Background and Approach

The primary scholarly interest of this project is to better understand the potential for community and/or regional energy self-sufficiency as a strategy for coupling the need for more stable sustainable rural economic development with the urgent, global necessity of shifting to a low-carbon energy system. Progressive approaches in the geospatial sciences – in particular political ecology, rural geography, and landscape architecture – have identified local to regional level self-sufficiency in meeting basic energy needs as a promising development approach. This project will incorporate diverse strands of contemporary geospatial thinking to produce a holistic assessment of the energy landscape of the Mid-Willamette, in order to answer three fundamental questions:

1. How much renewable energy can the study area reliably produce?
2. At what cost and with what impacts?
3. Given a logical need to maximize {1} while minimizing {2}, what energy landscape designs can best serve this objective, and with what confidence?

Rural communities face persistent difficulties in sustaining healthy political-economic and socio-cultural systems. Many rural communities remain marginalized in modern society, both socially and economically. The costs of economic globalization are spread unevenly,[1] and are causing rapid change in the demographic and economic makeup of rural places worldwide. In order to reverse this dynamic, it is necessary to determine how rural communities can adapt to, even resist, pressures exerted by global markets.[2]

Neoliberal perspectives on development typically emphasize economic competitiveness via specialization and trade, decades of working within this paradigm has produced mixed results. Extraction of wealth from less-advantaged groups is a feature of contemporary capitalism,[3] rooted in systems of unequal exchange that tend to disproportionately benefit the already privileged.[4] Rural places are typically at a disadvantage socially and economically relative to more urban places,[5] despite their essential role in underpinning the material function of global production, which remains underwritten by food and fiber – materials obtained from predominantly rural areas.[6] Rent seeking, capture of institutions, and pervasive information asymmetries tend to reproduce "webs of relation"[7] that tend to systematically marginalize rural communities.

1 Hornborg 2014; Bauhardt 2014; Bumpus & Liverman 2008; Peet & Hartwick 2009
2 Halfacree 2007, 2012; Hibbard & Lurie 2013; McCarthy 2006, 2008; Sherman & Sage 2011
3 Blaikie 2008, 2011; Mann 2009; Simon 2008; Walker 2003; Peet & Hartwick 2009
4 Hornborg 2014; Foster & Holleman, 2014
5 Nesbitt & Weiner 2001; Wallerstein 1974
6 Bell 2007; Fisher 2001; Hibbard & Lurie 2013
7 Rocheleau and Roth 2008

Progressive approaches have emerged in the past twenty years, predominantly political ecology and rural geography, that argue for development of alternative strategies. Local production that meets local needs has been see to function as a counter to external wealth extraction pressures[8]. Becoming self-sufficient in energy production may offer a beneficial alternative to more orthodox development efforts,[9] promoting rural development by taking advantage of the opportunities inherent in energy transition.

The pressing global need to shift from fossil-fuel to renewable energy systems offers an opportunity for rural communities to pursue energy self-sufficiency. Contemporary energy systems rely on centralized production and delivery of energy through vast transportation networks[10] – a type of system that is vulnerable to capture by private interests. Given the perpetual human need for energy and the concomitant universality of energy systems, such capture – whether through corruption, regulatory failure, or the design of formal management institutions all play a role in the persistence of energy poverty in developed[11] and developing world alike.[12]

Decentralized energy production is increasingly discussed as a means of supporting the global energy transition.[13] Renewable energy production tends to require a large physical footprint,[14] making land area and variation in local characteristics vital determinants in siting decisions[15] – ensuring that rural areas will be deeply affected by renewable energy development. This represents both an opportunity for and threat to institutions of locally oriented landscape management: It may promote a degree of job creation, but the structural inequalities of the contemporary political economic system may instead result in most benefits accruing to external owners of capital, which will ultimately undercut local economic development and local control over the landscape.

The concept of the 'energy landscape'[16] has emerged predominantly from academic discourse in Europe, where a growing body of literature on alternative renewable energy systems discusses the degree of intersection between the concept of the landscape and the transition to renewable energy systems.[17] Landscape is a fairly flexible term with respect to boundaries and content;[18] at its core is the idea that physical and social patterns and processes manifest and interconnect across a common physical space, with important patterns and processes sometimes only becoming apparent at a particular spatial level. Conceiving of an area as an energy landscape is

8 Pender et al 2012; Bauhardt 2014; Glenna et al 2014; Vergunst 2002; Pickerill & Chatterton 2006
9 Muller et al 2011; Ohimain & Izah 2014; Pugesgaard et al 2013; Zhang & Fu 2011; Bradley & Callum 2012
10 Chicco & Mancarella 2009; Brass et al 2012; Kayagusuz 2011
11 Harrison & Popke 2011; Sherman & Sage 2011
12 Pasqualette & Brown 2014; Milder et al 2008; Sovacool 2012
13 Stremke & van den Dobbelsteen 2013; Stremke 2014; Chicco & Mancarella 2009; Bridge et al 2013
14 Blaschke et al 2013; Burgess et al 2012; Bridge et al 2013; Coleby et al 2012; Calvert et al 2013
15 Tenerelli & Carver 2012; Dale et al, 2016; Resch et al 2014; Howard et al 2013; Stremke & Dobbelsteen 2012
16 Blaschke et al 2013; Stremke 2014; Pasqualetti 2011
17 Stremke & van den Dobbelsteen 2013; Howard et al 2013; Blaschke et al 2013; Pasqualetti & Brown 2014
18 Neumann 2011; Walker & Fortmann 2003; Pasqualetti et al 2014

functionally about spatially mapping relevant indicators impacting energy supply, transportation, storage, and consumption, and using some combination of these to explain patterns observed. This enables geographic assessment of phenomena, such as the density and location of potential energy resources that could be developed in the future and the implications of this, both essential questions with respect to fully understanding the effects a decentralized renewable energy system is likely to have in an area.[19]

