Assessing the Carbon Footprint of ODFW Operations

Base Year GHG Inventory Report

September 17, 2021

ENVIRONMENTAL CONSULTING, AUDITING AND SCIENTIFIC SERVICES

Assessing the Carbon Footprint of ODFW Operations

ODFW Base Year GHG Inventory Report

Prepared For:

Oregon Department of Fish and Wildlife

Prepared By:

AET Group Inc.

531 Wellington St. North
Kitchener ON N2H 5L6
T (519) 576-9723
F (519) 570-9589
www.aet98.com

September 17, 2021

AET File No. OFW_GHG2021_088

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

BACKGROUND

In recent years the Oregon Department of Fish and Wildlife (ODFW) has developed several strategic plans and policies pertaining to the increased sustainability of the organization. ODFW's Strategic Plan requires "*Sustainable management of existing ODFW assets and infrastructure consistent with their value to the mission*." ODFW's Sustainability Plan commits ODFW to begin measuring and reporting on the carbon footprint of their operations. ODFW's Climate and Ocean Change Policy sets an ambitious goal of the Department becoming carbon neutral by mid-century. ODFW's base year (July 1 2019 – June 30 2020) greenhouse gas inventory, summarized in this report, provides the ability to measure, analyze and report ODFW's greenhouse gas emissions (GHG). However, the real benefits of a GHG inventory are realized over time, as multiple years of GHG emission data will allow ODFW to monitor the performance of its planned GHG reduction strategy and progress towards its carbon neutral goal.

KEY TAKEAWAYS

This report summarizes the approach, process, and results of the GHG inventory calculated for ODFW's base year. The results of future GHG inventories will be compared to the results of this inventory to measure change and progress over time. The key takeaways from this data include:

- ODFW's total base year GHG emissions are 9,280 tonnes of equivalent carbon dioxide (CO_2e);
- The top three sources of GHGs from ODFW operations are electricity use, vehicle fuel combustion, and fish production (nitrous oxide emissions from fish life processes); and
- The estimated carbon sequestration in ODFW's wildlife areas is equivalent to almost 61,000 tonnes of CO_2e per year and is over 6.5 times larger than ODFW's base year GHG emissions total.

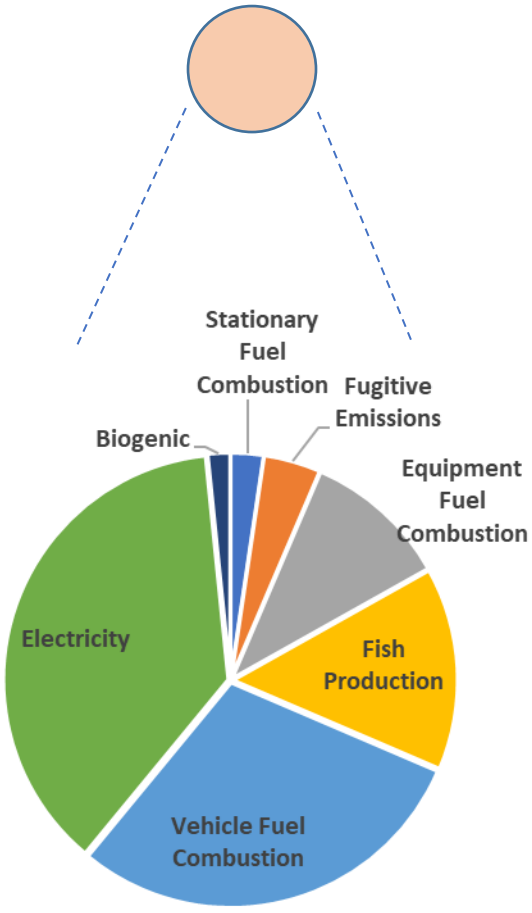
ASSESSMENT APPROACH AND BOUNDARY

ODFW's GHG inventory was prepared in accordance with *The Greenhouse Gas Protocol's* framework for U.S. public sector organizations. GHG emissions are categorized into 'scopes' for reporting purposes. The table below describes the scopes and sources of GHG emissions that are reported in ODFW's base year GHG inventory:

	Scope 1	Scope 2	Non-Scope GHG
Description of scope	Emissions that occur from sources within the organizational boundary of the GHG inventory, from mechanical or non-mechanical sources.	Emissions from the consumption of electricity purchased by ODFW.	Other sources of GHG emissions or reductions not associated with a scope.
ODFW GHG emission sources included	1. Fuel combustion in ODFW facilities for heating/cooling 2. Fuel consumption for on-road vehicles 3. Fuel combustion in equipment and boats 4. Fugitive emissions from refrigerant use in ODFW facilities and vehicles 5. Emissions from microbial breakdown of aquatic nitrogen during fish production	1. Electricity or steam purchased for consumption in ODFW facilities	1. Annual changes in carbon storage in ODFW wildlife areas 2. Biogenic GHG emissions from the combustion of biomass fuels

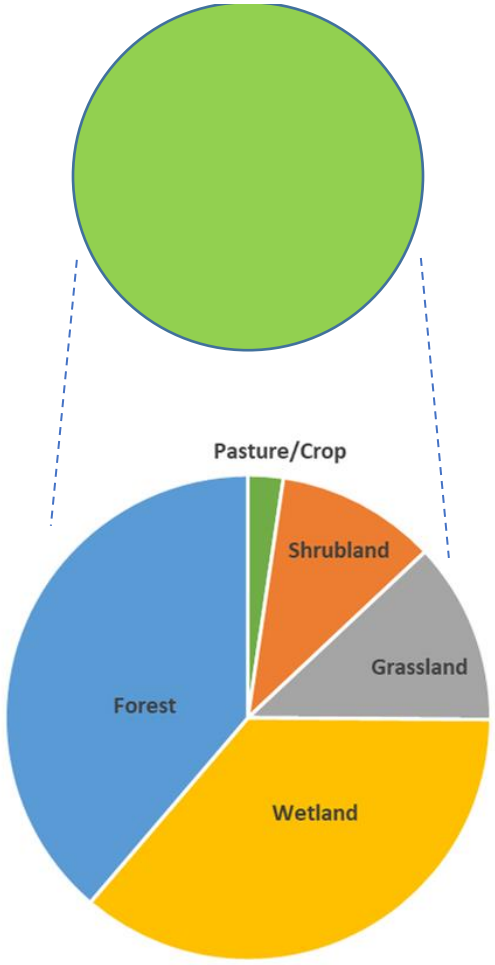
ODFW Base Year GHG Emissions:

9,280 tonnes CO_2e



ODFW Annual Carbon Sequestration:

60,955 tonnes CO_2e



NORMALIZED ODFW ENERGY CALCUATIONS

In order to compare across facilities, an energy intensity metric is calculated for each facility. Energy consumption in ODFW campuses was assessed per square foot and per employee in recognition that ODFW has numerous very large campuses that have relatively small number of employees, which can skew the intensity metrics. Note that ODFW does not have consistently complete data on the full square footage of large, complex campuses like fish hatchery facilities, so the per square foot metrics are likely overestimates of the actual energy intensity and the per employee metrics should be treated as the most accurate measures of intensity. ODFW's campuses were assigned to one of three function categories in the analysis of normalized energy variables: fish hatchery facilities, office/research, and wildlife areas. The results of ODFW's normalized energy assessment for the three categories of campuses are provided in the table below.

Campus Type	kWh / employee	kWh / ft^2
Fish Hatchery Facility	23,698	17.0
Office / Research	4,415	9.7
Wildlife Area	10,478	2.5

ODFW's fish hatchery facilities have the highest energy consumption and energy intensity. This is a function of both the small number of employees that work at these facilities and the need to pump groundwater at multiple campuses.

The normalized energy intensity per square foot of ODFW's office and research facilities was compared to the energy intensity of office buildings in Portland Oregon. The average energy intensity of all office buildings (over 20,000 square feet) in Portland in 2019 was 18 kWh/ft^2. The average energy intensity of ODFW's office and research facilities was 9.7 kWh/ft^2, approx. 45% lower than the Portland office building average. It is also worth noting that despite being the most energy intensive campuses in ODFW's portfolio, fish hatchery facilities have an average energy intensity lower than the average Portland office building.

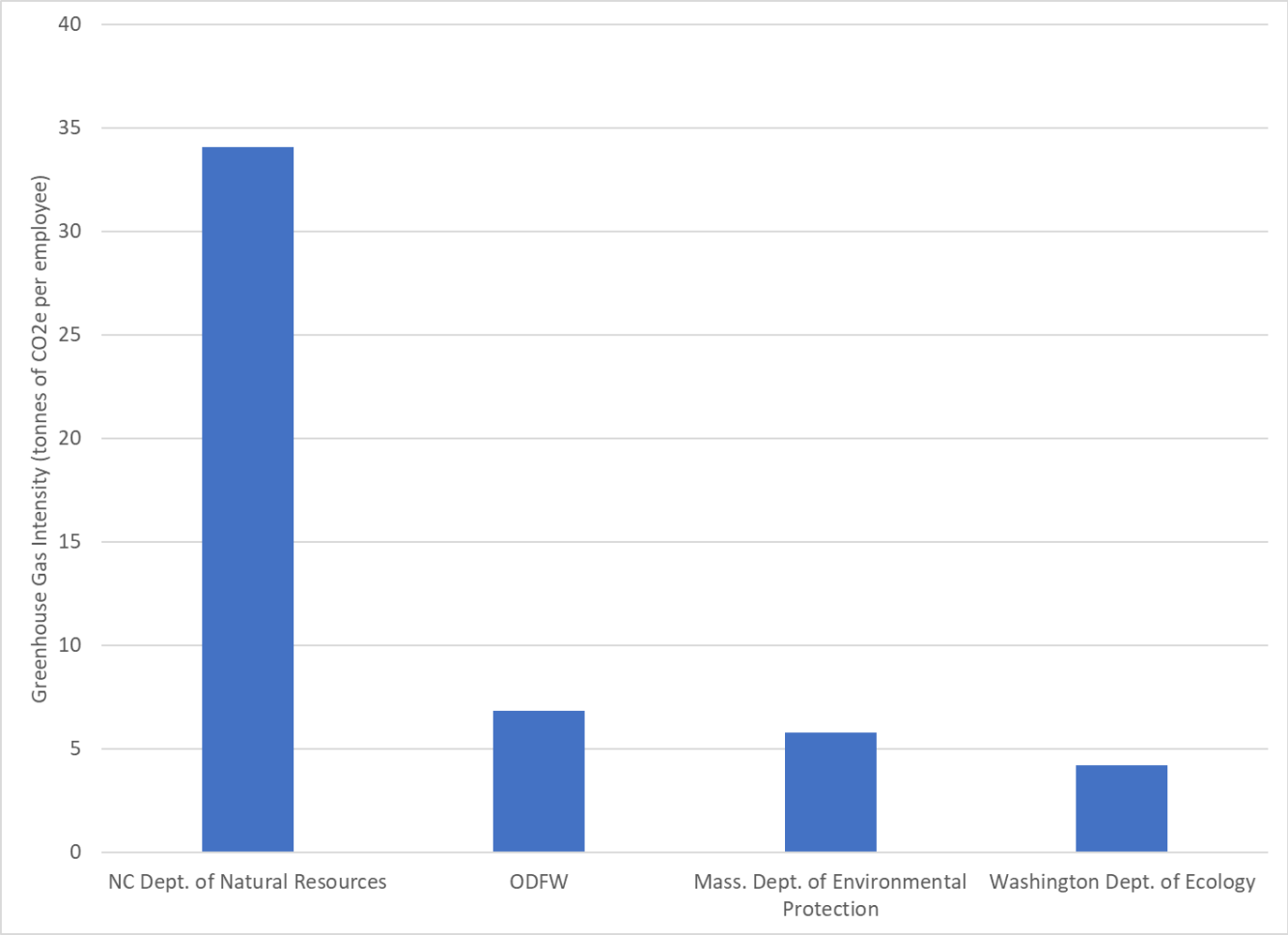
CARBON SEQUESTRATION IN ODFW WILDLIFE AREAS

The approximately 200,000 acres of wildlife and recreation lands managed by ODFW have a significant impact on annual carbon sequestration. ODFW's lands will remove carbon dioxide from the atmosphere in years that the vegetated land remains in its current state. ODFW's lands could be a source of carbon dioxide emissions to the atmosphere in years that vegetated land areas are lost (e.g. fires, harvest, and other land changes).

