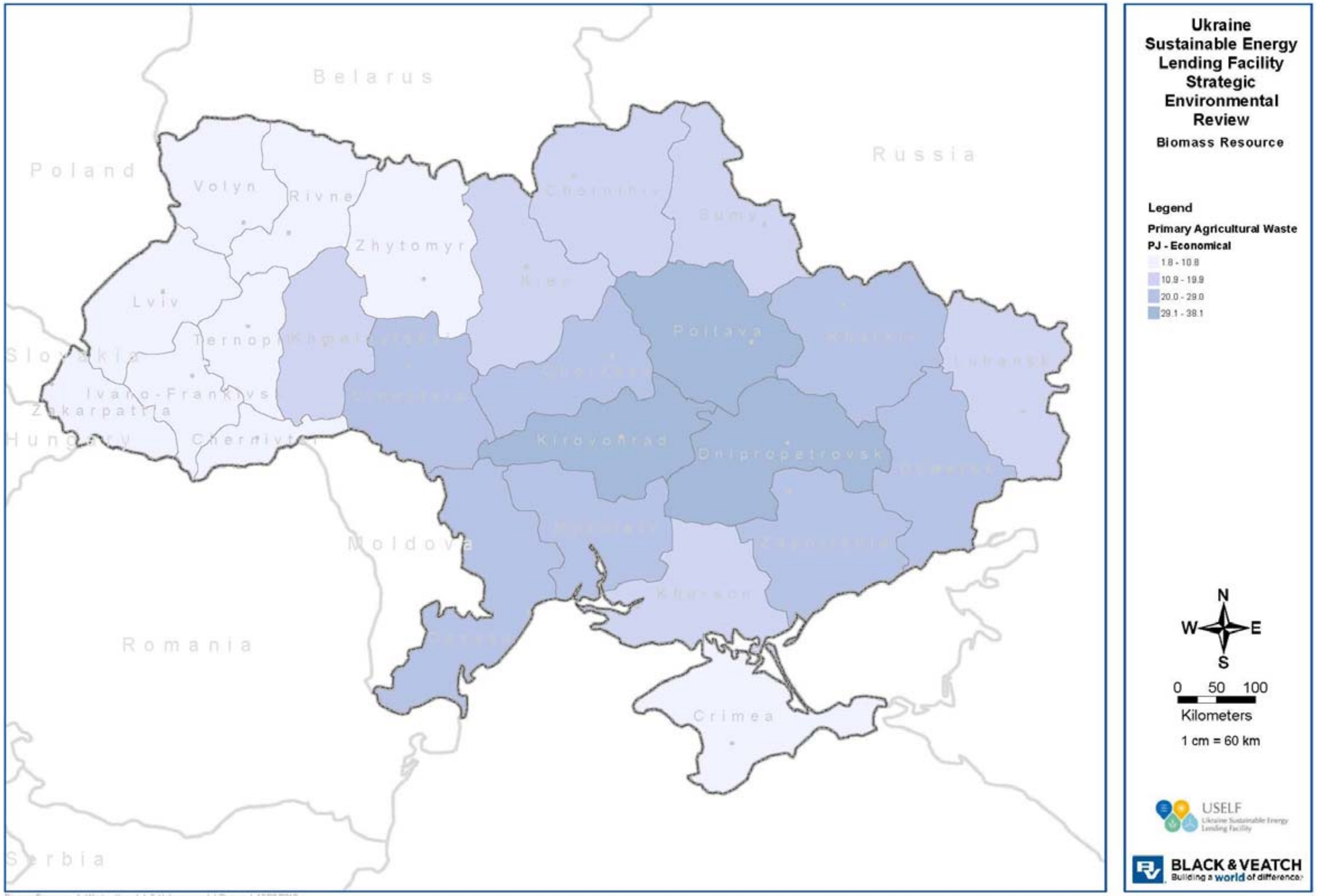


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Figure 2-2. Map of Agricultural Residues