This project will develop a Geo-Spatial Intelligence Platform (GSIP) and employ it to characterize and understand the potential impacts and productivity of future energy landscapes characterized by renewable energy production that supports energy self-sufficiency at the community to regional level. Following efforts and practices discussed by a growing clique of researchers,[20] the GSIP[21] will holistically assess the study area, combining high-resolution spatial and temporal data from satellite imagery[22] and other existing spatial datasets into a geographic information system (GIS) capable of analytically processing indicators to represent the renewable energy *potential* of the study area's physical landscape. A qualitative study of community knowledge and attitudes about local renewable energy and their assessment of where in their community it may be appropriately developed will be combined with a regulatory restriction assessment, and production costs and demand dynamics will be cohesively incorporated into a customizable and parameter-based optimization process. This will take the form of a multi-criteria decision support tool (MCDST)[23] and produce optimized *designs* for potential energy landscapes as they could exist in the study area.[24]

The advantage of this approach is that it is capable of holistically incorporating the complex trade-offs implicit in different land use decisions in a cohesive system.[25] The basic methodology has been successful in case studies in the Netherlands, England, Austria, and Canada, among others[26] However, researchers openly accept that there is room for improvement in the methods employed to date, both in ensuring that local knowledge of and preferences for the landscape are sufficiently understood[27] and in accounting for the temporal variability inherent in renewable energy, which is dependent on time-specific local conditions.[28]

The approach will address temporal variability by employing the three decades of available Landsat and ancillary data to characterize the time-trajectory[29] of relevant indicators. We will

19 Pasqualetti et al 2016, Halfacree 2007; Neumann 2011; Walker & Fortmann 2003
20 Stremke & Dobbelsteen, Resch et al 2014; Tenerelli & Carver 2012, Calvert et al 2013, Matejicek, 2015
21 Derived from Calvert et al, 2013, describing a 'geo-spatial intelligence system'
22 Predominantly Landsat 5, (6 failed on launch) 7, and 8, per USGS, 2016
23 Gret-Regamey & Hayek 2012, Tenerelli & Carver 2012
24 Dale et al 2016; Stremke & Dobbelsteen 2012;
25 Resch et al, 2014, Dale et al, 2016, Pasqualetti & Brown 2014, Calvert et al, 2013
26 Stremke & van den Dobbelsteen, 2013, Burgess et al, 2012, Resch et al, 2014, Calvert & Mabee, 2015
27 Calvert et al, 2013, Pasqualetti 2011, Pasqualetti & Brown 2014, Stremke 2014
28 Resch et al, 2014, Stremke & van den Dobbelsteen, 2013
29 Kennedy et al, 2009, 2010, 2012

address local knowledge and preferences by conducting a qualitative study with voluntary participants living in communities in rural Northwest Oregon. One Landsat scene[30] will function as the underlying foundation for initial GSIP development, and all data gathered will be categorized and 'layered' on top of this scene in the GIS. This structure allows for systematic spatial assessment rooted in statistical analysis and dynamic modeling, enabling methodological consistency and transparency.

The MCDST will incorporate results of qualitative work with community participants, a necessity in producing useful spatial analysis, including assessment of energy landscapes[31] The methods employed will be structured around researcher-guided discussions and participative counter-mapping[32] based on local knowledge and perceptions of the landscape and the effects of current regulatory regimes to 'weight' regions of the study area. This weighting will determine where and to what degree renewable energy production in study area communities is enabled or restricted by local values, aesthetics, and local understanding of the landscape. Though it is always difficult to ensure an accurate, meaningful conversion of qualitative information into a numeric form, triangulation will be employed to mitigate bias.

The end product will be useful design scenarios for sustainable energy landscapes that contribute to understanding of the technical and social potential for renewable energy production in the area and the degree to which self-sufficiency is both practicable and feasible. All data and analysis will be made publicly available via the [33] web-based interface established to allow users to interact with the GSIP and actively experiment with MCDST parameters to explore and better understand the mid-Willamette energy landscape. All scholarly publications will be open-access, and open-source software used for the GSIP architecture, to better enable the broad dissemination of data and results and to allow for the GSIP to be readily updated and adapted.

