4 ASSESSMENT SCENARIOS

4.1 Identifying the renewable energy scenarios

Stage B of the SER process required the identification and development of scenarios for renewable energy under the USELF programme (see Section 2.1). The SER Environmental Scoping Report identified areas with good potential for renewable energy development in Ukraine and a short-list of technologies likely to be deployed in the near-term under USELF or other programmes. The identification of a short-list is not intended to preclude or limit the future development of other renewable energy resources or technologies that have not been identified for review; the short-list is simply within the scope of this SER whilst others are outside of the scope.

In identifying the types of renewable energy resources and technologies to be assessed through the SER, projects that may apply or be eligible for the USELF programme were given special consideration. Since the lending facility seeks renewable energy projects that are technically and economically viable, similar parameters were taken into account in developing the list of technologies for the SER. Factors considered include that:

- Smaller projects are likely to apply to USELF due to its focus on smaller schemes (with the exception of on-shore wind which potentially includes larger-scale projects, see Table 4-1);
- Primary energy production must be electricity, rather than as thermal energy (space heating, hot water, etc.). Some thermal energy production is permitted, but cannot be the primary energy output[7];
- Projects should qualify for the Green Tariff under present or future legislation so there is a guaranteed revenue stream to support the project;
- To qualify for Green Tariff, projects must sell the electricity output to Energomarket, who is obligated to purchase all renewable energy not sold elsewhere at Green Tariff rates[8]. In order to sell to Energomarket, the project must be interconnected to the transmission grid[9];
- To be technically and economically viable in the near-term, projects are more likely to use available technologies with proven performance records in commercial application; and
- Projects are owned or primarily owned by private companies. Government entities are not eligible, except as partial owner only.

[7] Cogeneration or CHP projects, where thermal energy production is the primary output and electricity production is secondary, are not the key focus of the USELF program.

[8] Energomarket is the Wholesale Buyer/ Wholesale Supplier of electricity in Ukraine and is a state enterprise. Projects under 20 MW are not obligated to sell to Energomarket, but Energomarket is required to purchase electricity from renewable energy projects at Green Tariff rates, which is typically higher than alternative avenues.

[9] To sell to Energomarket, generators must obtain a generation licence (issued by NERC), sign the Wholesale Electricity Market Members' Agreement – WEMMA (the multi-party contract which specifies the rules of trades and settlement), and sign an electricity purchase-sale agreement with Energomarket (template contract, approved by NERC).

Having initially defined the short-list of technologies, further study has been undertaken in order to:

- Define scenarios of renewable energy development that will form the basis of the SER 'assessment of effects' stage, including the technology characteristics and likely construction activities (as detailed Section 4.2); and,
- Identify geographic areas of good potential for renewable energy development given resource quality, geographical constraints, existing infrastructure, and transmission considerations (as detailed in Section 7).

4.2 Description of the renewable energy scenarios

4.2.1 Description Overview

Based upon current renewable energy opportunities in Ukraine and the USELF Programme considerations, five types of renewable energy resources have been reviewed as part of this SER. These have been termed 'scenarios' for the SER to distinguish them from specific projects. The five renewable energy scenarios are categorised as:

- On-shore wind;
- Small hydropower (<10 MW);
- Solar photovoltaic;
- Biomass:
  - using wood residues;
  - using agricultural residues;
- Biogas[10]:
  - using gas generated from municipal landfill sites; and,
  - using gas generated from animal manure.

The following technologies are **not** included in the SER because they are not currently listed as eligible types under the Green Tariff, and are not being considered for future inclusion under the Tariff:

- Concentrating solar thermal power;
- Geothermal power;
- Co-firing of biomass with conventional fuels; and,
- Incremental hydropower at existing facilities (increase in installed capacity).

Technologies that are in development stages or that are not commercially available on a wide-scale, such as biomass gasification, are not included in the SER because they are assumed to be less likely to be developed in the near-term. Furthermore, offshore wind is not included in the SER because of the availability of more cost-effective wind options on-shore that could be developed first. Additionally, the Green Tariff for wind is insufficient to support offshore wind projects in the near-term (for further details refer to the SER Environmental Scoping Report (www.uself-ser.com)).

[10] Although biogas projects currently do not qualify for the Green Tariff, they have been included within the SER because legislative changes to include them are being considered.

Scenarios for each of the five renewable energy resource types (including two resource types for both biomass and biogas) have been developed to provide a basis for impact assessment in the SER using through the following steps:

1. Identification of areas of Ukraine in which the resources can technically and realistically be utilised (based upon a high level assessment) and exclusion of certain locations from further consideration (for example, where the available resource is insufficient to support the viable development of a project, where there is insufficient demand from neighbouring oblasts and / or where the existing transmission network is insufficient to carry further load[11]);
2. Characterisation of typical projects. For example, in terms of likely size, footprint and technologies utilised; and,
3. Determination of special factors that would influence the scale, grouping of projects, or type of development in these areas.

The determination of the scale for each USELF renewable energy scenario takes into account the overall estimate of potential energy generation (MW) of the renewable energy resource under consideration that would practically be exploited by the types of project under the consideration of the USELF SER. This means that the scenario scale is based upon near-term renewable energy development and therefore has assumed that existing constraints (such as geographical constraints, transmission network considerations, demand, resource quality and resource availability) will limit the level of potential for the USELF scenarios. 'Technical exclusions' have been defined to eliminate certain areas from consideration for specific renewable energy scenarios, so that the focus is on only those areas that are suitable. Were further study to be undertaken into such constraints, with the aim of facilitating *further* potential for the renewable technologies under USELF, then it is realistic that the scale of the current scenarios may be expanded; however, this is not within the scope of this SER.