The estimated carbon sequestration in ODFW's wildlife areas is equivalent to almost 61,000 tonnes of CO_2 per year and is over 6.5 times larger than ODFW's base year GHG emissions total. Approximately 75% of the carbon sequestration in ODFW wildlife areas occurs in forest and wetland ecosystem types.

BENCHMARKING

Benchmarking is an opportunity to learn from the actions of similar organizations to ODFW regarding the quantification of GHG emissions and to confirm the reasonableness of the values calculated for ODFW. Several other state-level departments from across the USA with a similar mandate as ODFW were selected for a benchmarking assessment. Generally, ODFW's operational GHG emissions are comparable to other state-level natural resources agencies as is shown in the chart on the following page.



RECOMMENDATIONS

In the development of ODFW's base year GHG inventory, several opportunities or initiatives have been identified for ODFW's consideration in the interest of improving the quantification of its GHG emissions and maintaining momentum going forward.

1. Set Interim GHG Reduction Targets to Facilitate Progress Towards ODFW's Carbon Neutrality Goal
2. Implement Procedures for Improved Management of ODFW Energy Data
3. Implement an Organizational Sustainability Implementation Process
4. Prepare a Complete Database of ODFW Campuses and Facilities
5. Begin Management and Reporting of ODFW's Relevant Scope 3 GHG Emissions
6. Conduct Further Research into Impact of Process GHG Emissions from Fish Production

1.INTRODUCTION

The Oregon Department of Fish and Wildlife (ODFW) has a mission to protect and enhance Oregon's fish and wildlife and their habitats for use and enjoyment by present and future generations. ODFW's operations are geographically dispersed around the state with approximately 100 locations (district offices, research centers, fish hatchery facilities, maintenance shops, etc.) and an extensive fleet of vehicles that includes passenger vehicles, heavy trucks, and large fish liberation trucks. ODFW also owns or manages nearly 200,000 acres of land set aside for wildlife use and public recreation which act as a significant source of carbon dioxide removal from the atmosphere.

In recent years ODFW has developed several strategic plans and policies pertaining to the increased sustainability of the organization. ODFW's Strategic Plan requires "*Sustainable management of existing ODFW assets and infrastructure consistent with their value to the mission*." ODFW's Sustainability Plan commits ODFW to begin measuring and reporting on the carbon footprint of their operations. ODFW's Climate and Ocean Change Policy sets an ambitious goal of the Department becoming carbon neutral by mid-century.

ODFW's baseline carbon footprint assessment (also referred to as a 'greenhouse gas inventory') provides the ability to measure, analyze and report ODFW's emissions from the sources of greenhouse gas (GHG) that are included. However, the real benefits of a carbon footprint assessment are realized over time, as multiple years of GHG emission data will allow ODFW to monitor the performance of its planned GHG reduction strategy and progress towards its carbon neutral goal. This report describes the methodological approach and findings of the ODFW baseline carbon footprint assessment. A spreadsheet-based "ODFW GHG Calculation Tool" has been developed to complement this report which will assist ODFW in quantifying and tracking the GHG emissions from its operations going forward.

Section 2 of this report describes the design and development of the baseline ODFW GHG inventory, including the guiding framework in GHG management that was followed, the time period of the inventory report, and a definition of both the operational boundary and organizational boundary of the GHG inventory.

Section 3 provides details on the quantification of the GHG emissions for each GHG source included in the inventory, including a description of the input data used, the sources and values of emission factors used to convert input data into GHG emissions, a summary of ODFW GHG emissions, an assessment of intensity-based metrics used to monitor GHG emissions performance on a normalized basis, and an assessment of uncertainty of ODFW GHG emission sources.

Section 4 of this report summarizes the results of a benchmarking assessment of several other state-level departments from across the USA that was conducted to assess how GHG emissions are managed and reported by organizations similar to ODFW.

Section 5 provides details on the quantification of atmospheric carbon dioxide sequestration that is occurring within vegetated ecosystems of ODFW-managed wildlife areas, including a description of the input data used and the sources and values of carbon sequestration factors used to convert input data into estimated removals/uptake of atmospheric carbon dioxide.

Section 6 provides several recommendations for ODFW to consider in the interest of continual improvement of its GHG inventory and data management efforts going forward.

2. GREENHOUSE GAS INVENTORY DESIGN AND DEVELOPMENT

2.1 GUIDING FRAMEWORK

The Greenhouse Gas Protocol is a suite of guidance documents and support tools developed by The World Resources Institute and the World Business Council for Sustainable Development that has emerged as the leading global framework for the quantification of organization-based GHG emissions. In recognition of the unique GHG emission sources and management characteristics of public-sector / government organizations, *The GHG Protocol* developed a stand-alone version of its framework specific to these kinds of organizations[1] which was used to guide the development of ODFW's base year GHG inventory.

2.2 BASE YEAR REPORTING PERIOD

The GHG Protocol requires that an organization choose a 12-month period as the base year for their GHG inventory. Establishing a base year enables the tracking of emissions and progress towards emission reduction goals over time. While many organizations choose to utilize a calendar year (January 1 – December 31) as their base year, *The GHG Protocol* provides flexibility in when a base year starts and ends. This allows organizations to align their GHG inventory base year with a fiscal reporting year or some other form of temporal reporting.

The State of Oregon utilizes a biennium model for its budgetary planning, running from July 1 to June 30 of odd-numbered years. The most recently completed biennium is the period of July 1 2019 – June 30 2021.

Organizations are encouraged to select a base year that is representative of normal operating practices as much as possible ("business as usual"). The COVID-19 pandemic introduces unique challenges to organizations that are seeking to define their GHG inventory base year, as the past years of operation may no longer represent 'business as usual' compared to the upcoming post-pandemic time period. **ODFW has chosen to assign the period of July 1 2019 – June 30 2020 as the base year for its GHG inventory.** This base year was selected for the following reasons:

- The alignment with the first half of the state's recently completed fiscal biennium provides the ability to analyze both fiscal performance and GHG emissions performance concurrently.
- The selected base year includes 8.5 months (July 1 2019 – March 15 2020) of pre-pandemic operations and 3.5 months (March 16 2020 – June 30 2020) of pandemic operations. This blend of pre-pandemic and pandemic operations may provide an estimate for what ODFW's operations will be like in the post-pandemic time periods.

2.3 ORGANIZATIONAL BOUNDARY

The *organizational boundary* defines the structures that collectively describe the organization. There are two options for establishing an organizational boundary in *The GHG Protocol*: the 'equity share' approach and 'control' approach, defined as follows:

[1] World Business Council for Sustainable Development and World Resources Institute, 2010. *The Greenhouse Gas Protocol for the US Public Sector (Interpreting the Corporate Standard for US Public Sector Organizations).* Available at: https://ghgprotocol.org/public-sector-protocol-0

- Equity Share Approach: Under this approach, an organization accounts for GHG emissions from operations according to its share of equity in the operation, which often aligns with percentage ownership but more generally reflects an organization's share of economic interest in the operations.
- Control Approach: Under this approach, an organization accounts for 100 percent of the GHG emissions from operations over which it has control, of which there are two kinds:
  - *Financial Control*: An organization has financial control if it directs the financial and operating policies of the operation with a view to gaining economic benefits from its activities.
  - *Operational Control*: An organization has operational control if it has the full authority to introduce and implement its operating policies.

The benchmarking assessment (see Section 4 of this report) revealed that the operational control approach is most often selected by public sector organizations to define their organizational boundary. Under this approach, the organization defines a boundary that includes operations where they can implement operational policies that impact GHG emissions. ODFW has opted to utilize the **operational control approach** to define its organizational boundary.

A list of the ODFW campuses that are included in the organizational boundary of the base year GHG inventory is provided in Appendix A of this report. The 'campus' level of organization recognizes that many ODFW locations that are managed as a singular facility have multiple structures on-site that contribute to the campus' total energy consumption. Campus is defined as the base unit for ODFW's GHG emissions from building energy consumption. Note: ODFW supports and manages many fish hatchery facilities around the state in partnership with volunteers and federal agencies. Operational control was determined to extend to those facilities for which the department can control fuel and electricity consumption, independent of who owns the facility.

2.4 OPERATIONAL BOUNDARY

The *operational boundary* defines which GHG emission sources an organization will include in its inventory. Operational boundaries are defined to prevent double-counting of GHG emissions. In accordance with *The GHG Protocol*, GHG emission sources are categorized into three 'scopes' (Figure 1).

The GHG Protocol dictates that Scope 1 and Scope 2 are mandatory components of a GHG inventory, while Scope 3 sources are optional to include. ODFW has elected to only include Scope 1 and Scope 2 GHG sources in its base year inventory. Refer to Table 1 for a description of the GHG scopes and the sources of emissions included in the operational boundary of ODFW's base year GHG inventory.

ODFW undertakes many actions to enhance fish and wildlife populations. Included in these actions is the production of fish at hatcheries, which in many instances is intended to directly mitigate for the loss of fish that would otherwise have been produced in the wild were it not for the presence of dams or other habitat issues. For the purposes of this assessment ODFW chose to include GHG emissions resulting from production of fish at hatchery facilities given these are directly under ODFW's control and ODFW may be able to reduce these emissions by refinement of hatchery processes.

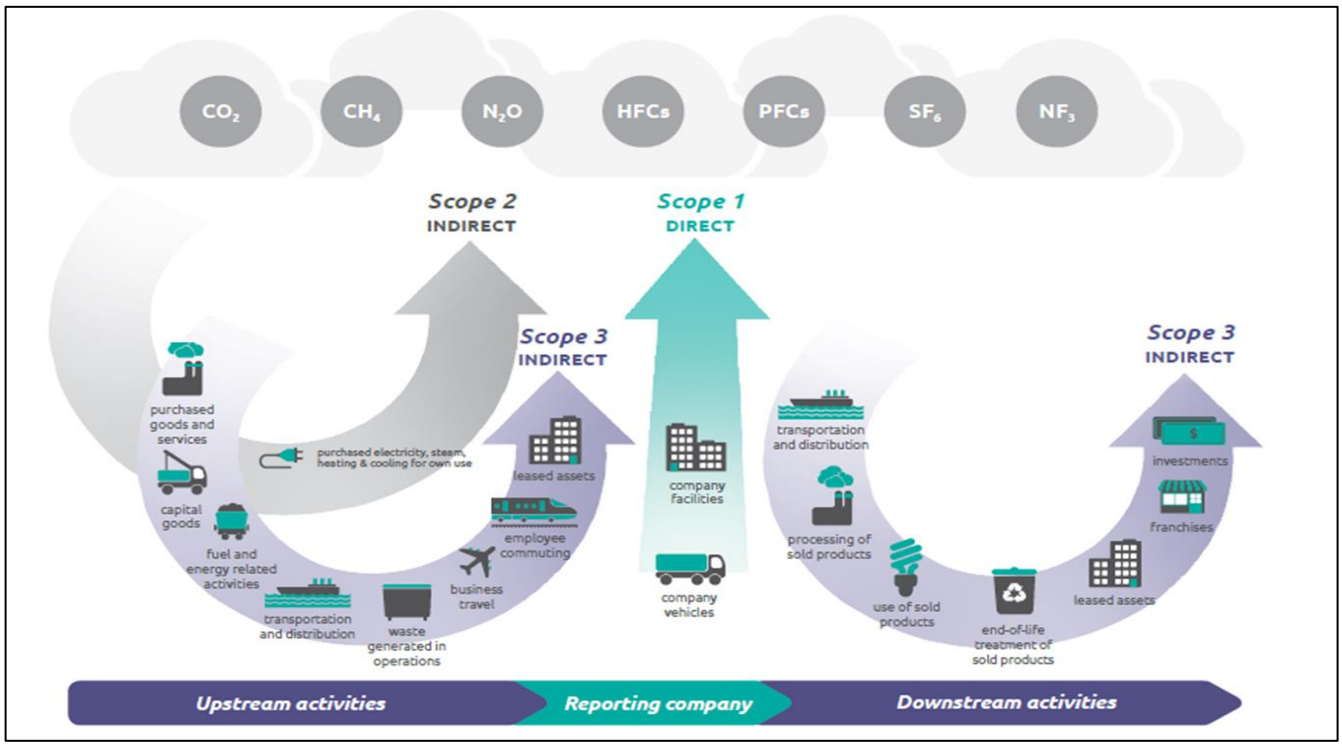


Figure 1: Schematic that shows the relationship between the three scopes of GHG emissions and the primary sources that contribute to each scope (image courtesy of WRI/WBCSD).