Mid-Willamette Valley as Study Area

Northwestern Oregon is notable for high biological productivity and concomitant agricultural and silvicultural capabilities[34] as well as a unique regime of land use planning that has managed urban expansion for more than three decades.[35] Bounded by the Coast, Klamath, and Cascade Mountains to the west, south, and east and the Columbia River to the north, the Willamette River cuts through the 240km long valley. The predominantly rural mid-Willamette Valley, [36] part of the region covered by the Northwest Forest Plan, was like other area communities hard hit by the

30 A 170km by 183km georeferenced image re-acquired by satellite every sixteen days – USGS 2016
31 Zimmerer 2011; Calvert 2016; Liverman 2004
32 Rocheleau 1995
33 Hosted by Sponsoring Organization
34 Chen & Weber 2013
35 Walker & Hurley 2011
36 The definition of 'Rural' is very context (and observer) specific, this project employs the term in a manner concomitant with the US Department of Agriculture when determining eligibility for rural support programs. This preserves maximum flexibility and includes the majority of the land area in the region

collapse of the timber industry in the 1990s and the economic turmoil of the 2000s[37], and experiences relatively high rates of poverty, drug addiction, out-migration, and loss of heritage, like much of the broader rural US west.[38] Some communities have been successful in pursuing a strategy of amenity development, effectively catering to the market for 'experiences' geared towards tourists from urban areas.[39] However, the sustainability and broad applicability of this strategy is questionable. Sustainable development in rural Oregon must grapple with the competitive demands of the globalized capitalist economy, which continues to be problematic.

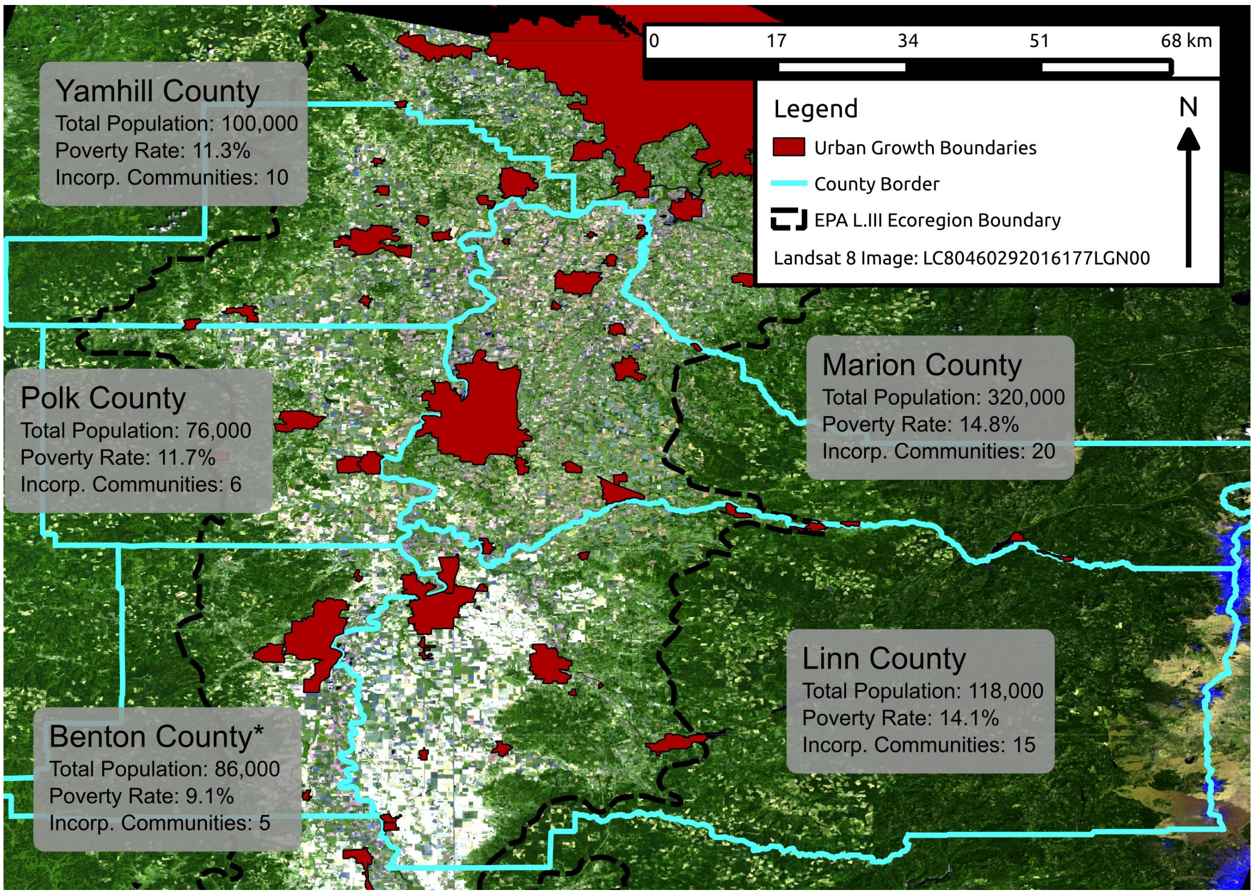

Illustration 1: Mid-Willamette Valley. Landsat 8 false color image, Portland visible at north edge

This project will focus on five counties[40] and 52 incorporated communities[41] within them, an area colloquially referred to as the 'Mid-Willamette' portion of the greater Willamette Valley. At its core is an agriculturally productive level III ecoregion,[42] which transitions in the west and east to the more mountainous Coast Range and Cascade level III ecoregions, respectively. Forest