Table 4-1 provides an overview of the renewable energy technologies that comprise each of the renewable energy scenarios that are considered in this SER. A more detailed table of the scenarios is provided in Appendix A – covering technology characteristics and likely construction methodologies associated with each. Full details of each of the renewable energy scenarios are set out in a series of five technical reports on renewable energy for the USELF SER (www.uself-ser.com).

[11] For further details refer to an appendix to the Technical Reports, titled 'Interconnection and Transmission Considerations in Renewable Energy Development in Ukraine'

Table 4-1 USELF renewable energy scenarios

Resource scenario	Resource characteristics	Grouped Technologies or "Projects"	Areas with good potential	Technical Exclusions	Scenario scale
On-shore 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 turbines)	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/m2 • Slope >20% • Urban Areas • Major Waterbodies	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.
Small Hydro	River Flow and Existing Hydro Project Sites	Small hydropower (<10 MW of capacity)[12] • Small hydropower with Impoundment • Hydropower Retrofit/Rehab at retired/existing hydropower sites (presumed at existing impoundments)	Carpathian area (Dniester, Tissa River Basins) and Central Ukraine area (larger tributaries of Dnieper).	• Areas away from existing watercourses • Very low head[13] • Low to intermittent stream flow • Protected areas (such as parks and recreational areas)	Total potential is 50-100 MW in Carpathian region. Potential capacities in other parts of the Ukraine are unknown.
Solar photovoltaic	Solar Insolation for Optimal Tilt and Tracking PV	Utility-scale, ground-mounted projects. • Small (1-5 MW) • Medium (5-20 MW) • Large (>20 MW)	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	• Low solar insulation areas • Slope >5% • Major Waterbodies • Forested land	Total Solar Only Development Scenario is 9 900 MW across country. Combined Wind and Solar Development Scenario is

[12] Small-hydropower projects are constrained by this Green Tariff capacity criteria.
[13] Definition of 'head': vertical height of the water measured from upstream of the turbine, for example a reservoir or river intake elevation, to the elevation of water downstream or below the turbine, such as the tailrace or receiving water body.

Resource scenario	Resource characteristics	Grouped Technologies or "Projects"	Areas with good potential	Technical Exclusions	Scenario scale
		Rooftop installations are not included in this resource scenario.	oblasts and mountainous terrain areas)		13 300 MW of wind and 2 600 MW of solar across the country.
Biomass [14]	Agricultural Residue (wheat, barley, straw, rapeseed straw, corn and sunflower)	Direct-fire in power-only or Combined Heat and Power (CHP) configurations. • Small Stoker CHP (<5 MW) • Stoker (20-50 MW) • Bubbling fluidised bed (20-50 MW) • Replacement boiler (50 MW)	Preliminary data shows good concentrations across most of Ukraine, and notably higher potential than wood residue.	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.	Total development potential of 1 114 MW for wood and agricultural residue combined across country.
	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)	Higher concentrations in northern Ukraine (Zhytomyr, Kyiv, 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, or up to 300km away from high quality/very economic fuel	

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

Resource scenario	Resource characteristics	Grouped Technologies or "Projects"	Areas with good potential	Technical Exclusions	Scenario scale
				source.	
Biogas	Animal Manure	Anaerobic digester coupled with Internal Combustion Engine (ICE) (250 kW to 5 MW). Power only or CHP. Pending Green Tariff rule change to qualify biogas for tariff.	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 Dnepropetrovsk. 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 head in one location) Small to medium sized pig operation (less than 6 000-8 000 head in one location). Small to medium sized poultry operation (less than 100 000 head in one location).	Total manure biogas potential is 160 MW across country.
	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.	Landfills near high population centres with sufficient size.	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. -Landfills that cannot be capped or covered.	Total development scenario LFG potential is 48 MW across country.