	Scope 1	Scope 2	Non-Scope GHG
Description of scope	Emissions that occur from sources within the organizational boundary of the GHG inventory, from mechanical or non-mechanical sources.	Emissions resulting from the generation of energy purchased by ODFW.	Other sources of GHG emissions or reductions not associated with a particular scope.
ODFW GHG emission sources included	1. Fuel combustion in ODFW facilities for heating/cooling 2. Fuel consumption for on-road vehicles 3. Fuel combustion in equipment and boats 4. Fugitive emissions from refrigerant use in ODFW facilities and vehicles 5. Emissions from microbial breakdown of aquatic nitrogen during fish production	1. Electricity or steam purchased for consumption in ODFW facilities	1. Annual changes in carbon storage in ODFW wildlife areas 2. Biogenic GHG emissions from the combustion of biomass fuels

Table 1: GHG emission sources included in the operational boundary of ODFW's base year GHG inventory.

2.5 BASE YEAR RECALCULATION POLICY

The GHG Protocol requires that organizations define a base year recalculation policy as a component of their GHG inventory report. A base year recalculation policy is intended to ensure that an organization's reported GHG emissions are comparable over time. The base year recalculation policy should ensure that reported changes in GHG emissions are due to an actual increase or reduction of emissions as opposed to a transfer of emissions to/from another organization. ODFW's base year GHG emissions will be recalculated if any of the following changes occur that impacts the total GHG emissions by ±10 %:

- A major change in the business operations, such as transfer of operational control of ODFW campuses or services to another State of Oregon department
- A change in ODFW's operational boundary (addition or removal of GHG emission sources, such as the potential inclusion of relevant Scope 3 sources in the future)
- A change in calculation methodology that impacts reported GHG emissions, such as an improved methodological approach

ODFW's base year GHG emissions will not be recalculated due to organic growth or shrinkage or consolidation of its business activities.

3. GREENHOUSE GAS QUANTIFICATION AND EMISSIONS

3.1 CALCULATION AND REPORTING APPROACH

Calculation Approach – GHG Emissions

The quantification methodology for GHG emissions uses an emission factor calculation. This methodology requires three types of data:

- the appropriate input "activity data" (e.g., energy utility invoices, fleet vehicle fuel consumption reports)
- the fuel-specific or activity-specific "emission factor"
- the "global warming potential" for each GHG (see below)

These three types of data are combined into the following equation to calculate the GHG emissions:

*GHG emissions = [activity data] * [emission factor] * [global warming potential]*

The activity data and emission factors used in the ODFW base year GHG calculations are described in detail in Section 3.2 and 3.3 of this report.

Calculation Approach (Changes in Wildlife Land Carbon Storage)

Organizations that manage land-based resources can quantify and report the impact of those lands in terms of carbon dioxide that is either removed from the atmosphere or emitted to the atmosphere. Calculations of the annual carbon storage change for the approximately 200,000 acres of ODFW-managed wildlife and recreation lands will utilize carbon storage rates reported in research studies of forest and non-forest land cover types in Oregon and the western USA. ODFW's lands will likely remove carbon dioxide from the atmosphere in years that the land uses remain in their current state. ODFW's lands will likely be a source of carbon dioxide emissions to the atmosphere in years that land use changes occur (e.g., fires, harvest, or other land changes).

The *GHG Protocol* stipulates that the annual change in carbon storage in ODFW-managed wildlife and recreation lands must be reported as a separate line item in ODFW's GHG emission report and should not be included in any of the GHG reporting scopes. ODFW's GHG emissions inventory (the total of Scope 1, Scope 2 and biogenic GHG) must be maintained as a stand-alone dataset and its emission totals must not be reduced based on any carbon dioxide that is removed by ODFW wildlife or recreation lands.

Reporting Approach

The ODFW GHG inventory includes the emissions associated with the following types of GHG:

- Carbon Dioxide – CO_2
- Methane – CH_4
- Nitrous Oxide – N_2O
- Refrigerants (presumed to be HFC-134A)

For reporting purposes, GHG emissions are expressed in metric tonnes of equivalent carbon dioxide (CO_2e). Global warming potentials (GWPs) must be applied to convert different types of GHG into the common reporting unit of CO_2e. GWPs are a relative measure that allow for different pollutants to be compared in terms of their climate change impacts – CO_2 is the reference value and is equal to 1. For pollutants other than CO_2, the 100-year GWP values are used to convert emissions to CO_2e (Table 2).

Table 2: Global warming potentials (GWPs) used in ODFW GHG calculations (from Intergovernmental Panel on Climate Change).

Greenhouse Gas	Global Warming Potential
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
HFC-134A Refrigerant	1430

3.2 SCOPE 1 GHG EMISSIONS

Scope 1 emissions occur from both combustion and non-combustion sources within the organizational boundary of the GHG inventory. ODFW's base year GHG inventory includes the following sources of Scope 1 emissions:

- Fuel combustion in ODFW facilities for heating / cooling
- Fuel combustion (on-road ODFW vehicles)
- Fuel combustion (ODFW equipment and boats)
- Fugitive Emissions (refrigerant use in ODFW facilities and vehicles)
- Emissions from microbial breakdown of fish wastes during fish production.

A description of the activity data source, data synthesis actions, and source of emission factors for each source of Scope 1 GHG are provided in the following sub-sections.

3.2.1 Stationary Fuel Combustion

Stationary Scope 1 GHG are emitted from the combustion of natural gas and propane for space heating in ODFW campuses. A total of nine ODFW campuses use natural gas and ten ODFW campuses use propane. A consolidated ODFW summary of stationary fuel combustion activity data, data synthesis actions, emission factors, and calculated Scope 1 GHG are provided in Table 3.

The specific ODFW campuses that use natural gas or propane can be identified in the campus list provided as Appendix A to this report. A detailed campus-level breakdown of Scope 1 emissions for each contributing GHG (CO_2, CH_4, N_2O) is available in the *ODFW Greenhouse Gas Calculation Tool* that complements this report.

Table 3: Activity data, data synthesis actions, emission factors, and calculated stationary fuel combustion Scope 1 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor and Source	GHG (tonnes CO_2e)
Natural Gas	2,439 mmBTU (Natural gas utility invoices)	Natural gas consumption data tabulated from utility invoices and entered into *ODFW Greenhouse Gas Calculation Tool*	53.11 kg CO_2e / mmBTU (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 1)	129.5
Propane	15,460 gallons (Propane delivery receipts)	Propane consumption data tabulated from supplier receipts and entered into *ODFW Greenhouse Gas Calculation Tool*	5.74 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 1)	88.8
TOTAL				**218.3**

3.2.2 Mobile Fuel Combustion (On-Road Vehicles)

Mobile Scope 1 GHG are emitted from the combustion of fuels in ODFW on-road vehicles. ODFW operates a fleet of over 1000 on-road vehicles including passenger cars, heavy trucks, and fish liberation trucks. A consolidated ODFW summary of mobile fuel combustion (on-road vehicle) activity data, data synthesis actions, emission factors, and calculated Scope 1 GHG are provided in Table 4.

Table 4: Activity data, data synthesis actions, emission factors and calculated mobile fuel combustion (on-road) Scope 1 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor and Source	GHG (t CO_2e)
Gasoline Vehicles	125,699 gallons (Fuel purchases)	Gasoline consumption data tabulated from ODFW organizational fleet fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	8.81 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 2)	1,107.8

E-10 Gasoline Vehicles	169,575 gallons (Fuel purchases)	E-10 gasoline consumption data tabulated from ODFW organizational fleet fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	Gasoline emission factor x 90% + Ethanol emission factor x 10%	1,345.2 Non-Biogenic 97.5 Biogenic
E-85 Gasoline Vehicles	209 gallons (Fuel purchases)	E-85 gasoline consumption data tabulated from ODFW organizational fleet fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	Gasoline emission factor x 15% + Ethanol emission factor x 85%	0.3 Non-Biogenic 1.0 Biogenic
Diesel Vehicles	9,332 gallons (Fuel purchases)	Diesel consumption data tabulated from ODFW organizational fleet fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	10.24 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 2)	95.6
B5 Biodiesel Vehicles	19,771 gallons (Fuel purchases)	B5-biodiesel consumption data tabulated from ODFW organizational fleet fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	Diesel emission factor x 95% + Biodiesel emission factor x 5%	192.4 Non-Biogenic 9.3 Biogenic
Propane Vehicles	81 gallons (Fuel purchases)	Vehicle propane consumption data tabulated from ODFW organizational fleet fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	5.74 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 2)	0.5
TOTAL:		**2,741.7 Non-Biogenic, 107.9 Biogenic**		

ODFW's base year consumption of on-road vehicle fuel by fuel type and GHG emission factor is presented in Figure 2. ODFW has the lowest amount of fuel consumption in the two lowest-emitting categories of vehicle fuel (E-85 gasoline, propane). Given the significantly lower GHG emissions associated with these fuel types, ODFW could consider converting to flex-fuel vehicles or propane vehicles in the future if it is deemed that market supply of these fuel types would be sufficient for ODFW purposes, but should balance this with consideration of other

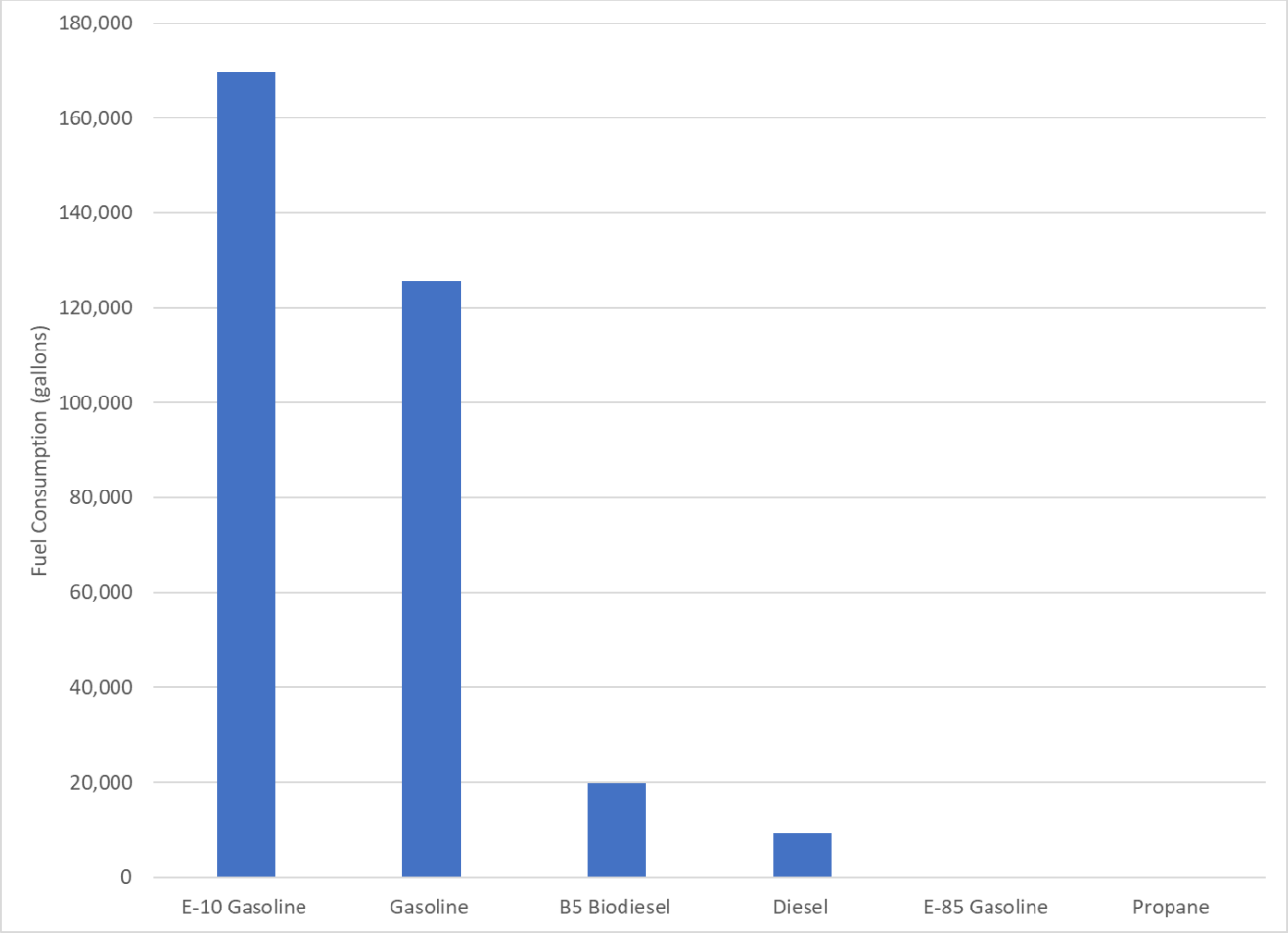


Figure 2: Amount of fuel consumed in on-road vehicles by fuel type in ODFW's base year GHG inventory.

ecological effects of these fuel types. Another opportunity to reduce ODFW's GHG emissions from on-road vehicle fuels would be a conversion to hybrid or fully electric vehicles.