37 Chen & Weber 2013; Sherman & Sage 2011; Nelson 2001
38 Hibbard & Lurie 2013; Hagerman 2007; Walker & Fortmann 2003;
39 Chen & Weber 2013; Hibbard & Lurie 2013
40 Benton, Linn, Marion, Polk, Yamhill Counties
41 Excluding the mid-sized cities of Salem, Albany, and Corvallis, defined by their urban growth boundaries
42 US Environmental Protection Agency 2016

resources have long been important in the state, with commercial harvest largely limited for the past twenty years due to the provisions of the Northwest Forest Plan,[43] which is partly responsible for the major buildup of fuels and concomitant wildfire risks.[44] Solar, wind, and small hydroelectric resources are also present in the region. While Oregon at large generates most of its electricity from long-operating dams over the Columbia, its export of electricity to the massive and far more coal-reliant markets in California[45] means that local renewable energy generation helps reduce fossil-fuel use elsewhere. In addition, Oregon imports natural gas and petroleum products, further tying it to the contemporary fossil-fuel system, but in recent years has increasingly moved to embrace renewable energy production.[46]

GSIP Architecture and Plan of Work

To assess the energy landscape of the mid-Willamette with respect to the various renewable ‘energy carriers’[47] present in the region, a Geo-Spatial Intelligence Platform[48] will be constructed to holistically assess both the supply of renewable energy in the area and the many limitations on renewable energy development, not least of which are production costs and the need to minimize deleterious ecological impacts. Construction of the GSIP will require three distinct (though overlapping) phases, incorporating quantitative and qualitative spatial data to address the essential questions of *how much* energy potential exists in the study area and *at what cost / with what impact* development can take place.

The GSIP will be a melding of geographic information system (GIS) and multi-criteria decision support tool (MCDST),[49] relying on publicly available geo-spatial data and a layer-based architecture to enable cross-comparison using a geographic coordinate system as the basic common reference point. This system will be constructed in three main phases, with workflow illustrated by Illustration 2. A key advantage of the GSIP approach is that it allows for application of statistical and modeling approaches across multiple data types, which can enable subsequent optimization assessments to be made that incorporate a wide variety of relevant parameters.[50] It therefore serves as a crucial interface between purely technical data – such as the potential renewable energy yield associated with a particular location – and more qualitative information, such as land use regulation and social preferences.

43 Chen & Weber 2013; US Department of Agriculture – Forest Service 2016
44 Hibbard & Lurie 2013
45 Orans et al 2007; California Public Utilities Commission 2016
46 Oregon Department of Energy 2016
47 Resch et al 2014; Tenerelli & Carver 2012; Stremke & Dobbelsteen 2012; Calvert & Mabee 2015
48 'Protocol' might be a better term than 'Platform', either way basis is derived from Calvert et al 2013
49 Stremke & Dobbelsteen 2012; Calvert et al 2013; Resch et al 2014; Blaschke et al 2013
50 Tenerelli & Carver 2012; Stremke & Dobbelsteen 2012; Calvert & Mabee 2015; Matejicek, 2015