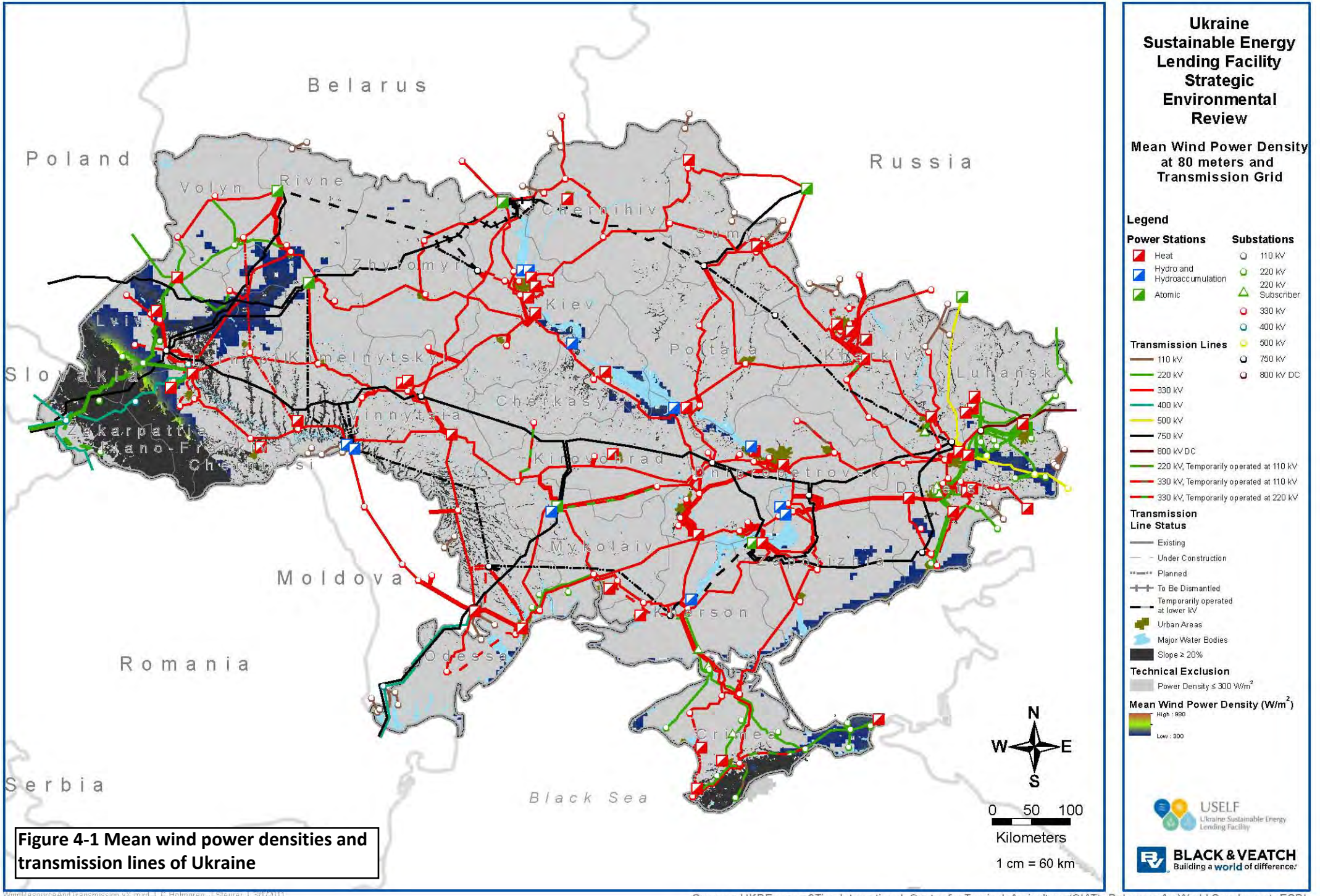

Figure 4-1 Mean wind power densities and transmission lines of Ukraine

WindResourceAndTransmission vX.mxd | © Holmgren, J.Steurer | 3/7/2011

Sources: UKREnergo; 3Tier, International Centre for Tropical Agriculture (CIAT), DeLorme, ArcWorld Supplement, ESRI.