3.2.3 Mobile Fuel Combustion (Equipment and Boats)

Mobile Scope 1 GHG are emitted from the combustion of fuels in ODFW boats and off-road equipment including generators, water pumps, and earth-moving equipment. A consolidated ODFW summary of mobile fuel combustion (equipment and boats) activity data, data synthesis actions, emission factors, and calculated Scope 1 GHG are provided in Table 5.

Table 5: Activity data, data synthesis actions, emission factors and calculated mobile fuel combustion (off-road equipment and boats) Scope 1 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor and Source	GHG ($t CO_2e$)
Gasoline Equipment	5,747 gallons (Fuel purchases)	Gasoline consumption data tabulated from ODFW organizational equipment fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	8.81 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 2)	50.6
E-10 Gasoline Equipment	7,963 gallons (Fuel purchases)	E-10 gasoline consumption data tabulated from ODFW organizational equipment fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	Gasoline emission factor x 90% + Ethanol emission factor x 10%	63.2 Non-Biogenic 4.6 Biogenic
Diesel Equipment	7,081 gallons (Fuel purchases)	Diesel consumption data tabulated from ODFW organizational equipment fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	10.24 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 2)	72.5
B5 Biodiesel Equipment	79,940 gallons (Fuel purchases)	B5-biodiesel consumption data tabulated from ODFW organizational equipment fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	Diesel emission factor x 95% + Biodiesel emission factor x 5%	778 Non-Biogenic 37.8 Biogenic
Kerosene Equipment	320 gallons (Fuel purchases)	Kerosene consumption data tabulated from ODFW organizational equipment fuel purchase records and entered into *ODFW Greenhouse Gas Calculation Tool*.	10.18 kg CO_2e / gallon (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 2)	3.3
TOTAL:		**967.6 Non-Biogenic,**	**42.4 Biogenic**	

3.2.4 Fugitive Emissions (Refrigerant Use in ODFW Facilities and Vehicles)

Fugitive Scope 1 GHG are emitted when refrigerants are lost from refrigeration and air conditioning systems in ODFW campuses and vehicles. A standard level of refrigerant loss is assumed to occur for all refrigeration and air conditioning systems. A consolidated ODFW summary of fugitive emission activity data, data synthesis actions, emission factors, and calculated Scope 1 GHG are provided in Table 6. Note that the department does not have a complete list of currently operating refrigeration and air conditioning systems. Future assessments should seek to gather such a list.

Table 6: Activity data, data synthesis actions, emission factors, and calculated fugitive Scope 1 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor and Source	GHG (tonnes CO_2e)
Campus Refrigerants	ODFW campus GHG emissions (Scope 1 stationary + Scope 2)	ODFW campus fugitive GHG emissions are calculated based on one of the following methods: 1. Assumed annual loss rate based on known refrigerant capacity and refrigerant type for air conditioning equipment in ODFW campuses 2. Estimated based on fugitive GHG emission rate (2.5% of GHG emissions from facility energy consumption) determined from benchmarking assessment of other state agencies **Method 2 used in the base year GHG inventory*	1430 kg CO_2e / kg HFC134-A (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 11)	92.6
Vehicle Refrigerants	ODFW fleet vehicle count	ODFW vehicle fugitive GHG emissions are calculated by applying the following assumptions to the count of ODFW vehicles: ▪ Refrigerant capacity of 1 kg / vehicle ▪ Annual refrigerant leak rate of 20%		288.3
TOTAL				**380.9**

3.2.5 Emissions from microbial breakdown of aquatic nitrogen during fish production

Process Scope 1 GHG are emitted as N_2O from microbial nitrification and denitrification processes as a result of fish production in ODFW fish hatchery facilities. There is a high level of uncertainty in the emission factors that have been developed for N_2O emissions from fish production, as the emissions are dependent on the highly variable pH and dissolved oxygen content of the water bodies and on the processes and equipment used to treat effluent water. Additionally, a significant proportion of fish production is mitigating for the loss of wild fish

production that would occur were it not for the presence of dams and other issues associated with their habitat. Notwithstanding this and the high uncertainty of this emission source, it was decided it should be included given the number of fish hatchery facilities under ODFW's control and the fact that these emissions occur directly at ODFW facilities, making them Scope 1 emissions. A consolidated ODFW summary of process emission activity data, data synthesis actions, emission factors, and calculated Scope 1 GHG are provided in Table 7.

It is important to note that aquaculture systems are considered a lower-impact category of livestock with GHG intensities comparable to pork or chicken production. The GHG intensity of aquaculture systems are approx. 15% of the GHG intensity of beef production (Figure 3).

Table 7: Activity data, data synthesis actions, emission factors, and calculated process Scope 1 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor and Source	GHG (tonnes CO_2e)
Process Emissions	1,708,620 kg of fish production (from 2019 *ODFW Fish Propagation Annual Report*)	Fish production data tabulated from ODFW Fish propagation Annual Report and entered into *ODFW Greenhouse Gas Calculation Tool*.	0.791 kg CO_2e / kg production (MJ MacLeod et al. 2020. Quantifying greenhouse gas emissions from global aquaculture. *Nature Scientific Reports*, 10: 11679)	1,351
TOTAL				**1,351**

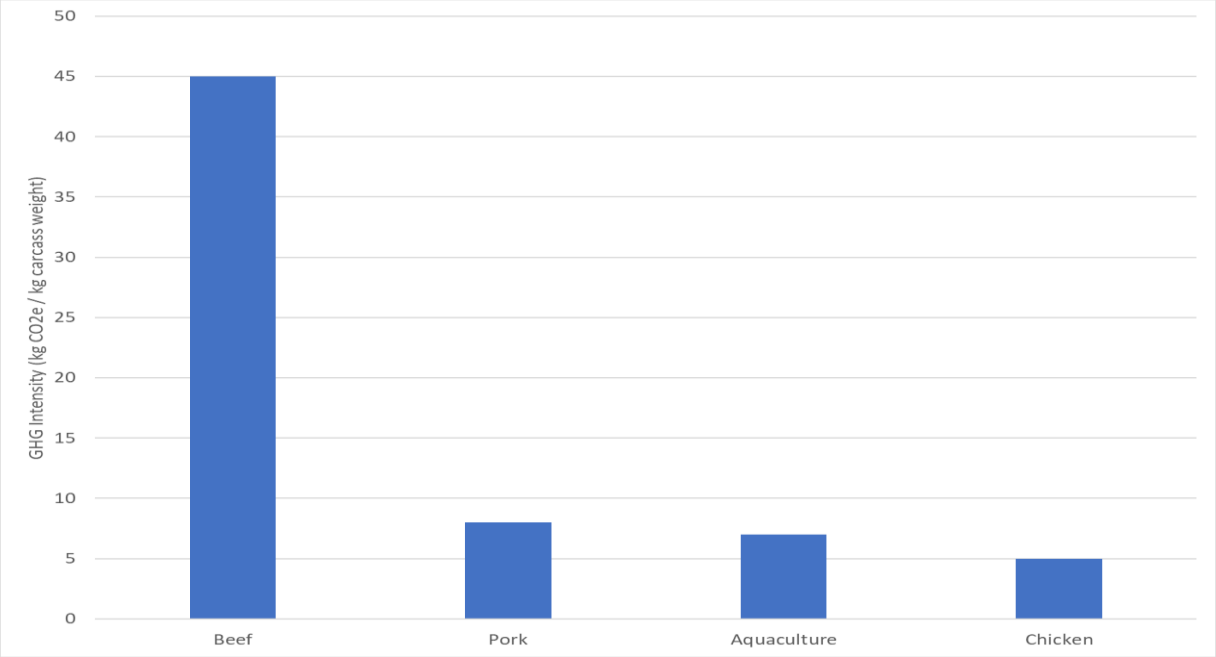


Figure 3: GHG intensity (kg CO2e / kg carcass weight) of livestock systems (MJ MacLeod et al. 2020).

3.2.6 Scope 1 Summary

ODFW's total Scope 1 emissions are calculated as 5,659 tonnes of CO_2e. A graphic representation of ODFW's base year Scope 1 GHG emissions by source is presented in Figure 4. Scope 1 represents the largest category of ODFW GHG emissions, contributing 61% of all GHG in the base year. Mobile fuel combustion in ODFW on-road vehicles represents approx. half of the Scope 1 GHG. ODFW's future GHG reduction planning should consider several factors including the size of the emission source and the reduction opportunities that are available. Mobile fuel combustion in on--road vehicles is a significant emission source for ODFW that has multiple options for significant reductions (e.g. conversion to electric or hybrid vehicles, anti-idling policies, optimized route planning) and therefore should be regarded as a high-priority for ODFW's GHG reduction efforts.

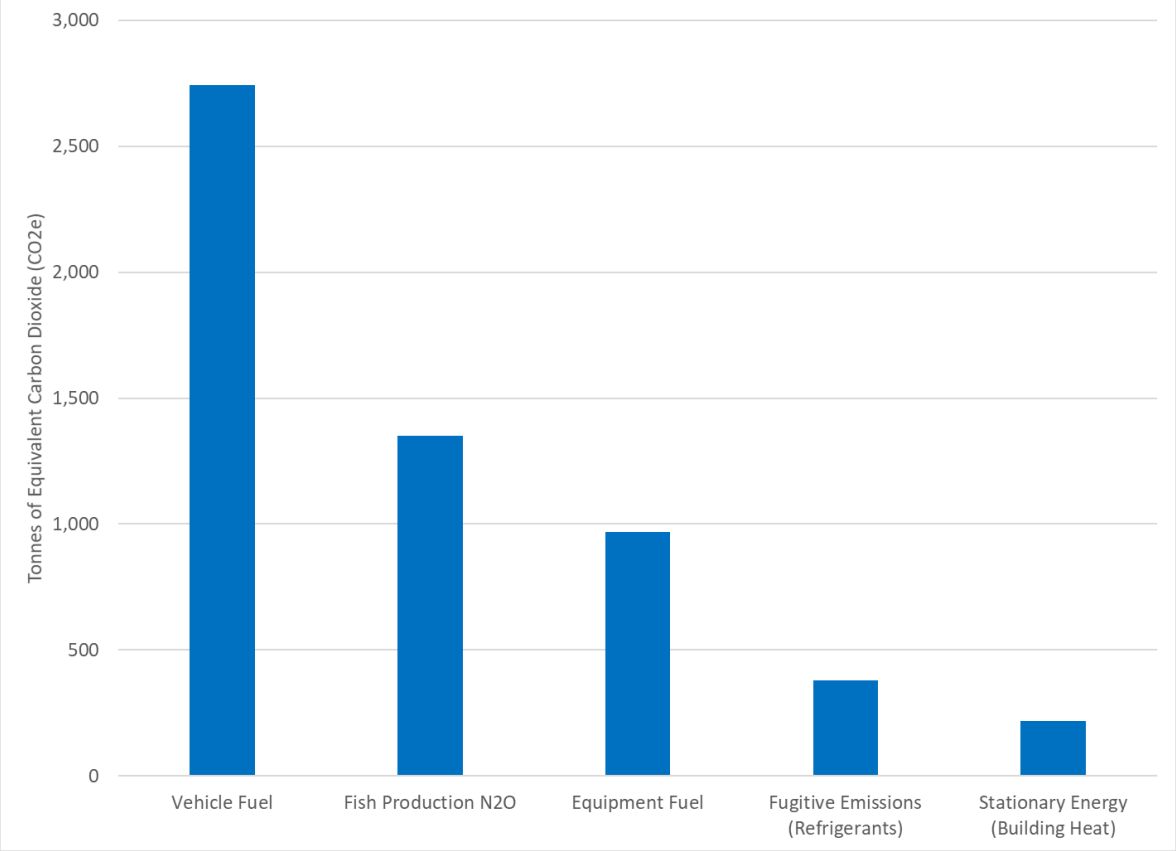


Figure 4: ODFW's base year Scope 1 GHG emissions by source.