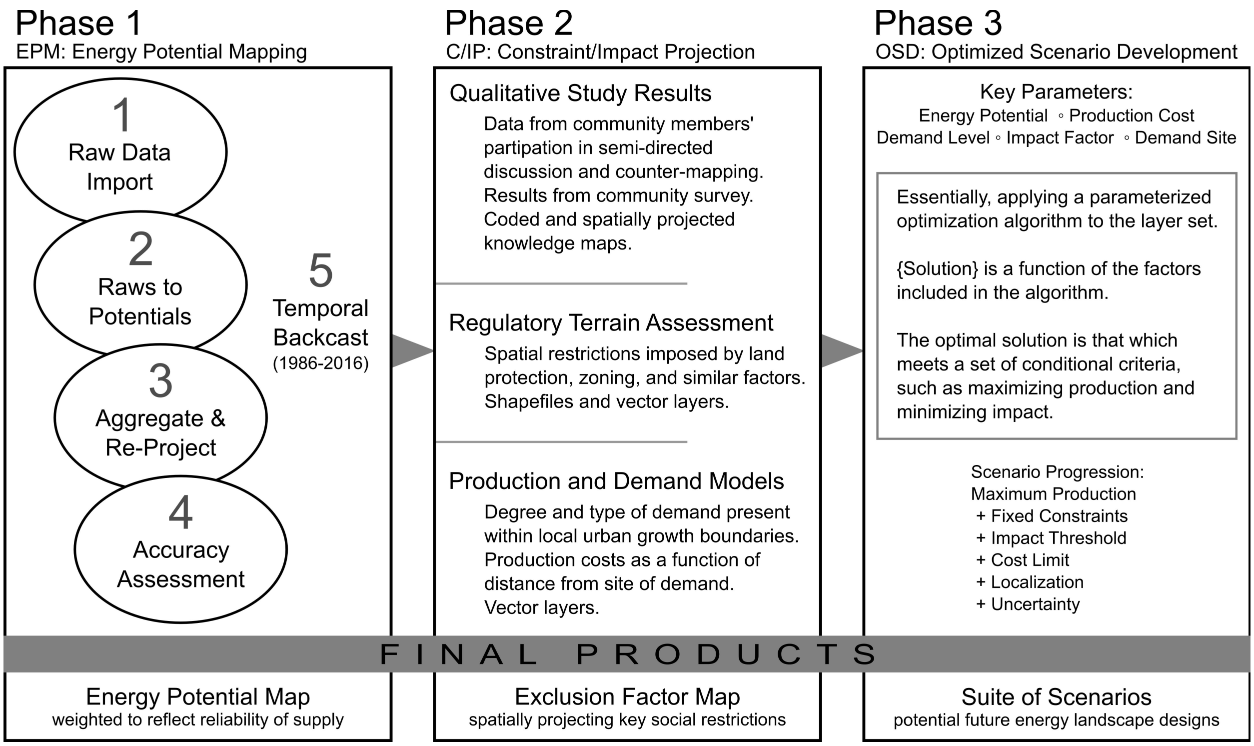

Illustration 2 - GSIP flow by sub-component

Phase 1: Energy Potential Mapping of the Mid-Willamette

Understanding the location and quantity of renewable energy resources in a given area is at the heart of the study of energy landscapes, and Energy Potential Mapping involves collecting relevant geo-spatial data and incorporating it into a GIS-type affair to allow spatially explicit cross-comparison of important spatial patterns.[51]In essence, this technique transforms georeferenced base data into usable energy potential values.[52] This can be accomplished by applying conversion algorithms incorporating site and energy-carrier specific factors to weight locational values according to relevant technical criteria[53] and map their distribution.

Many studies focus on one particular energy carrier, such as biomass,[54] photovoltaic solar,[55] or wind,[56] this project seeks to comprehensively characterize rural energy landscapes and will incorporate data layers relevant to each form of renewable energy present in useful amounts[57] in the study area. Table 1 includes a list of the pertinent renewable energy sources included, as well

51 Resch et al 2014; Burgess et al 2012; Blaschke et al 2013, Calvert et al 2013, Stremke & Dobbelsteen 2012
52 Stremke & Dobbelsteen 2012; Barrington-Leigh & Ouliaris 2016; Calvert et al 2013
53 Calvert & Mabee 2015; Tenerelli & Carver 2012; Stremke & Dobbelsteen 2012; Blaschke et al 2013
54 Dale et al 2016; Coleby et al 2012; Elmore et al 2008; Milder et al 2008
55 Pasqualetti 2011; Pasqualetti et al 2016
56 Calvert & Mabee 2015; Pasqualetti et al 2016
57 Wave/tidal, geothermal, non-photovoltaic solar, dam-based hydroelectric systems, as examples

as the type of information which will be used to convert underlying raw data to a useful estimate of the potential renewable energy available at each location on the landscape.

Energy Carrier	Raw Data Source (temporal availability)	Data, Conversion Method	Primary End Use(s)
Biomass (forest)[58]	Landsat (decades)	Landsat 30m x 30m multispectral NDVI/NPP filter * conversion factor from literature	Liquid Fuel, Heat, Electricity
Biomass (crop)[59]	Landsat (decades)	Landsat 30m x 30m multispectral NPP filter/Spectral profile * conversion factor (lit)	Liquid Fuel, Heat, Electricity
Photovoltaic Solar[60]	Landsat/Topography (years to decades)	Solar Irradiance at Ground Level Function of {latitude, topography, climate}	Electricity
Small Hydroelectric[61]	Topography, Gauges (decades)	Elevation change, Water flow, In-pipe pressure Head (elevation change) * flow rate	Electricity
Wind Turbines[62]	Wind Speed (years)	Observed Wind Speed Conversion factor from literature	Electricity
Waste Processing[63]	Existing Maps (decades)	Aggregate production of useful waste Conversion factor from literature	Heat, Electricity

Table 1: Energy Potential Layers

The process of converting a general geospatial value to an energy potential varies depending on the energy carrier being considered, but will be approached in the following manner, an adaptation of methods published in the recent literature.[64]

1. Raw Data Import
   - For each energy carrier, identify and obtain useful raw data, as outlined in table 1. Incorporate into GSIP as spatially-explicit layers, with a land classification map functioning as the base layer.

Landsat data will be used to evaluate biomass inventories as well as establish a base classification map, which will aid in determining the functional ability of a particular location to support renewable energy production.[65] As an example, heavily forested areas are likely unsuitable for intensive photovoltaic solar development, although solar irradiance data tends to focus on latitude and climate as most relevant for calculating energy potential. Land use maps can function as a simple filter, enabling easy exclusion of areas contextually certain to be unsuitable to intensive development of a particular potential. Further, the presence of existing land use estimates for the region enables a cross-checking mechanism to ensure that project methods and procedures are producing legimate results.

58 NDVI = Normalized Density Vegetation Index, NPP = Net Primary Productivity, see Jensen 2006, 2007
59 Cropscape, as an example of a product containing this type of information, (USDA-NASS 2016)
60 The National Solar Radiation Database is a good example, (National Renewable Energy Labratory 2016)
61 Kosnik 2010 offers a good overview
62 The National Renewable Energy Labratory 2016
63 Stremke & Dobbelsteen 2012
64 Resch et al 2014; Matejicek 2015; Stremke & Dobbelsteen 2012
65 Burgess et al 2012, Stremke & Dobbelsteen 2012, Howard et al 2013

2. Convert Raw Data to Usable Energy Potentials

- For each energy carrier across the scope of the study area, apply a conversion algorithm to transform raw data into a common metric, the 'energy potential'.

This is the fundamental, and most crucial, step in energy potential mapping. Because of the many differences between different energy carriers in terms of necessary utilization technology and resource management practices, direct comparison requires a common metric. The specific algorithms used to convert observed data signals to this metric will be obtained via review of recent and foundational literature.