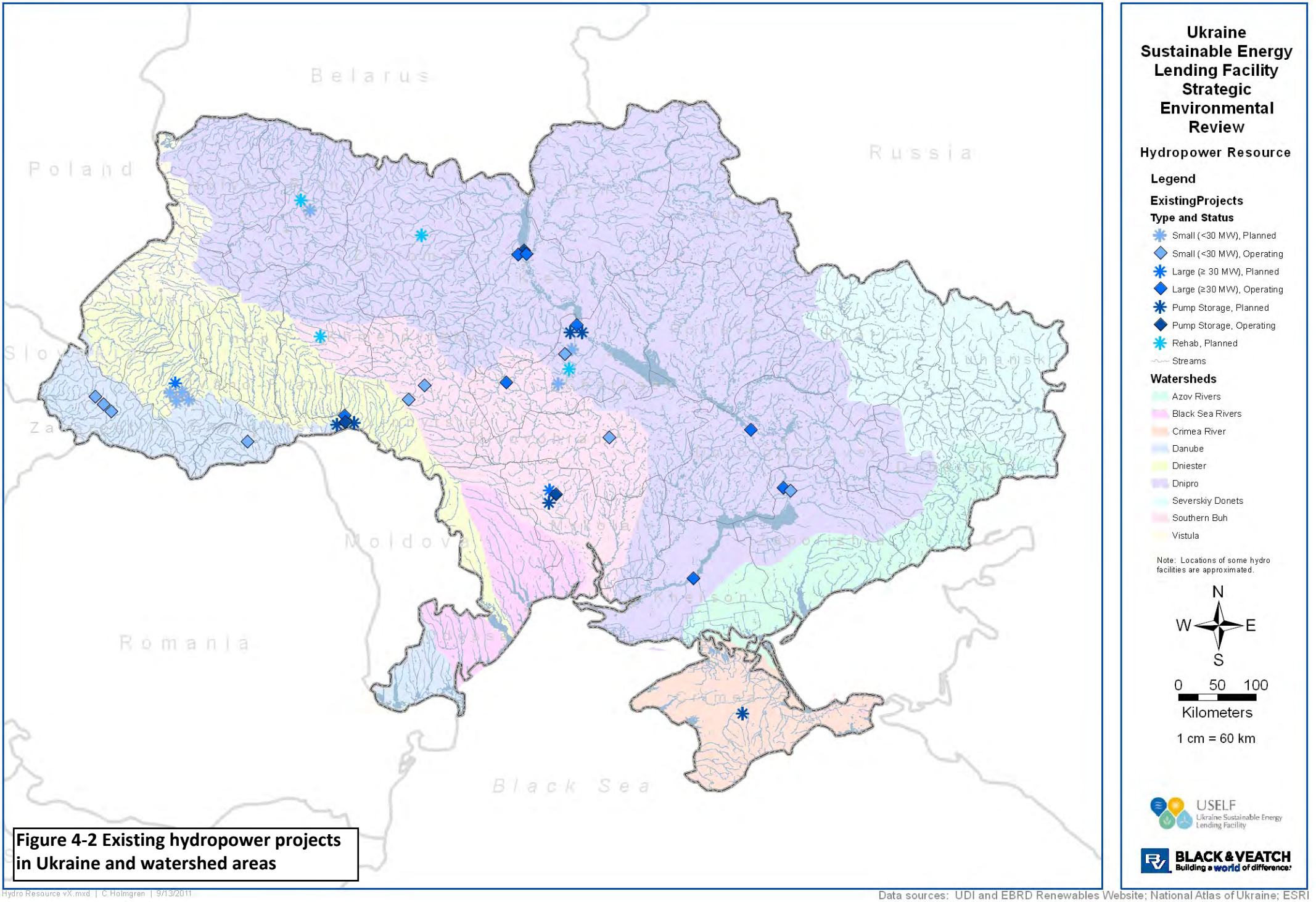

Figure 4-2 Existing hydropower projects in Ukraine and watershed areas

Hydro Resource vX.mxd | C Holmgren | 9/13/2011

Data sources: UDI and EBRD Renewables Website; National Atlas of Ukraine; ESRI

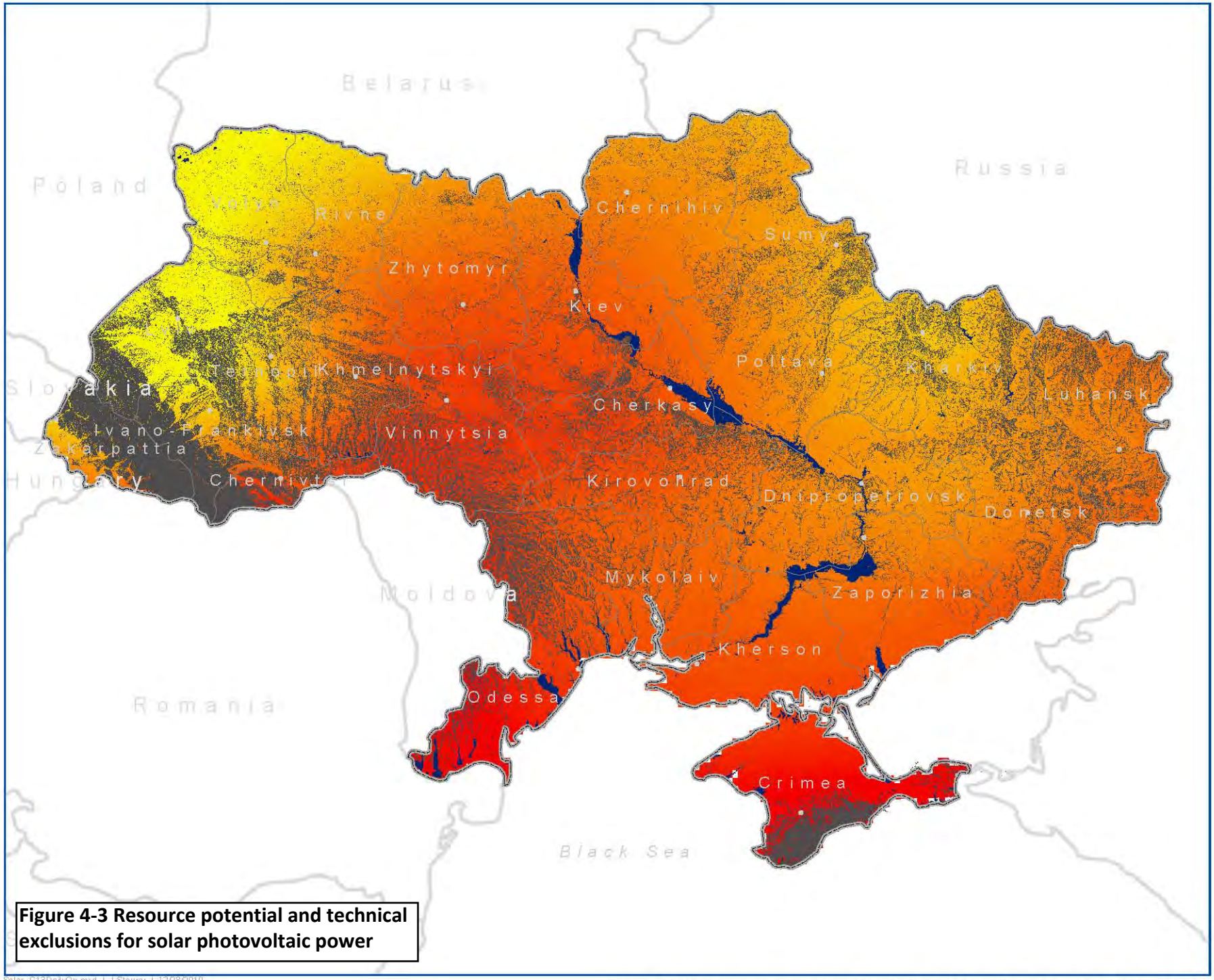

Figure 4-3 Resource potential and technical exclusions for solar photovoltaic power

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Daily Average of Global Irradiation on Optimally-Inclined Surface (kWh/m^2) Period 1981-1990