3.3 SCOPE 2 GHG EMISSIONS

Consumption of purchased electricity in ODFW campuses results in Scope 2 GHG emissions (note that any self-generated electricity consumption is not included in Scope 2). To maintain compliance with *The GHG Protocol*, Scope 2 GHG must be calculated using two distinct approaches: Location-Based and Market-Based. Details about each of these two Scope 2 calculation approaches is provided in the appropriate sub-sections below. Note that in the interest of avoiding double-counting only one of the two Scope 2 approaches is included in the ODFW base year GHG emission total (Location-Based is used in ODFW's base year GHG emission total). Note that the availability of the Oregon Department of Environmental Quality's data on the emission factor for each electric utility combined with the fact that ODFW's operations across the entire state has resulted in the Location-Based and Market-Based approaches resulting in very similar emissions.

3.3.1 Location-Based Scope 2

Location-Based Scope 2 GHG emissions are calculated using the average state-wide emission factor for Oregon grid-based electricity consumption obtained from the US EPA. A description of the activity data, data synthesis actions, emission factors, and calculated Scope 2 Location-Based GHG are provided in Table 8. Electricity consumption in ODFW campuses was determined from a combination of both measured (utility invoices) and estimated data.

Table 8: Activity data, data synthesis actions, emission factors, and calculated Location-Based Scope 2 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor Source	GHG (tonnes CO_2e)
Measured Electricity Consumption	9,048,923 kWh (Electricity utility invoices)	Electricity consumption data tabulated from utility invoices and entered into *ODFW Greenhouse Gas Calculation Tool*	291.8 g CO_2e / kWh* (US EPA Emission Factors for GHG Inventories – March 2020 version; Table 6) *WECC Northwest EPA eGRID subregion	2,640.4
Estimated Electricity Consumption	2,898,670 kWh (Estimated)	The following approach was used to estimate electricity consumption where utility invoices were not available: 1. Electricity intensity (kWh / employee) was calculated for ODFW campuses with measured electric utility data 2. Average electricity intensity values were calculated for the following ODFW campus categories: Fish Hatchery Facility, Office / Research, Wildlife Area		845.8

		3. Average electricity intensity value was used to estimate electricity consumption based on employee counts		
TOTAL				**3,486.2**

3.3.2 Market-Based Scope 2

Market-Based Scope 2 GHG emissions are calculated using utility-specific GHG emission factors provided for individual electricity utilities that supply ODFW campuses. Utility-specific emission factors were obtained from the electricity supplier database maintained by the Oregon Department of Environmental Quality (DEQ)[2]. A description of the activity data, data synthesis actions, emission factors, and calculated Scope 2 Market-Based GHG are provided in Table 9. Electricity consumption in ODFW campuses was determined from a combination of both measured (utility invoices) and estimated data.

Table 9: Activity data, data synthesis actions, emission factors, and calculated Market-Based Scope 2 GHG.

GHG Source	Activity Data	Data Synthesis Actions	Emission Factor Source	GHG (tonnes CO_2e)
Measured Electricity Consumption	9,048,923 kWh (Electricity utility invoices)	Electricity consumption data tabulated from utility invoices and entered into *ODFW Greenhouse Gas Calculation Tool*	Variable emission factors based on electric utility (from electricity supplier database maintained by Oregon DEQ)	2,437.8
Estimated Electricity Consumption	2,898,670 kWh (Estimated)	The following approach was used to estimate electricity consumption where utility invoices were not available: 1. Electricity intensity (kWh / employee) was calculated for ODFW campuses with measured electric utility data 2. Average electricity intensity values were calculated for the following ODFW campus categories: Fish Hatchery Facility, Office / Research, Wildlife Area 3. Average electricity intensity value was used to estimate electricity consumption based on employee counts		1,007.1
TOTAL				**3,444.9**

[2] https://www.oregon.gov/deq/aq/programs/Pages/GHG-Emissions.aspx

3.3.3 Scope 2 Summary

ODFW's base year Scope 2 emissions were calculated to be 3,486 tonnes of CO_2e using the Location-Based approach and 3,445 tonnes of CO_2e using the Market-Based approach. Scope 2 represents 37.4% of all ODFW GHG in the base year. At an organizational level the Scope 2 emission totals using the Location-Based and Market-Based approaches are nearly identical. However, at the campus level some significant differences in Market-Based emission factors exist (Figure 5). When analyzed by consumption, 60% of ODFW's base year electricity consumption is supplied by utilities that have Scope 2 market-based emission factors of less than 200 grams CO_2e / kWh, which is significantly lower than Oregon's Scope 2 location-based grid average emission factor of 291.8 grams CO_2e / kWh. When analyzed by number of campuses, over half of ODFW's campuses are supplied by utilities that have Scope 2 market-based emission factors of less than 100 grams CO_2e / kWh.

The data in Figure 5 suggests that as a potential GHG reduction opportunity, in the future ODFW may choose to utilize the GHG emissions intensity of specific electricity suppliers when making decisions for siting of operations and personnel. For existing facilities, those that are currently supplied with electricity by utilities with the highest emissions factors should be targets for switching to locally produced electricity from roof-top solar or other low-emissions sources.

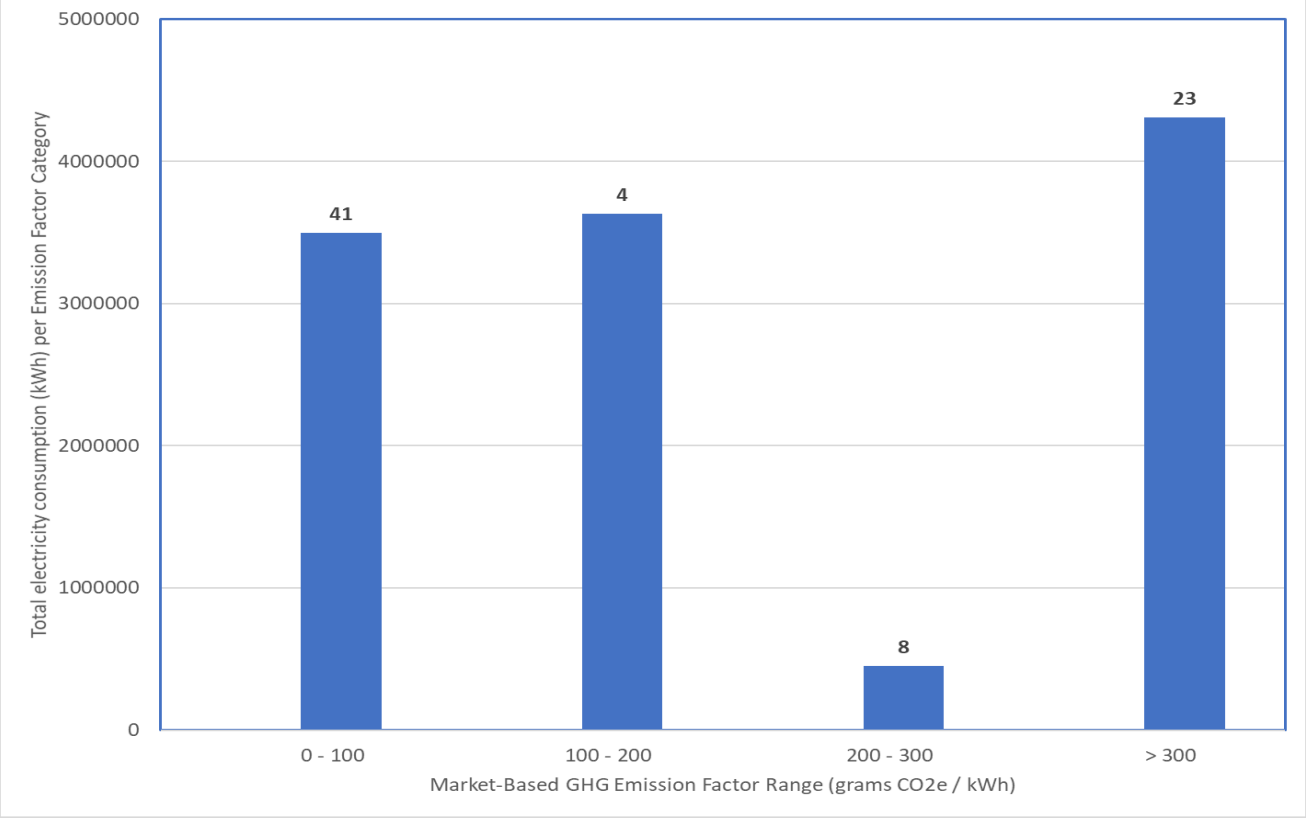


Figure 5: ODFW base year electricity consumption (blue bars) and number of campuses (value on top of bars) categorized using ranges of market-based Scope 2 emission factors

3.4 SUMMARY OF ODFW BASE YEAR GHG EMISSIONS

A breakdown of total ODFW base year GHG emissions by scope and source is provided in metric tonnes of CO_2e and as a percentage of all ODFW GHG emissions (Table 10, Figure 6).

Table 10: Summary of total ODFW base year GHG emissions by scope and source.

GHG Source	GHG Emissions (in tonnes of CO_2e)						% of ODFW GHG
	Bio-CO_2	CO_2	CH_4	N_2O	R-134A	CO_2e	
Stationary Fuel Combustion	0	217.8	0.2	0.3	0	218.3	2.4
Mobile Fuel Combustion (on-road)	0	2,731.4	3.0	7.4	0	2,741.7	29.5
Mobile Fuel Combustion (equipment)	0	964.3	1.0	2.3	0	967.6	10.4
Fugitive Emissions (refrigerant loss)	0	0	0	0	380.5	380.5	4.1
Process Emissions (N_2O from hatcheries)	0	0	0	1,351	0	1,351	14.6
Total Scope 1	***0***	***3,913.5***	***4.2***	***1,361***	***380.5***	***5,659.2***	***61.0***
Electricity (Location-based)	0	3,447.4	8.6	14.5	0	3,470.5	37.4
Total Scope 2	***0***	***3,447.4***	***8.6***	***14.5***	***0***	***3,470.5***	***37.4***
Biogenic	150	0	0	0	0	150	1.6
TOTAL ODFW Base Year GHG	**150**	**7,511.2**	**12.8**	**1,375.5**	**380.5**	**9,280**	**100**

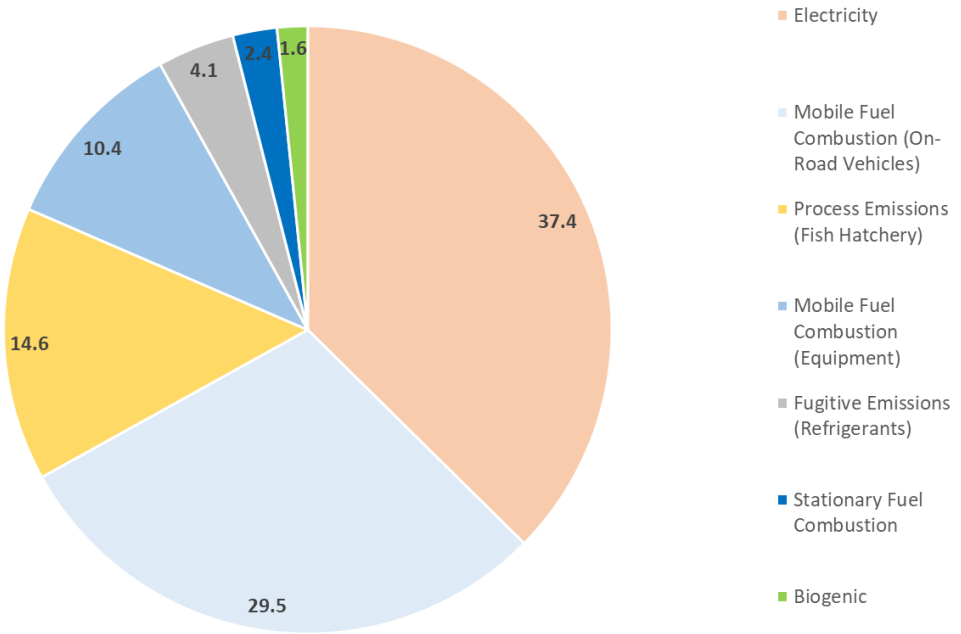


Figure 6: Graphic representation of ODFW base year GHG emissions by source (numbers indicate % of total ODFW GHG).

3.5 NORMALIZED ASSESSMENT OF ODFW CAMPUS ENERGY USE

Several types of energy are consumed at ODFW campuses, including electricity and other fuels combusted for space heating such as natural gas or propane. Organizations are encouraged to define normalized variables that can be used to monitor their energy performance on an intensity basis in addition to the absolute totals. The intensity metric allows for more direct comparison between facilities of different sizes.