3. Aggregate and/or Re-project to 90m base unit

- A filter will be passed over all sub-90m resolution data that takes the median value of the energy potentials within the kernel filter in order to mitigate the effect of inherent and classification errors.[66]

For actual management purposes, a 30m spatial resolution is too fine to be useful, in part because registration issues and other noise means that there is a 1-2 pixel uncertainty associated with any particular 30m unit in a Landsat image,[67] but also because most lands are managed at far more coarse scales. Aggregating 30m data increases the overall reliability of the energy potential estimate while reducing data processing overhead by almost an order of magnitude.

4. Uncertainty Assessment

- All energy potential layers will be accompanied by an uncertainty/error layer. This will record the degree of uncertainty associated with the particular dataset, collectively enabling estimation of total error.

Error and uncertainty are unavoidable when working with large spatial datasets. All data imported into the GSIP will be accompanied by an evaluation of error and uncertainty, expressed as statistical confidence level. Where the data itself fails to contain a spatially explicit uncertainty layer, one will be created by projecting what error information is available from the relevant literature across the spatial extent of the layer. This will enable a final energy potential layer 'stack' to include an overall error assessment, indicating the spatial variation in certainty about the values recorded.[68]

5. Temporal Back-Cast

- Steps 1-4 will be repeated for each year in the period 1986-2016 where data is available, and the results stored. This will provide, for each locational energy potential for each energy carrier, a portrait of its trajectory over time, in terms of average values and variance.

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66 Jensen 2006, 2007; Resch et al 2014
67 Jensen 2006, 2007; USGS 2016
68 Stremke & Dobbelsteen 2012

Finally, *temporal* characteristics of energy potentials must be accounted for in order to accurately understand not only the gross quantity of theoretically available energy associated with a location, but also its *reliability*. Renewable energy sources can vary on a daily, seasonal, annual, even decadal basis. A crucial consideration for understanding energy potentials on a landscape is determining the natural variability in availability over time – something inadequately addressed in most energy potential mapping projects currently available.[69]

Fortunately, the multi-decade temporal span of the underlying data described above allows for estimating the trajectory[70] of a given locational energy potential over time, which can be used to produce end energy potential maps that reflect a best estimate of *reliable* energy potential.[71] This will enable analysis to take into account the natural dynamism of the landscape, further filtering the study area's energy potential map to ensure that mapped energy potentials reflect, as accurately as possible, the true long term resource potential associated with a given location.

Phase 2: Constraint and Impact Projection

EPM produces only one type of layer pertinent to holistic assessment of energy landscapes.[72] Characterization of supply is in and of itself useful, but insufficient, to assess the technical prospects for local-regional energy self-sufficiency. Costs of production must be taken into account, and demand dynamics estimated to the degree possible.[73] Even more important are qualitative considerations rooted in the social terrain of the energy landscape – often difficult to observe and yet fundamental in existing and potential land use and land management practices.[74]

1. Local Perspectives on the Mid-Willamette Energy Landscape

Citizen perspectives of the landscape are widely recognized in the energy landscape literature as crucial factors in addressing questions of sustainability.[75] Aesthetic, material, spiritual, and ideological factors are essential to understanding the full character of the landscape. More than one renewable energy project has foundered under the opposition of citizen groups who oppose development.[76] Qualitative data can be mapped and incorporated into a GSIP, and this project will conduct focus-group type participant observation exercises in counter-mapping[77] in each county, ideally each incorporated community, in the study area.

Six to twelve community leaders – elected officials, civil service professionals, volunteer organization staff, and others suggested by these individuals, will be recruited in each county and

69 Resch et al 2014; Blaschke 2013; Burgess et al 2012; Stremke & Dobbelsteen 2012
70 Kennedy et al 2009, 2010, 2012
71 Reliable: energy potential 'stream' that can be relied on without undermining its ability to self-restore over time
72 Pasqualetti 2011; Pasqualetti et al 2016; Stremke 2014; van der Horst & Vermeleyen 2010, 2011
73 Resch et al 2014; Burgess et al 2012; Blaschke et al 2013; Dale et al 2016
74 Pasqualetti et al 2016; Milder et al 2008; Calvert & Mabee 2015
75 Calvert et al 2013; Calvert & Mabee 2015; Howard et al 2013; Pasqualetti et al 2016;
76 Bridge et al 2013; Pasqualetti et al 2016; Calvert & Mabee 2015
77 Rocheleau 1995; also see Rocheleau & Roth 2008

community in the study area. No compensation will be offered, but snacks will be provided at each focus group meeting. All participants will be required to sign an opt-in sheet informing them that the focus group proceedings will be recorded, but no personally identifying information will be retained after transcript notes are generated – all data will be anonymized to the degree reasonable. Institutional Review Board approval and oversight will be obtained at any university where any individual associated with the conduct of this study has or gains affiliation.

This will allow assessment of human factors, as represented by a set of relatively engaged community members, in three ways: First, transcripts of a guided group discussion will be coded and assessed. Second an image of the physical result of the counter-mapping effort itself. Third, a survey of personal attitudes and characteristics will be administered to each participant before and after the focus group meeting. This approach will ensure adequate triangulation.[78]

Qualitative data will be collected according to the following protocol. A large base map of the local community will be laid out on a common table. A Moderator will administer a brief survey with demographic and attitudinal sections to all participants, and will then lead a semi-directed group discussion guided by the following key topics:

- How do participants feel about renewable energy in the community?
- What do participants believe will help their community's economic future?
- Do participants see merit in locally-provided energy services?