Legend

Daily Average of global irradiation kWh/m^2

High : 4.521

Low : 3.107

Technical Exclusions

Slope ≥ 5%

Major Water Bodies

N

W E

S

0 50 100

Kilometers

1 cm = 60 km

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Solar_GTSDailyOp.mxd | J.Steurer | 12/28/2010

Sources: PVGIS © European Communities, 2001-2008, International Centre for Tropical Agriculture (CIAT), DeLorme, ArcWorld Supplement, ESRI

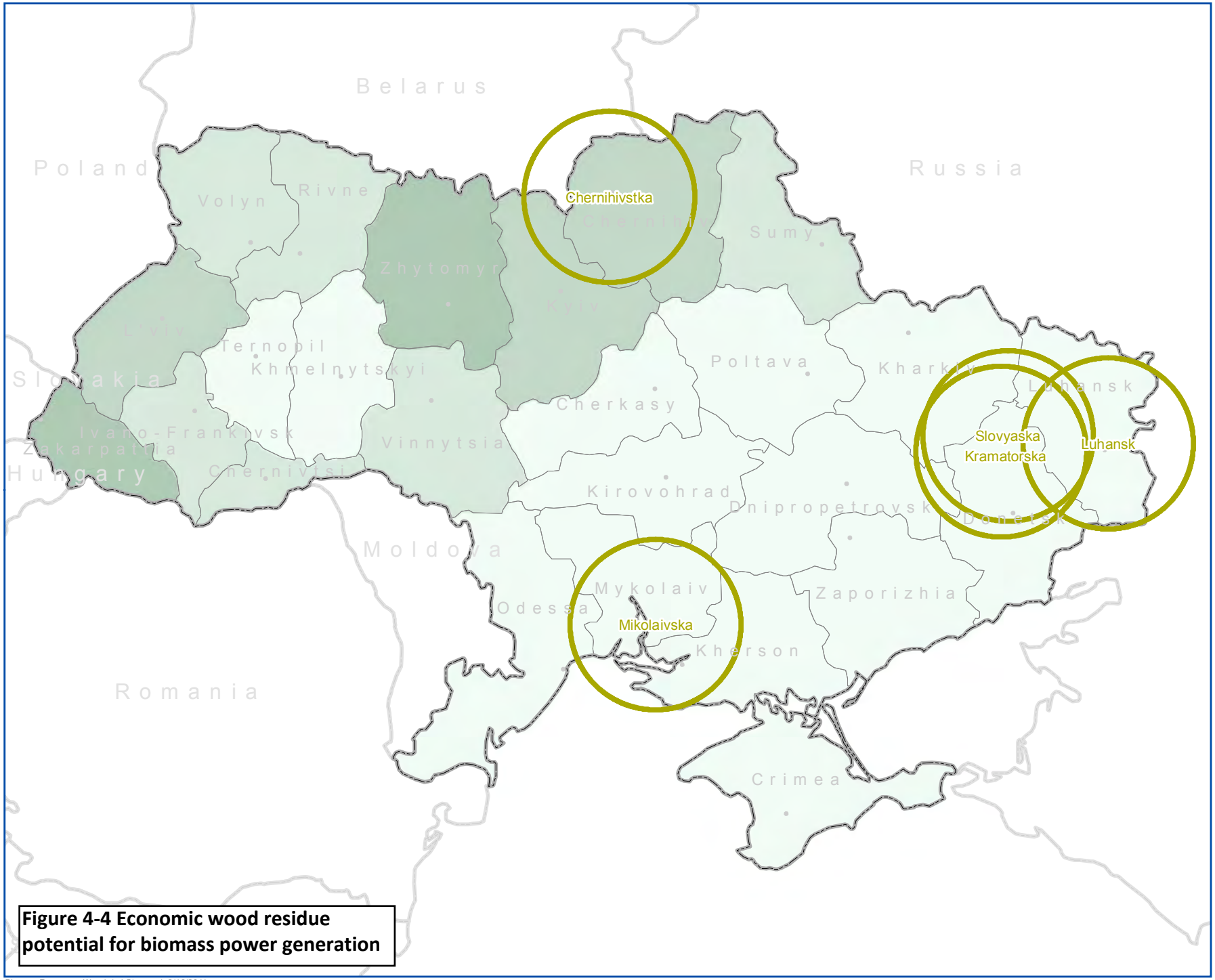

Figure 4-4 Economic wood residue potential for biomass power generation

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Biomass Resource

Legend

100-km Buffer

Wood Residue

PJ - Economical

- 0.3 - 1.8
- 1.9 - 3.4
- 3.5 - 5.0
- 5.1 - 6.5

N
W E
S

0 50 100

Kilometers

1 cm = 60 km

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BiomassResource_Wood | J.Steurer | 2/18/2011