The definition of a normalized variable to use for ODFW was challenging given the structure of ODFW's campuses. Many campuses include multiple facilities that contribute to the total building area but contribute little to the total energy consumption of the campus (i.e., pole garages, equipment sheds, etc.). Because of this it was decided to utilize both campus floor area and employees as normalized variables to monitor the intensity of campus energy consumption:

- Energy consumption by area (kWh / ft^2)
- Energy consumption per employee (kWh / employee)

Note that ODFW does not have consistently complete data on the full square footage of large, complex campuses like fish hatchery facilities, so the per square foot metrics are likely overestimates of the actual energy intensity. Because of the imprecise area information, the per employee metric should be treated as the most accurate measure of intensity. Energy consumption by area was included because it is the most standard metric and the department may use this metric in the future when better square footage data is available.

ODFW's campuses were assigned to one of three categories in the analysis of normalized energy variables: fish hatchery facilities, office/research, wildlife areas. The results of ODFW's normalized energy assessment for the three categories of campuses are provided in Table 11. Campus-specific data of total energy consumption and normalized energy is provided in Appendix A to this report.

Table 11: Summary of ODFW normalized energy variables.

Campus Type	kWh / employee			kWh / ft^2		
	MIN	MAX	AVG	MIN	MAX	AVG
Fish Hatchery Facility	6,638	255,855	23,698	1.1	173.2	17.0
Office / Research	1,023	44,227	4,415	2.4	56.7	9.7
Wildlife Area	1,642	23,886	10,478	0.3	7.1	2.5

When normalized on an employee basis, ODFW's fish hatchery facilities have the highest energy intensity. This is due to the small number of employees that work at these facilities combined with the higher energy needs of some facilities. ODFW's office and research campuses have the lowest energy intensity due to the higher number of employees working at these campuses and the energy efficient nature of many ODFW office and research buildings.

When normalized on a building area basis, ODFW's fish hatchery facilities have the highest energy intensity. This is due to the high energy needs of some facilities, presumably due to use of equipment such as water pumps. ODFW's wildlife areas have the lowest energy intensity per square foot due to the large number of facilities on these campuses that consume little or no energy (e.g. barns and storage buildings). ODFW's office and research campuses have an energy intensity per square foot that is the approx. mid-point between hatchery facilities and wildlife areas.

The normalized energy intensity per square foot of ODFW's office and research facilities was compared to the energy intensity of office buildings in Portland Oregon[3]. The average energy intensity of all office buildings (over 20,000 square feet) in Portland in 2019 was 18 kWh/ft^2. The average energy intensity of ODFW's office and research facilities was 9.7 kWh/ft^2, approx. 45% lower than the Portland office building average.

ODFW's office and research facility energy intensity is equal to the average of all facilities in the Portland office building database that had an ENERGY STAR score of at least 90%. ODFW is to be commended for the average energy performance of its office and research facilities and is encouraged to investigate whether there are energy efficiency actions that can be promoted in other ODFW campuses.

3.6 UNCERTAINTY ASSESSMENT

Table 12 presents an opinion of the level of uncertainty related to ODFW's GHG inventory. These opinions of uncertainty are based on the guidance found in "Measurement and Estimation Uncertainty of GHG Emissions"[4] by *The Greenhouse Gas Protocol*. Recommendations have been provided in Section 6 of this report that are intended to reduce the uncertainty of ODFW's GHG inventory data going forward.

Table 12: Uncertainty assessment for GHG sources included in ODFW's GHG inventory.

Activity Data	Uncertainty Assessment
Stationary Fuel Consumption (Natural Gas, Propane)	**Moderate Uncertainty** • All natural gas and propane consumption used in GHG calculations is from measured invoice data from natural gas utilities or propane suppliers • Some uncertainty introduced due to the organization's lack of data management and controls pertaining to the organizational boundary (number of campuses) and campus-level energy consumption

[3] In the City of Portland all commercial buildings over 20,000 square feet are required to submit their annual energy use through the *Commercial Building Energy Reporting Program.*
[4] https://ghgprotocol.org/calculation-tools

	• GHG emission factors are from a reliable source (US EPA)
Electricity Consumption	**Moderate Uncertainty** • Approx. 75% of the electricity consumption used in GHG calculations is from measured invoice data from electricity suppliers • Some uncertainty introduced due to the organization's lack of data management and controls pertaining to the organizational boundary (number of campuses) and campus-level energy consumption • Electricity emission factors are from a reliable source (US EPA = location-based; Oregon DEQ = market-based)
Mobile Fuel Consumption **(on-road vehicles, equipment, boats)**	**Low Uncertainty** • Consumption is based on fuel expense purchases made using ODFW fuel accounts • GHG emission factors are from a reliable source (US EPA)
Fugitive Emissions **(refrigerants in buildings and vehicles)**	**High Uncertainty** • Amounts for both vehicle-based and facility-based refrigerant losses are based on estimated approaches • Type of refrigerant used in calculations is assumed • GHG emission factor for assumed refrigerant is from a reliable source (US EPA)
Emissions from microbial breakdown of aquatic nitrogen during fish production	**High Uncertainty** • Amount of fish production is from a reliable source (ODFW Fish Propagation Report) • GHG emission factor is from a peer-reviewed scientific journal article that recognizes N2O emissions from fish production are highly variable

4. BENCHMARKING ASSESSMENT

Benchmarking is an opportunity to learn from the actions of similar organizations to ODFW regarding the quantification of GHG emissions. Several other state-level departments from across the USA with a similar mandate as ODFW were selected for a benchmarking assessment. A description of the organizations included in the benchmarking and a summary of the findings relevant to this project are presented in Table 13.

Table 13: Summary of the results of the benchmarking assessment.

Organization	Number of Employees	Total GHG ($t CO_2e$)	GHG Intensity (t CO2e / employee)	Percent of Total GHG Emissions					
				Stationary Combustion	Mobile Fuels	Fugitive	Scope 2	Biomass	Other
Massachusetts Dept. of Environmental Protection	726	4,194	5.78	21.1	7.5	10.5	55.1	5.8	0
North Carolina Dept. of Environment and Natural Resources	1,531	52,140	34.06	8.1	33	1.4	56.9	0.7	0
Washington (State) Dept. of Ecology	1,600	6,759	4.22	9.9	26.6	2.5	60	1.1	0
Oregon Department of Fish & Wildlife	1,353	9,280	6.86	2.4	39.9	4.1	37.4	1.6	14.6

On an intensity basis (GHG emissions per employee) the ODFW performance is comparable to the Massachusetts Department of Environmental Protection and the Washington Department of Ecology. The GHG intensity of the North Carolina Department of Environment and Natural Resources is approx. 5 times greater than ODFW; additional information about the North Carolina GHG inventory data would be needed to assess the reason for this significant difference in GHG intensities.

When comparing ODFW's breakdown of GHG inventory sources to other departments the following observations can be made:

- ODFW has a smaller contribution of stationary combustion GHG emissions compared to other departments, due to the relatively low number of ODFW facilities that use natural gas or propane for heating energy

- ODFW has a large contribution of mobile combustion GHG emissions (vehicles plus equipment) compared to other departments, likely due to the contribution of fish hatchery facility equipment such as water pumps
- ODFW has a smaller contribution of Scope 2 GHG emissions from electricity consumption compared to other departments, largely due to the relatively low GHG emission factor for grid-based electricity consumption in the state of Oregon
- None of the departments included in the benchmarking assessment had 'Other' sources of GHG emissions (ODFW had nitrous oxide emissions from fish production in the 'Other' category)
- Contributions of fugitive GHG emissions and biogenic GHG emissions to the ODFW GHG inventory are within the range reported by other departments

5. CARBON SEQUESTRATION ASSESSMENT

5.1 ESTIMATING CARBON SEQUESTRATION IN VEGETATED ECOSYSTEMS

Vegetated ecosystems (e.g., forest, wetland, shrubland, grassland) store a significant amount of carbon in the living biomass of the vegetation (aboveground and belowground), debris (litter), and soil. The main pools of carbon in vegetated ecosystems and the primary carbon flux pathways are shown in Figure 7.

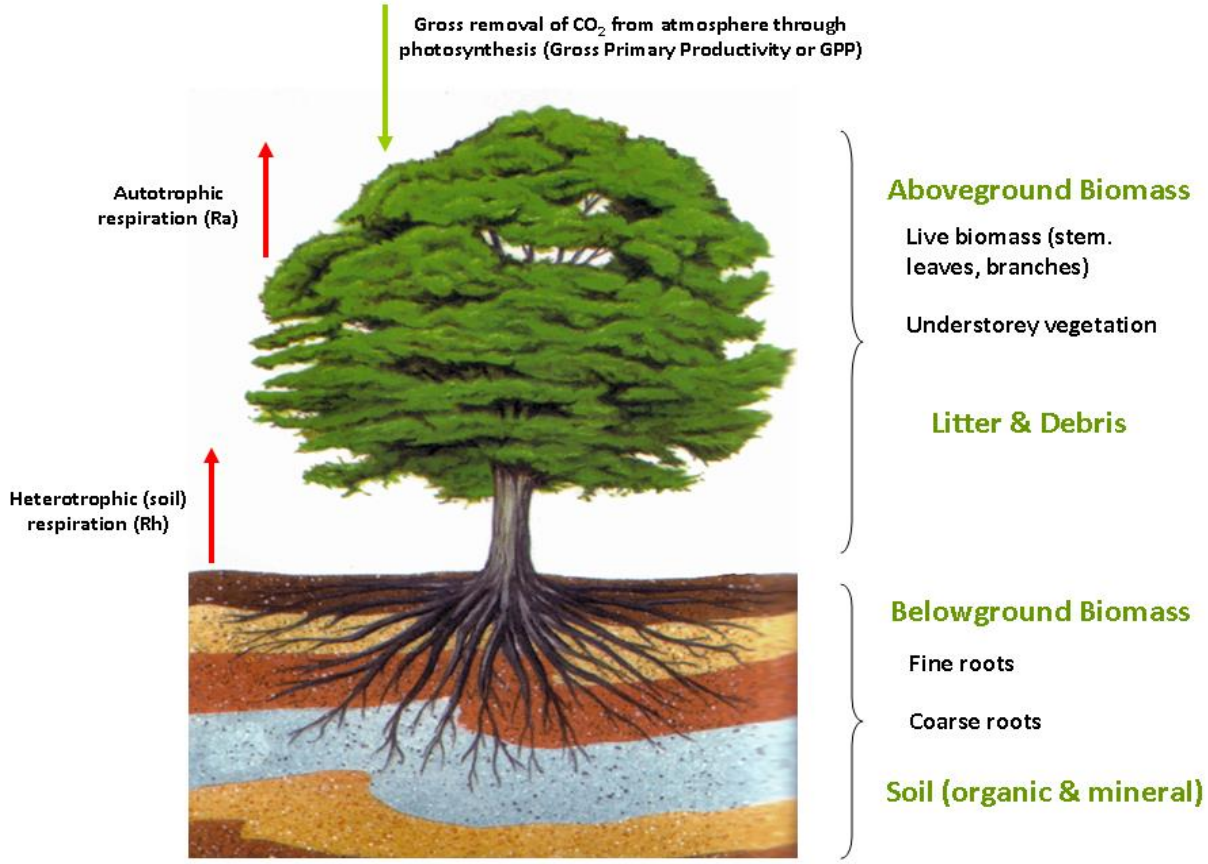


Figure 7: The carbon cycle (carbon pools and pathways). Primary carbon flux pathways are indicated with arrows. Net carbon gains through photosynthesis are shown as a green arrow; net carbon losses from respiration are shown as red arrows

The *Greenhouse Gas Protocol for the U.S. Public Sector* describes how carbon sequestration should be quantified in a public sector organization's GHG inventory. The Protocol recognizes that some of the most significant GHG aspects for organizations managing large stocks of biomass such as public lands and forests will occur through the management of sequestered carbon. Public sector organizations that choose to quantify and report carbon sequestration should consider the following impacts:

- Annual rate of change in carbon stocks per acre
- Any land-use changes (removal or addition of vegetated land) since the previous reporting period

Organizations that quantify and report their carbon sequestration impacts should ensure it is reported separately from the reported GHG emissions (Scope 1, Scope 2, Scope 3, biogenic). A literature review was conducted to identify data sources for carbon sequestration estimates of vegetated ecosystems in Oregon (Table 14).