This discussion will last approximately 30 minutes, and be followed by a break. The moderator will then briefly present local results of the Energy Potential Mapping carried out in phase 1, summarizing the meaning behind the imagery with respect to the potential for their community to carry out renewable energy production on local lands. This presentation will take no more than ten minutes, followed by a brief question and answer period of varying length.

The participants will then be asked to work together to produce a map, sketched on the base map provided, that characterizes their own understanding of the landscape in terms of:

- What areas they feel are suitable sites for renewable energy production
- The degree to which they would prevent production in certain areas

This exercise should last 30-45 minutes, but can go on as long as the Moderator feels additional useful information is being added. Upon culmination, the moderator will administer a repeat of the original survey, leaving out the demographic information section. Total participant time commitment is expected to last no more than 2 hours, however if participants continue to voluntarily participate beyond the expected time, that will not be discouraged.

78 Bernard 2011; Rocheleau 1995

All raw qualitative data coded and integrated into the geo-spatial intelligence platform as modifying or exclusionary factors mapped across the energy landscape.[79] This technique will essentially enable factor transformations on a range of 0 to 1 to be applied representing the degree to which areas of the landscape appear to be classified by local informant opinion as unsuitable for renewable energy development. A basic coding scheme will be decided upon in consultation with the qualitative research assistant prior to initial data collection, and will be pilot-tested a minimum of three separate times with a test population to allow time for revision prior to deployment.

2. Regulatory Terrain Assessment

The limitations on landscape use for renewable energy production can be established using publicly available information such as land zoning, protected areas, and so on. These are important factors to consider, as they create particular realities of the social-political-economic system in any area, that play a crucial role[80] in enabling and/or limiting the feasibility of utilizing renewable energy in spite of its abundance, or lack thereof, in a given landscape. These 'exclusionary factors'[81] can significantly impact renewable energy production in an area, placing significant restrictions on land use.

Factors such as specific exclusionary criteria emerging from land use regulations and the like, can be directly integrated as a factoral modification of the energy potential on a 0 to 1 scale – 0 being total exclusion, 1 being total inclusion. Layers will be produced that assess the degree of exclusion structurally present, weighting subsequent analysis by using this impact/exclusion factor as a simple multiplier. Use of a multiplier in this context is helpful as it can be easily combined with the factoral assessment derived from the Qualitative effort to produce a *total* impact/exclusion factor.

3. Production and Demand Models

It is essential to address demand factors as well as production costs associated with managing land for renewable energy production.[82] This will be achieved by localizing demand to incorporated community 'urban growth boundaries'[83] in the study area, then aggregating energy requirements by class – electricty, heat, fuel – using published average population use of energy in the area to estimate total energy demand.[84] This admittedly neglects a more nuanced treatment of demand dynamics, however, analytically the simplification is reasonable to make as understanding local demand at scale levels finer than the community requires a major investment in household-level surveys, which are beyond the scope of this project.

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79 Matejicek 2015; Resch et al 2014; Tenerelli & Carver 2012
80 Blaikie 1985; Peet & Hartwick 2009; Walker & Fortmann 2003; van der Horst & Vermeleyen 2011
81 Tenerelli & Carver 2012; Stremke & Dobbelsteen 2012
82 Elobeid et al 2013; Resch et al 2014; Calvert et al 2013
83 See Walker & Hurley 2011, essentially a designated urban expansion area intended to prevent sprawl.
84 Aggregation of this type explored by Resch et al 2014; Dale et al 2016

Production costs will be estimated by using existing literature estimates for renewable energy production per-unit costs, and incorporating these into a distance-cost function that models the effect of proximity to a locational energy potential on total exploitation cost.[85] This function will use existing maps of local transportation networks to simulate the effect road infrastructure has on enabling physical access to portions of the study area, particularly the rugged terrain of the Coast and Cascade Ranges, and will play a major controlling role in determining what energy potentials can be reliably developed.

Phase 3: Optimized Scenario Development

Knowledge of the spatial availability of renewable energy in an area and the corresponding technical and social limitations impacting its development are mutually beneficial, creating the basis for area or sub-area examination of both renewable energy potential and the potential opportunity costs and externalities associated with this form of energy production. But Once the energy landscape has been characterized, it must then be interrogated. Energy landscapes have been defined as places where people obtain and consume energy,[86] but the deeper utility of the paradigm lies in its ability to aid a re-think of current patterns, and determine how and where managers might best intervene to promote a more sustainable, resilient, and/or more just regime.

This project will apply optimization procedures via a Multi-Criteria Decision Support Tool (MCDST)[87] to produce a suite of scenarios, really potential energy landscape *designs*, capable of demonstrating both *how much* reliable renewable energy potential exists in the study area and at *what cost and impact* would be entailed by energy self-sufficiency. The basic idea behind the MCDST is to relate a series of variables/parameters according to some common quantitative outcome, or solution – such as, for example, total energy production as measured by the total aggregate energy potential across the landscape. This allows for conditions to be attached to each parameter, and the relationship between them structured to restrict the solution set.[88]

Naturally, each different configuration of parameter settings gives rise to a different solution space, so the outcome is highly dependent on these parameters. This enables the solution space to be *optimized* to meet a certain objective under select restrictions. The final phase of this project will be to produce a suite of optimized scenarios based on the interactions of energy potentials and the requirement to minimize associated costs and impacts. This will be accomplished sequentially, starting by calculating the total renewable energy potential in the study area, then adding restrictions step by step, per the following logic:[89]

85 Calvert et al 2013; Blaschke et al 2013
86 Stremke 2014; Blaschke et al 2013; Burgess et al 2012
87 Stremke & Dobbelsteen 2012; Tenerelli & Carver 2012; Resch et al 2014; Matejicek 2015
88 Matejicek 2015; Safian 2015; Elobeid et al 2013
89 Again, it must be stressed that this stage of work will very likely require adaptation of specific methods, algorithms, and similar considerations to reflect the current best practices given ongoing developments.