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

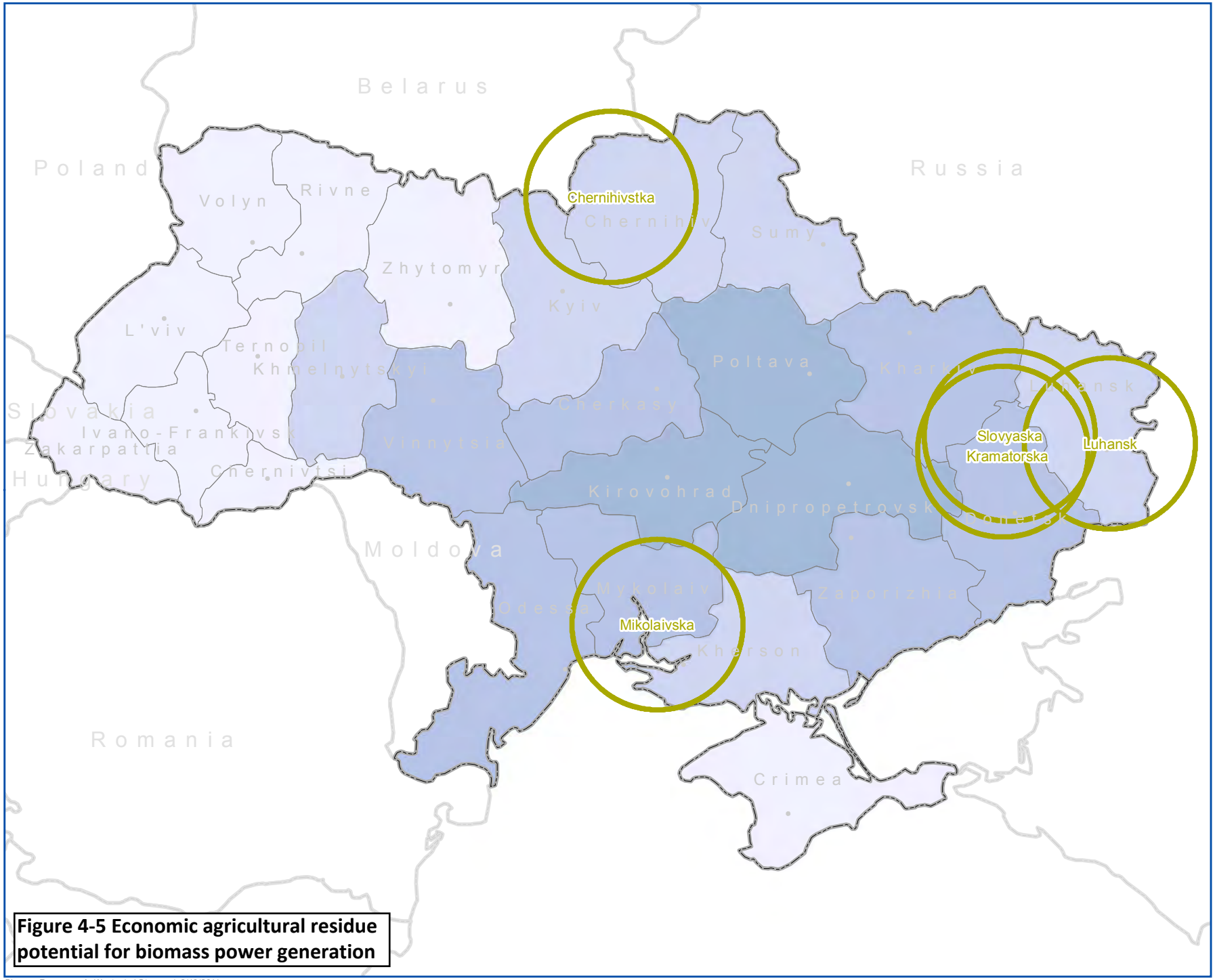

Figure 4-5 Economic agricultural residue potential for biomass power generation

Ukraine Sustainable Energy Lending Facility Strategic Environmental Review

Biomass Resource

Legend

100-km Buffer

Primary Agricultural Waste

PJ - Economical

- 1.8 - 10.8
- 10.9 - 19.9
- 20.0 - 29.0
- 29.1 - 38.1

N
W E
S

0 50 100

Kilometers

1 cm = 60 km

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BiomassResource_AgWaste | J.Steurer | 2/18/2011