Table 14: Summary of literature review findings for carbon sequestration rates of vegetated ecosystems in Oregon. Positive values in the table indicate a removal (uptake) of carbon from the atmosphere. Sequestration values for forest ecosystems are obtained from Christensen et al. (2019)[5]. Sequestration values for all other ecosystems are obtained from Liu et al. (2012)[6].

Ecoregion	CO_2e Sequestration Rate (tonnes / acre / year)			
	Forest	Grassland / Shrubland	Pasture / Cropland	Wetland
Blue Mountains	0.526	0.3934	0.1574	1.273
Eastern Oregon	0.1254	0.1708	0.2743	0.2184
Oregon Coast Range	1.6732	1.025	-0.077	1.283
Klamath Mountains	1.237	0.3934	0.1574	1.273
Willamette Valley	1.4899	0.3934	0.1574	1.273
East Cascades & Modoc	0.4374	0.3934	0.1574	1.273

5.2 CARBON SEQUESTRATION IN ODFW WILDLIFE AREAS

The approximately 200,000 acres of wildlife and recreation lands managed by ODFW have a significant impact on annual carbon sequestration. ODFW's lands will likely remove carbon dioxide from the atmosphere in years that the vegetated land remains in its current state. ODFW's lands will likely be a source of carbon dioxide emissions to the atmosphere in years that vegetated land areas are lost (e.g. fires, harvest, and other land changes). Annual carbon sequestration in ODFW's wildlife areas was estimated using the following data sources:

- Acreage in specific vegetated ecosystem types from wildlife area management plans
- Carbon sequestration rates for vegetated ecosystem types from sources listed in Table 14

The carbon sequestration rates estimated for the ODFW wildlife areas are presented in Table 15 and Figure 8. The estimated carbon sequestration in ODFW's wildlife areas is equivalent to almost 61,000 tonnes of CO_2e per year (Table 15) and is over 6.5 times larger than ODFW's base year GHG emissions total. Approximately 75% of the carbon sequestration in ODFW wildlife areas occurs in forest and wetland ecosystem types.

[5] Christensen GA, AN Gray, O Kuegler, AC Yost. 2019. Oregon Forest Ecosystem Carbon Inventory: 2001-2016. US Forest Service and Oregon Dept. of Forestry. (Tables B3 - B8)
[6] Liu, Shuguang, Liu, Jinxun, Young, C.J., Werner, J.M., Wu, Yiping, Li, Zhengpeng, Dahal, Devendra, Oeding, Jennifer, Schmidt, G.L., Sohl, T.J., Hawbaker, T.J., and Sleeter, B.M., 2012, Baseline carbon storage, carbon sequestration, and greenhouse-gas fluxes in terrestrial ecosystems of the Western United States, chap. 5 of Zhu, Zhiliang, and Reed, B.C., eds., Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of the Western United States: U.S. Geological Survey Professional Paper 1797, 20 p. (Also available at http://pubs.usgs/gov/pp/1797.) Table 5.4

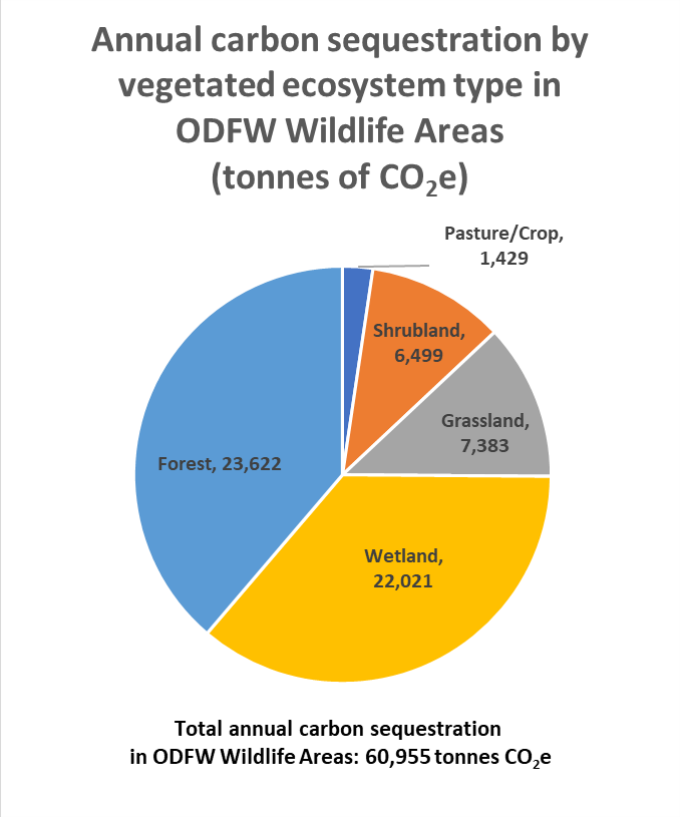


Figure 8: Graphic representation of the annual carbon sequestration in ODFW wildlife areas by land cover type

Table 15: Annual carbon sequestration by vegetated ecosystem type in ODFW wildlife areas.

ODFW Wildlife Area	ANNUAL CARBON SEQUESTRATION (tonnes CO_2e)					
	Forest	Shrubland	Pasture/Crop	Grassland	Wetland	Total
Bridge Creek	2,061	138	0	4,121	552	6,873
Courtney Creek	0	0	0	0	51	51
Elkhorn	2,775	358	112	206	236	3,688
Enterprise	0	0	6	0	51	56
Ladd Marsh	420	121	62	622	3,679	4,904
Little Sheep	0	118	0	91	0	209
Lostine	195	0	0	144	0	338
Minam	79	0	0	0	318	397
Wallowa	0	0	0	0	13	13
Klamath	44	160	92	96	1,883	2,275
Chickahominy	0	191	0	0	0	191
Columbia Basin	0	94	26	116	83	319
Crates Point	0	0	0	0	13	13
Hirsh Property	0	0	3	2	0	5
Leroy	0	27	0	0	0	27
Lower Deschutes	0	1,338	2	22	13	1,376
Phillip W Schneider	6,547	200	151	0	0	6,897
Prineville Reservoir	0	381	0	0	0	381

Riverside	0	534	13	0	57	603
Rogers	0	0	21	0	2	22
Rufus Ponds	0	0	0	2	2	4
Snake River Islands	0	0	0	17	22	39
Summer Lake	0	543	90	134	3,195	3,962
Warm Springs	0	11	0	0	16	27
Wenaha	627	914	274	132	22	1,968
White River	2,624	840	557	388	56	4,466
Denman	87	59	19	26	891	1,082
Gold Ray	124	0	0	0	140	264
Coquille Valley	105	25	0	0	639	769
God's Valley	502	0	0	134	0	636
Jewell Meadows	818	0	-33	0	164	949
Stowe Marsh	0	0	0	0	64	64
Tami Wagner	117	0	0	30	0	147
Fish Lake	0	62	0	0	0	62
Achterman	209	0	0	0	191	400
EE Wilson	413	339	0	125	181	1,057
Fern Ridge	1,332	47	35	43	3,498	4,955
JC Pond	0	0	0	8	0	8
Sauvie Island	4,544	0	0	877	5,809	11,230
St Louis Ponds	0	0	0	47	181	228
TOTAL	**23,622**	**6,499**	**1,429**	**7,383**	**22,021**	**60,955**

6. RECOMMENDATIONS

In the development of ODFW's base year GHG inventory, several opportunities or initiatives have been identified for ODFW's consideration in the interest of improving its GHG management program and maintaining momentum going forward.

1. Setting of Interim GHG Reduction Targets

ODFW's *Climate Change and Ocean Policy* defines an ambitious goal for the department to achieve carbon neutrality by mid-century. Reaching carbon neutrality could be measured by decreasing emissions to zero or, more realistically, some combination of reducing emissions as much as possible and offsetting what can't be reduced by increasing the amount of land that is sequestering carbon. A long-term goal like ODFW's carbon neutrality pledge should be accompanied by interim targets. Interim targets would serve as the measurable outcomes that are to be accomplished in the interest of advancing ODFW towards meeting its longer-term goal. ODFW is encouraged to define interim targets for both emissions and sequestration at regular intervals between the present time and mid-century, such as 2030 and 2040.

The definition of interim GHG emission reduction targets should be guided by a corresponding assessment of potential GHG emission reduction opportunities that exist within ODFW. Potential GHG reduction opportunities should be identified, assessed against ranking criteria (e.g. reduction impact, cost to implement, payback period, etc.) and assigned an implementation timeframe (e.g. immediate, less than 10 years, over 10 years). A detailed implementation plan would allow ODFW to define realistic and achievable interim energy and GHG reduction targets to ensure the path towards carbon neutrality is feasible.

2. Implementation of Improved Management of Input Data Required for GHG Emissions

Management of the input datasets required for GHG calculations should be improved with the intent of maximizing data quality, consistency, and completeness. While substantial efforts were made to collect and process energy consumption input data in ODFW's base year GHG assessment, many gaps remain in terms of estimated data having to be used in place of actual primary data from ODFW facilities. The presence of such gaps can have a significant impact on the accuracy of the findings and the resultant analysis that can be performed.

ODFW is encouraged to develop an internal procedure specifically for the consistent and on-going collection and management of the various input datasets that are vital to the accurate monitoring of the organization's energy and GHG emissions. Such a procedure should define the following:

- Identification of all datasets that need to be collected for the GHG inventory calculations
- The process (timeframe, data transfer mechanism) for obtaining data from the individual ODFW facilities
- Assignment of all ODFW energy accounts (electricity, natural gas, propane) to a particular ODFW facility or campus
- Storage and management of all GHG inventory activity data in a singular location for improved access
- The individuals responsible for supplying the data (at the facility level) and managing the compiled dataset at the organizational level

- Any quality control processes that are used to vet the accuracy of the data that is collected

The development of such a procedure is intended to instill a consistent data management approach that should reduce the time and effort required on an annual basis to collect, consolidate, and process the input datasets.

3. Adoption of Sustainability Implementation Process

AET's proprietary "Sustainability Implementation Process" is a graphic guide (Figure 9) that can provide ODFW with an implementation path for action items that result from this project. The steps that have partially been completed in this project are aligned with Steps 1 – 3 of the process. The process is based on the classic management system "Plan-Do-Check-Act" approach for continuous improvement enhanced with discrete steps and guidance based on AET's experience working with clients in implementing sustainability projects.

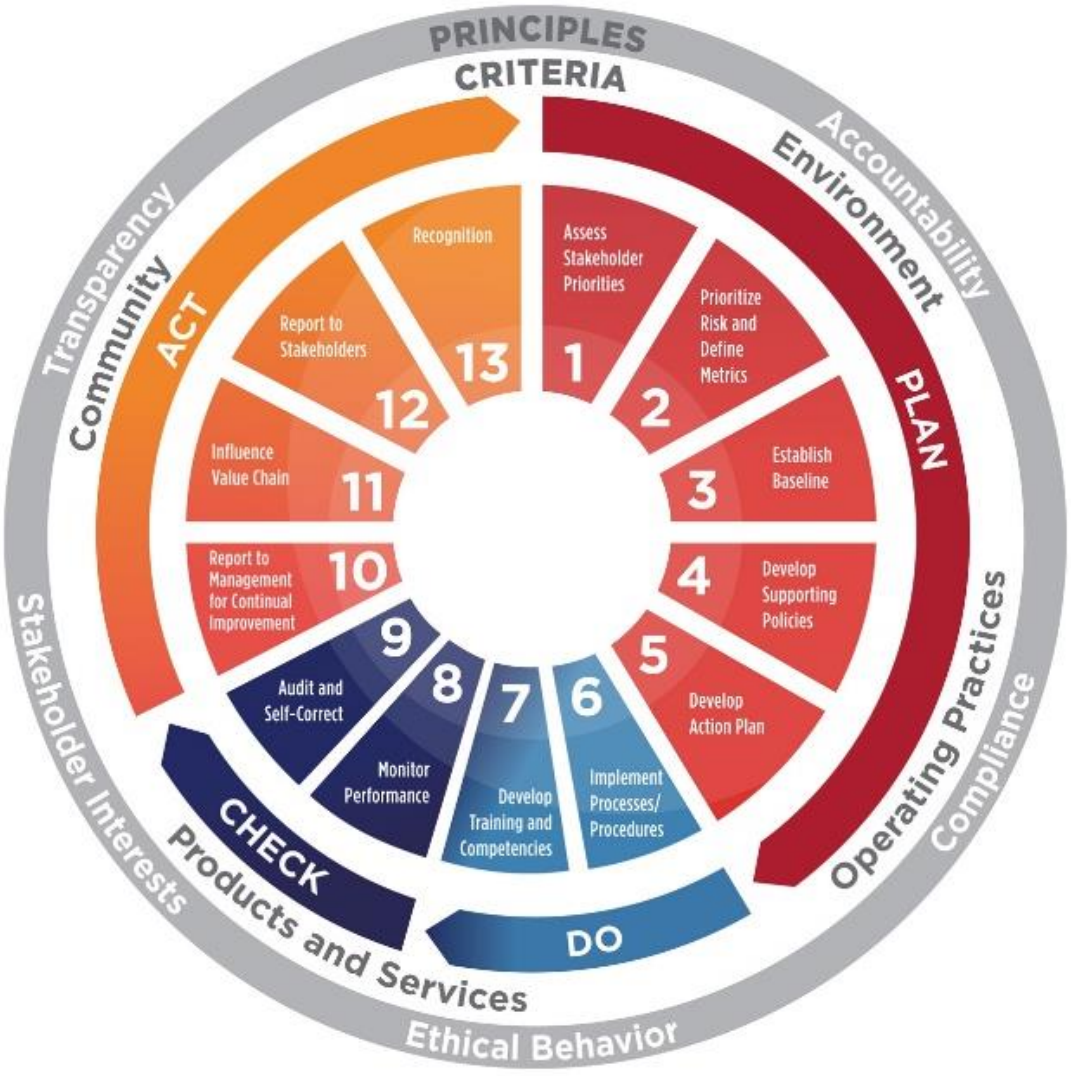


Figure 9: AET's proprietary Sustainability Implementation Process which can serve as an implementation path for ODFW's sustainability efforts going forward.