Scenario 0: Maximize total production

· unrealistic, gross estimate of total regional potential; serves as baseline

Scenario 1: Max. total production + Impact Threshold (IT)

· Exclude locations where total impacts exceed some threshold {x}

Scenario 2: Max. total prod. + IT + Cost Limitation (CL)

· Exclude as in 1, but also exclude locations where production cost is > {x}

Scenario 3: Max. total prod. + IT + CL + Localization (Loc.)

· Segment study area into community 'districts' for scale assessment[90]

Scenario 4: Max. total prod. + IT + CL + Loc. + Uncertainty

· Penalize all EP values according to total uncertainty

Other scenario trees will be devised and assessed as the project progresses, given advancements in methodology which can inform updates to the GSIP and the possibility that the qualitative research raises additional tractable questions.

The final products of this phase will be the culmination of the work, and will be made publicly available as they are produced and verified. A web interface will be established to serve as an access point for the public, enabling public view and download of all data collected and analysis conducted. Presentations in interested communities will also be given upon request, in order to obtain additional public feedback. As it is received, the GSIP will be adapted as possible.

Timeline **Project Phase – Sub-phase (personnel)**	Year 1: July 1, 2017 – June 30, 2018				Year 2: July 1, 2018 – June 30, 2019				Year 3: July 1, 2019 – June 30, 2020			
	Q3 (17)	Q4 (17)	Q1 (18)	Q2 (18)	Q3 (18)	Q4 (18)	Q1 (19)	Q2 (19)	Q3 (19)	Q4 (19)	Q1 (20)	Q2 (20)
1 – 1 (PI)	X	X										
1 – 2 (PI)		X	X									
1 – 3 (PI)			X	X								
1 – 4 (PI)				X	X							
2 – 1 (PI + QRA)		X	X	X	X	X	X	X				
2– 2 (PI + QRA)					X	X						
2 – 3 (PI + QRA)						X	X					
3 – 1 (PI)							X	X				
3 – 2 (PI)								X	X			
Web Interface Development (PI + WD)						X	X	X	X	X	X	X
Results Publication									X	X	X	X

90 Weight by population, check for local clustering, so forth. See Elmore et al 2008; Elobeid et al 2013

Broader Impacts, Challenges, and Conclusion

All data, analysis, and results will be made freely available to the public through open-access and peer-reviewed publishing. A web-based interface will be developed and publicized to enable public viewing and interaction, with materials written for a lay audience in order to facilitate broader communication of the basic concepts and results. The project's methodological design requires interaction with community leaders in five counties, containing a total of several dozen incorporated communities, which will serve as a channel for broader dissemination of project results to an interested audience. Open-source software will be employed to the degree technically possible to ensure that the GSIP can be readily updated and adapted to repeat the project procedure in subsequent study areas. The project will further the professional and academic education of the principle investigator, quantitative research assistant, and web developer, and the latter two will be recruited from under-represented populations in science.

Successful completion of the project will produce a publicly available GSIP, a suite of six or more parameterized and optimized energy landscape designs for the study area, at least three peer-reviewed, open-access academic publications, and a series of non-expert summaries published online. All materials and documentation will be made publicly available to allow for future work to readily replicate the basic methodology in other study areas. Given that significant research efforts are underway in the renewable energy sector, it is conceivable that algorithms envisioned and used in initial stages will become obsolescent. An advantage of the modular, layer-based format of the GSIP will be that individual layers can be updated and cross-layer calculations re-done at an intermediate stage in the project. Error tracking is embedded into the methodology, and will enable spatially explicit tracking of cumulative error incidence across the various layers, which may indicate a need to change certain procedures or techniques at a sufficiently early stage that adjustments can be made with minimum progress disruption.

Ultimately, this project will offer actionable intelligence to communities in the Mid-Willamette with respect to the opportunities of the transition to an energy system dominated by renewables. The deeper intent motivating the work is a desire to understand whether energy self-sufficiency can be a useful form of alterity, autarky or other configuration of radical autonomous space[91] that mitigates the marginalization of the community inherent in contemporary globalization. If progressive ideas of radical democratic governance, and the need to localize wealth streams are to have a practical impact, the deeper mechanics of how this may be achieved must be understood at a broader scale level than that of the individual community. How material systems of production can efficiently and sustainably satisfy human needs under a different socio-economic arrangement than currently present in much of the world is a prerequisite for actually making the change to a different material regime. Construction of a GSIP to assess the energy landscape of the Mid-Willamette Valley will help further understanding in this area.

91 McCarthy 2006, 2007; Halfacree 2007; Pickerill & Chatterton 2006