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

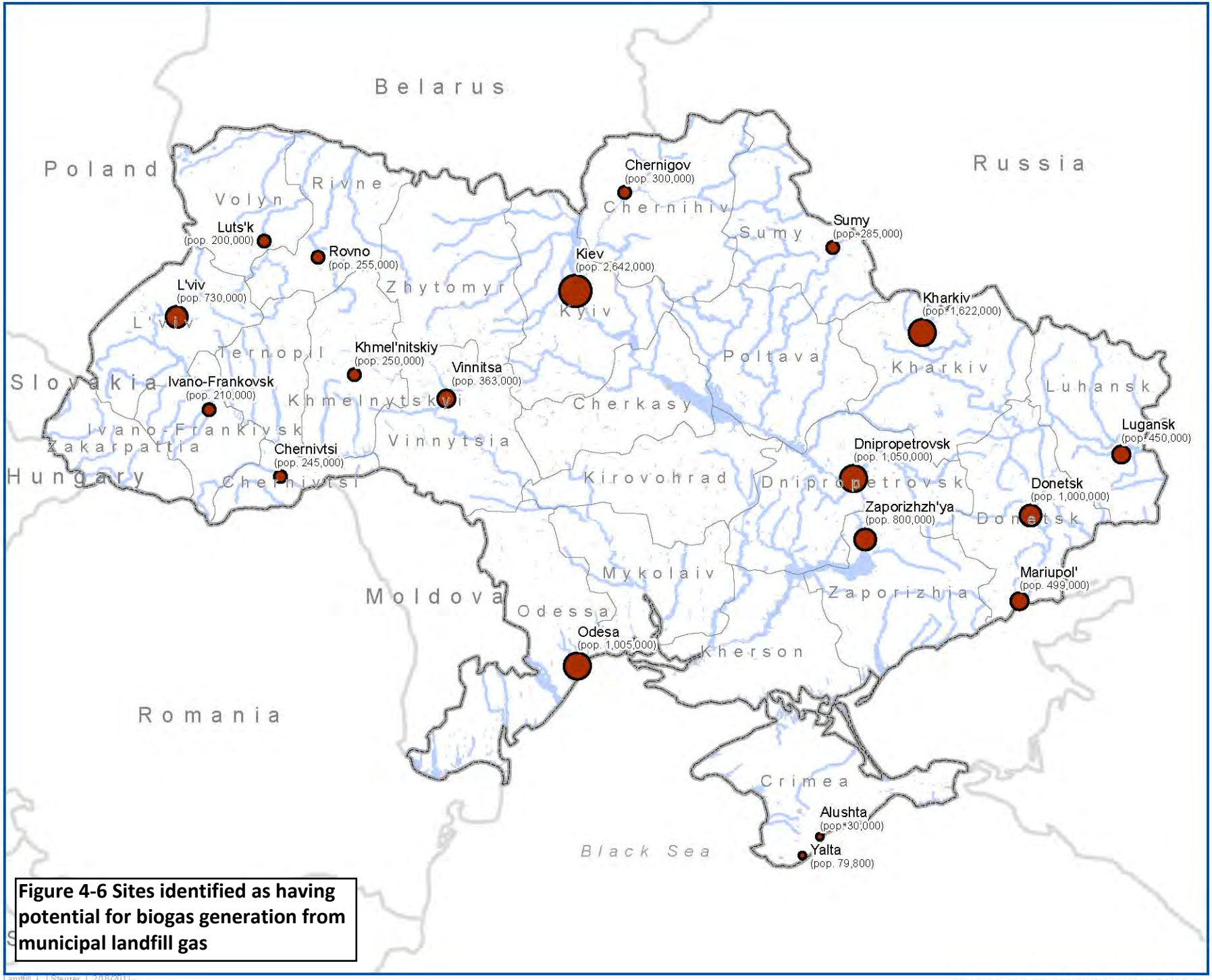

Figure 4-6 Sites identified as having potential for biogas generation from municipal landfill gas

Ukraine Sustainable Energy Lending Facility Strategic Environmental Review

Potential Landfill Sites

Legend

Population

- 30,000 - 100,000
- 100,001 - 300,000
- 300,001 - 500,000
- 500,001 - 1,000,000
- 1,000,001 - 2,000,000
- 2,000,001 - 2,642,000

N
W E
S

0 50 100
Kilometers

1 cm = 60 km

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Landfill | J.Steurer | 2/18/2011

Sources: Matveev,Y., 2010; Ukrainetrek.com; DeLorme; ArcWorld Supplement; ESRI.