4. Definition of Complete Database of ODFW Campuses and Facilities

During ODFW's base year GHG inventory project some challenges were encountered in defining a complete and updated list of all ODFW-managed buildings and facilities. A dataset of an organization's holdings of buildings and facilities (both owned and leased space) is a fundamental component of a GHG inventory that must be accurately defined.

ODFW is encouraged to develop an internal procedure specifically for the establishment and maintenance of an organizational-level list of ODFW's holdings of buildings and facilities and their campus-level association. Such a procedure should define the following:

- The facilities that are to be included
- Relationship between individual facilities and ODFW campuses
- Details of the data variables that are to be provided for each campus or facility
- A regular timeframe for facility-specific data to be collected or updated
- The individuals responsible for supplying the data (at the facility level) and managing the compiled dataset at the organizational level

5. Begin Management and Reporting of Relevant Scope 3 GHG Emissions

For many organizations Scope 3 GHG emissions can be a significant contribution to the overall carbon footprint. Unlike Scope 1 and Scope 2 GHG emissions, Scope 3 sources are optional to include in an organization's carbon footprint. The decision about whether to quantify and report Scope 3 sources can be challenging.

The GHG Protocol states that organizations should include all relevant sources of Scope 3 GHG emissions in their inventory. Relevancy is based on several factors including the size of the GHG source, the availability of data to quantify the source accurately, and the interest of the organization's stakeholders in the GHG source.

ODFW is encouraged to undergo a Scope 3 relevancy assessment exercise, whereby the various categories of Scope 3 emissions are assessed for their relevancy to the organization. Those that are deemed to be relevant to ODFW should be considered for future management and reporting as part of the organization's carbon footprint. Based on comparison to other organizations with a similar mandate to ODFW, Scope 3 categories that may be relevant to ODFW include:

- Employee commuting
- Waste generated in operations
- Business travel
- Purchased goods and services
- Upstream fuel and energy impacts

6. Conduct Further Research into Impact of Process GHG Emissions from Fish Production

Scope 1 Process Emissions considered in GHG's inventory were emitted as N_2O from microbial nitrification and denitrification processes from fish production. There is a high level of uncertainty in the emission factors that have been developed for N_2O emissions from fish production, as the emissions are dependent on the highly variable pH and dissolved oxygen content of the hatchery water bodies and on effluent treatment processes. The issue of N_2O emissions from fish production is a field of study that does not yet have an extensive amount of research or investigation completed. As a result the emission factors used for calculating process emissions in ODFW's base year GHG inventory were obtained from a single peer-reviewed scientific journal article that modeled rather than measured the emission factor.

Notwithstanding the high uncertainty of this emission source, it was decided it should be included given the number of fish hatchery facilities under ODFW's control and the mission-critical nature of ODFW's hatchery operations. ODFW is encouraged to include N_2O emissions from fish production as a future topic of research for ODFW's researchers to provide better understanding of the potential magnitude of this GHG emission source. There is a need to develop techniques to measure N_20 and to test the impact of various existing and potential new hatchery management techniques on GHG emissions.

APPENDIX A:

ODFW Campus List

Campus	Function	Area (ft^2)	Staff	Energy Consumption (kWh)			Energy Intensity	
				Nat. Gas or Propane	Electric	Total	kWh/ft^2	kWh/employee
Alsea Hatchery	Hatchery	14,629	9	0	59864	59864	4.1	6,652
Bandon Hatchery	Hatchery	10,054	3	0	50034	50034	5.0	16,678
Big Creek Hatchery	Hatchery	28,057	14	0	126698	126698	4.5	9,050
Bonneville Hatchery	Hatchery	117,133	17	0	3120	3120	0.0	184
Cascade Hatchery	Hatchery	17,636	5	0	125040	125040	7.1	25,008
Cedar Creek Hatchery	Hatchery	16,627	4	0	118852	118852	7.1	29,713
Clackamas Hatchery	Hatchery	4,704	5	0	118491	118491	25.2	23,698
Cole Rivers Hatchery	Hatchery	14,010	16	0	379171.2	379171	27.1	23,698
Dexter Pond	Hatchery	2,460		0	0	0	0.0	
Elk River Hatchery	Hatchery	6,348	11	0	74446	74446	11.7	6,768
Fall River Hatchery	Hatchery	13,537	2	14985	47396.4	62381	4.6	31,191
Gnat Creek Hatchery	Hatchery	16,402	4	0	12201	12201	0.7	3,050
Irrigon Hatchery	Hatchery	19,202	13	0	3326108	3326108	173.2	255,854
Klamath Hatchery	Hatchery	30,282	5	89154	118491	207645	6.9	41,529
Klaskanine Hatchery	Hatchery	26,634	3	0	8500	8500	0.3	2,833
Leaburg Hatchery	Hatchery	21,213	5	0	38112	38112	1.8	7,622

Lookingglass Hatchery	Hatchery	15,000	8	0	189586	189586	12.6	23,698
Marion Forks Hatchery	Hatchery	23,267	6	0	142189	142189	6.1	23,698
McKenzie Hatchery	Hatchery	15,044	5	0	219255	219255	14.6	43,851
Nehalem Hatchery	Hatchery	7,908	9	17226	213284	230510	29.1	25,612
Oak Springs Hatchery	Hatchery	27,243	8	0	17732	17732	0.7	2,217
Oxbow Hatchery	Hatchery	16,971	4	0	34686	34686	2.0	8,672
Roaring River Hatchery	Hatchery	13,488	5	0	56640	56640	4.2	11,328
Rock Creek Hatchery	Hatchery	17,857	4	0	683188	683188	38.3	170,797
S Santiam River Hatchery	Hatchery	17,569	4	0	42192	42192	2.4	10,548
Salmon River Hatchery	Hatchery	11,694	9	0	314120	314120	26.9	34,902
Sandy Hatchery	Hatchery	29,886	3	0	112560	112560	3.8	37,520
St. Paul Warm Water Hatchery	Hatchery	0		0	0	0		
Trask Hatchery	Hatchery	11,492	3	0	34654	34654	3.0	11,551
Umatilla Hatchery	Hatchery	15,000	7	0	165887.4	165887	11.1	23,698
Wallowa Hatchery	Hatchery	11,132	8	94689	174020	268709	24.1	33,589
Willamette Hatchery	Hatchery	33,509	13	0	129262	129262	3.9	9,943
Wizard Falls Hatchery	Hatchery	15,766	6	53757	166000	219757	13.9	36,626

John Day Screen Shop	Maintenance	63,124	23	14418	287272	301690	4.8	13,117
The Dalles Screen Shop	Maintenance	27,088	23	183447	96761	280208	10.3	12,183
Astoria Field Office	Office	4,000	26	0	114787.4	114787	28.7	4,415
Baker District Office	Office		4	6798	3542	10340		2,585
Brookings Field Office	Office	4,000	2	0	8829.8	8830	2.2	4,415
Charleston District Office (Millicoma STEP Facility)	Office	2,199	21	0	24766	24766	11.3	1,179
Deschutes WLA Office	Office	2,000	21	82860	30633	113493	56.7	5,404
East Region HQ	Office	20,018	25	0	50826	50826	2.5	2,033
Enterprise Field Office	Office	13,823	20	43821	62640	106461	7.7	5,323
Gold Beach Field Office	Office	2,000	12	0	52978.8	52979	26.5	4,415
Headquarters	Office	108,723	246	124818	892400	1017218	9.4	4,135
Hepner District Office	Office	8,000	4	187696	17660	205356	25.7	51,339
High Desert Regional HQ Deschutes Watershed District Office	Office	13,934	17	0	187536	187536	13.5	11,032
Hines District Office	Office	8,025	6	0	48955	48955	6.1	8,159
John Day District Office	Office	12,480	8	0	36679	36679	2.9	4,585
La Grande Wildlife	Office	8,000	6	0	26489	26489	3.3	4,415

Research Office								
Lakeview Field Office	Office	2,016	3	0	16703	16703	8.3	5,568
Marine Resources Program	Office	22,315	72	0	317873	317873	14.2	4,415
NW West Region HQ	Office	32,071	138	0	609256	609256	19.0	4,415
Ontario Field Office	Office	4,352	11	0	32316.4	32316	7.4	2,938
Pendleton District Office	Office	4,872	13	0	57394	57394	11.8	4,415
Prineville Field Office	Office	2,850	6	0	31198	31198	10.9	5,200
South Willamette Watershed District Office	Office	21,160	27	36889	184727	221616	10.5	8,208
Springfield Field Office	Office	8,000	13	0	19364	19364	2.4	1,490
SW Region Headquarters HQ	Office	54,586	38	0	21775	21775	0.4	573
The Dalles Field Office	Office	3,000	14	0	110032	110032	36.7	7,859
Tillamook North Coast Watershed District Office	Office		25	0	32694	32694		1,308
Trout Creek Office	Office	2,000	4	10929	17659.6	28589	14.3	7,147
Corvallis Research Laboratory	Research	7,391	81	65105	17733	82838	11.2	1,023

East Region Fish Research	Research	2,000	44	0	194255.6	194256	97.1	4,415
East Region Fish Research Umatilla	Research	2,000	12	0	52978.8	52979	26.5	4,415
Oregon Hatchery Research Center	Research	18,433	5	0	221137	221137	12.0	44,227
Bridge Creek Wildlife Area	Wildlife Area			0	0	0		
Columbia Basin Wildlife Area	Wildlife Area			0	0	0		
Coquille Valley Wildlife Area	Wildlife Area			0	0	0		
Denman Wildlife Area	Wildlife Area	23,448	35	0	57473	57473	2.5	1,642
EE Wilson Wildlife Area	Wildlife Area	62,574	2	0	20084	20084	0.3	10,042
Elkhorn Wildlife Area	Wildlife Area	28,155	5	8262	15482	23744	0.8	4,749
Fern Ridge Wildlife Area	Wildlife Area	6,960	4	0	33928	33928	4.9	8,482
Jewell Meadows Wildlife Area	Wildlife Area	21,237	4	0	42318	42318	2.0	10,580
Klamath Wildlife Area	Wildlife Area	30,686	12	32778	86810	119588	3.9	9,966
Ladd Marsh Wildlife Area	Wildlife Area	28,813	3	0	15157	15157	0.5	5,052
Lower Deschutes Wildlife Area	Wildlife Area			0	0	0		

Phillip W Schneider	Wildlife Area	8,150	2	0	17140	17140	2.1	8,570
Riverside Wildlife Area	Wildlife Area			0	0	0		
Sauvie Island Wildlife Area	Wildlife Area	43,980	19	16027	312717	328744	7.5	17,302
Summer Lake Wildlife Area	Wildlife Area	13,467	6	0	36993	36993	2.7	6,166
Wenaha Wildlife Area	Wildlife Area	21,245	3	48357	23300	71657	3.4	23,886
White River Wildlife Area	Wildlife Area	20,951	4	0	50273	50273	2.4	12,568