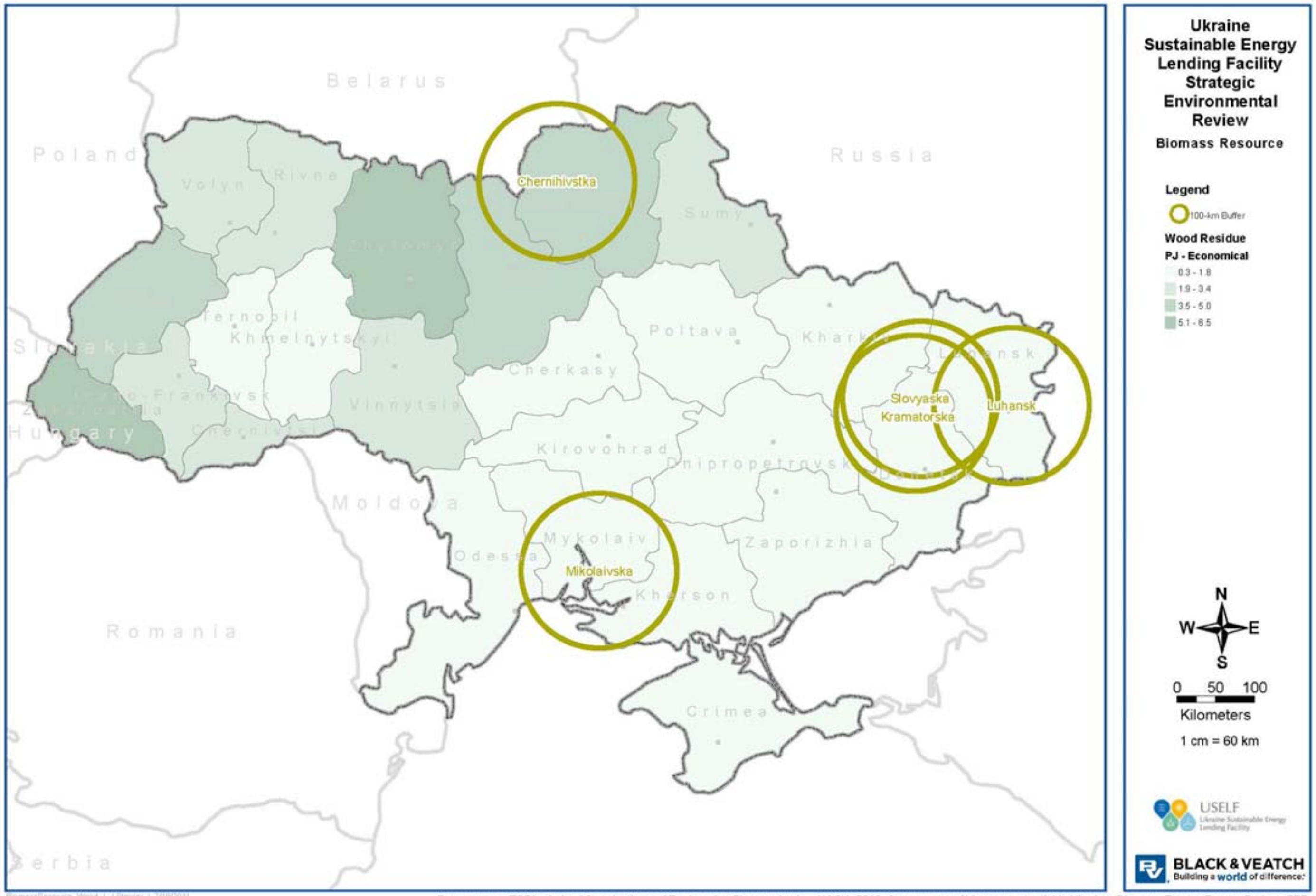

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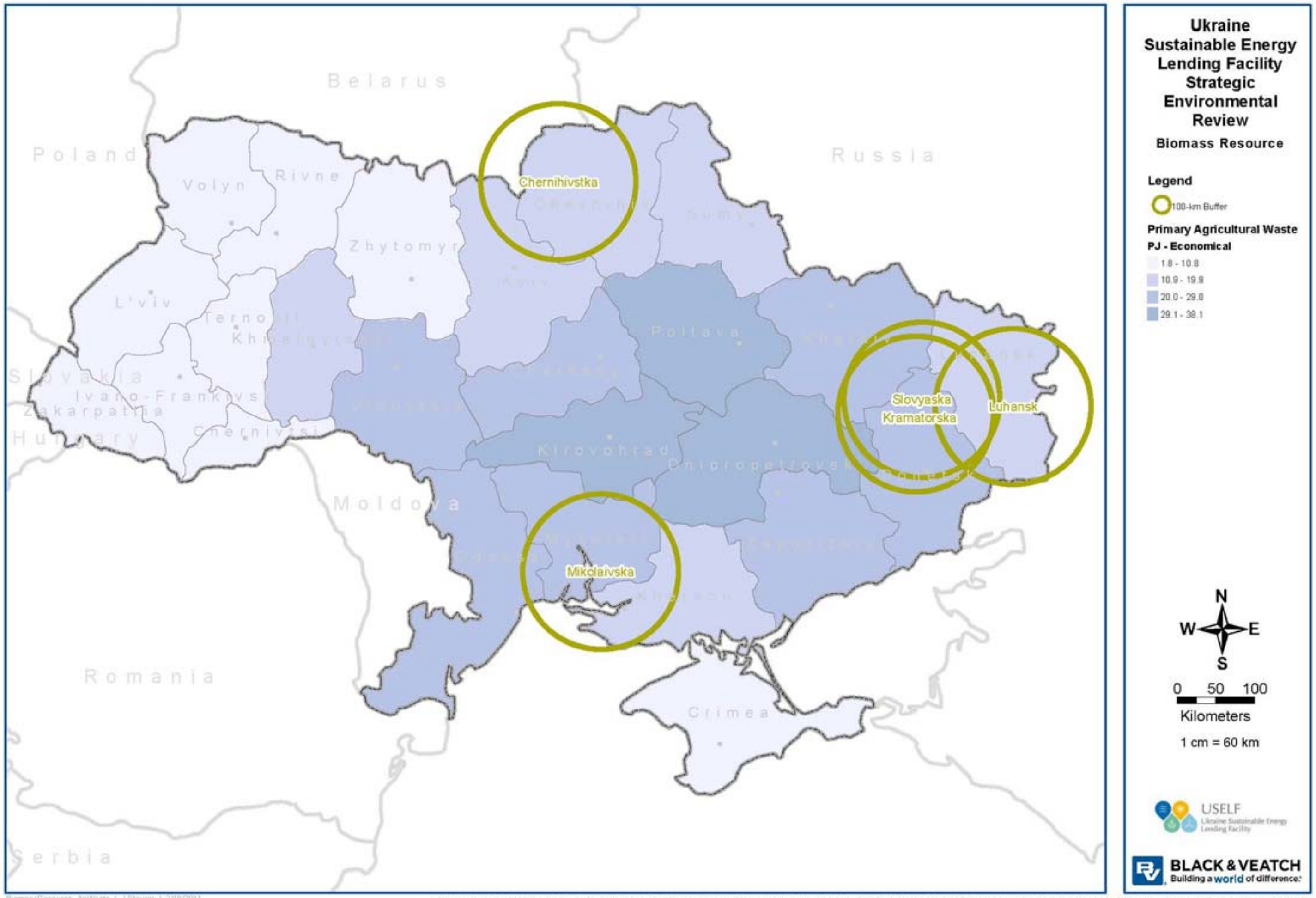
Figure 2-3. Potential Boiler Replacement Sites Using Woody Biomass



Data source: ESRI; derived from Institute of Engineering Thermophysics, NASU, 2010. Assessment of biomass potential in Ukraine, Biomass Energy Europe Project, FP7.

Figure 2-4. Potential Boiler Replacement Sites Using Agricultural Residue