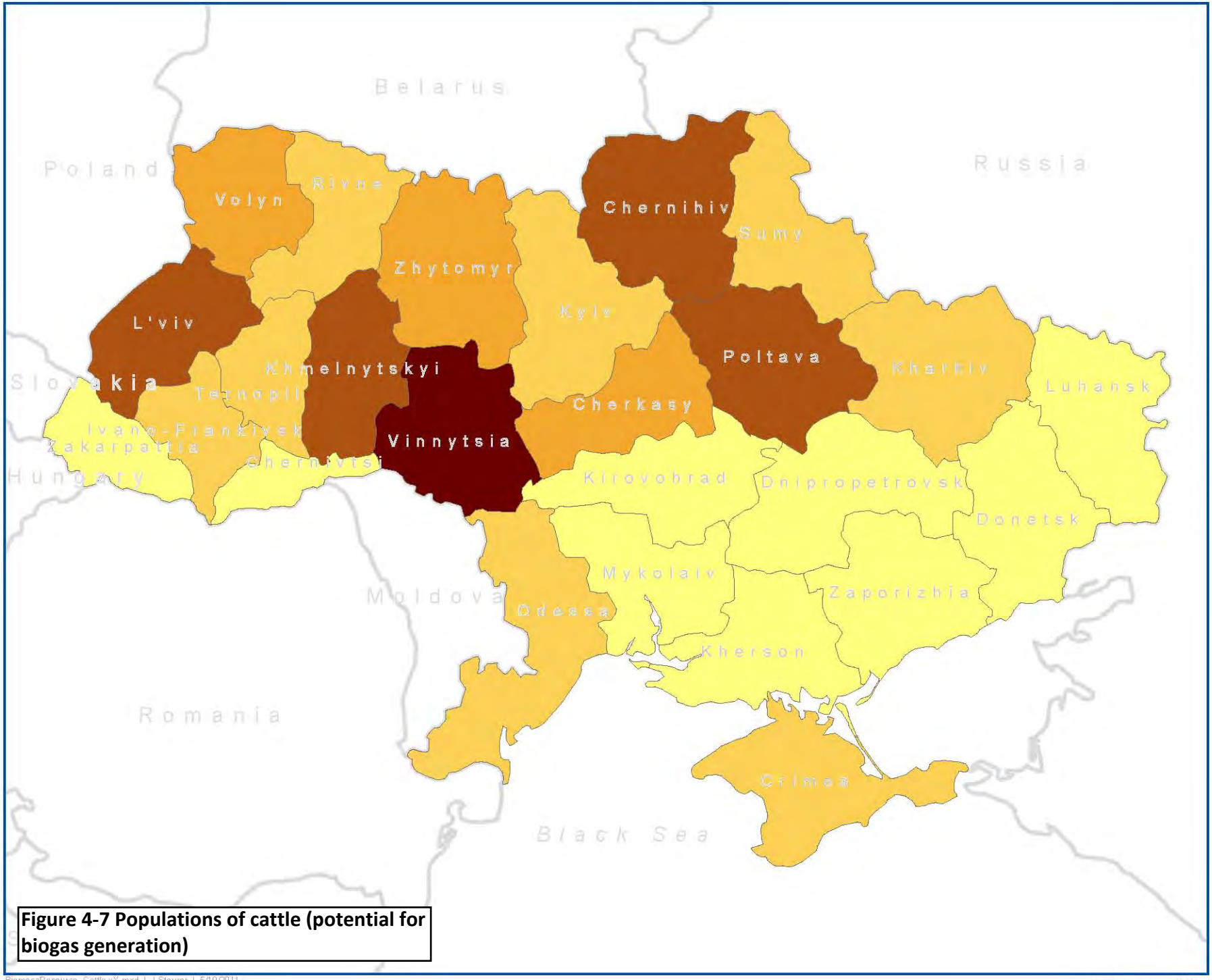

Figure 4-7 Populations of cattle (potential for biogas generation)

BiomassResource_Cattle vX.mxd | J.Steurer | 5/10/2011

Data source: ESRI; National Statistical Yearbook of Ukraine

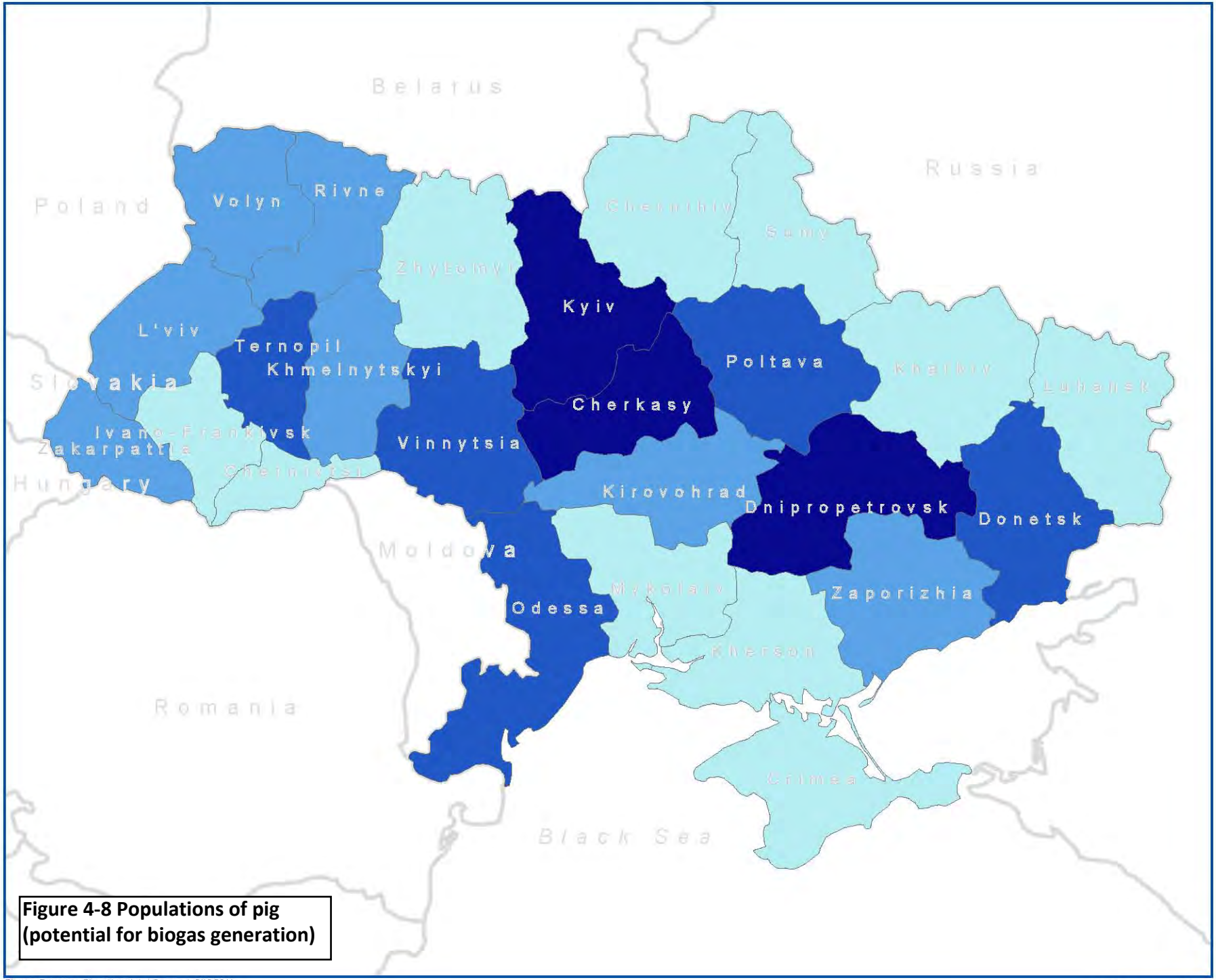

Figure 4-8 Populations of pig (potential for biogas generation)

Ukraine Sustainable Energy Lending Facility Strategic Environmental Review

Biogas Resource

Legend

Pig Population Year 2009

Thousand Head

- ≤ 250
- 250 - 350
- 350 - 450
- > 450

N
W E
S

0 50 100

Kilometers

1 cm = 60 km

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BiomassResource_Pigs vX.mxd | J.Steurer | 5/10/2011

Data source: ESRI; National Statistical Yearbook of Ukraine