

Headquarters U.S. Air Force

Integrity - Service - Excellence

How Green is Green Power?

**An Assessment of the Environmental Implications of
Manufacturing Solar and Wind Power
Alternative Energy Systems**

**Year of the Air Force
Family**



**Javier Santillan
Erica Becvar
AFCEE/TDV**



Background

- EPA launched Siting Renewable Energy on Contaminated Lands and Mining Sites at the 2008 Brownfield's Conference
- EPA's Green Remediation Primer
- Ever increasing focus on green and sustainable remediation strategies





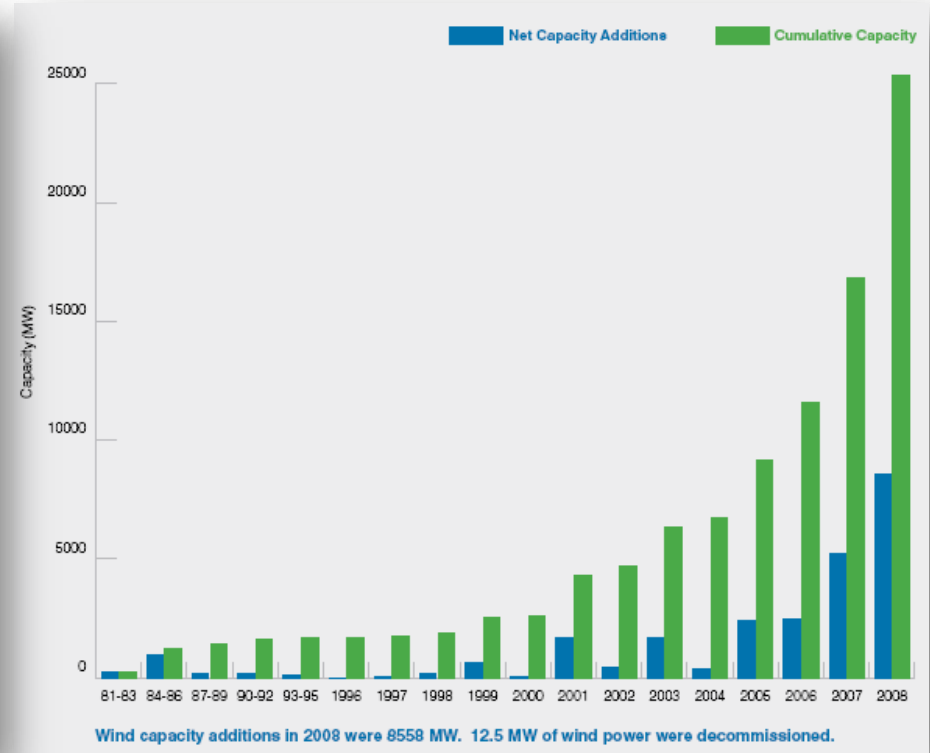
- Bush 1/24/07 Executive Order 13423
- Obama 10/8/09 Executive Order 13514
- 8/10/09 Under Secretary of Defense Memo
- EPA OSWER Green Principles
- Other State and Federal Programs



Executive Order 13514 - Federal Leadership in Environmental, Energy, and Economic Performance
October 8, 2009



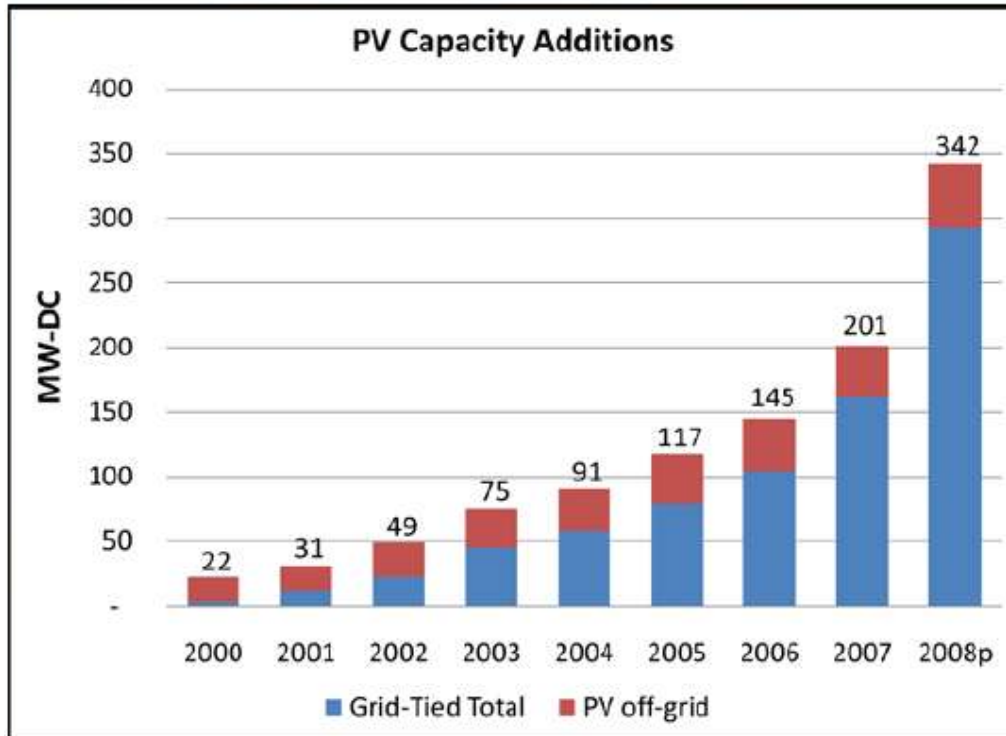
Growth of Wind Power



Source: AWEA 2009



Growth of Solar Power



p = preliminary

Source: Larry Sherwood (IREC), SEIA

Source: SEIA 2008



AF Energy Focus



*We can't rest until we harness the **renewable energy** that can create millions of new jobs and new industries. ...That's how we can grow our economy, enhance our security, and **protect our planet** at the same time.*

- President Obama, 29 Apr 2009

*The Air Force energy strategy furthers an **energy future that is secure, efficient, and environmentally sound.***

- Michael Donley, Secretary of the Air Force, Jan 2009



*We must continue to identify **innovative ways to conserve energy** and take actions to build upon our success. Let's **be passionate energy advocates**, set the example, and remind those around us that our individual actions can make a significant difference in creating a **more energy-efficient Air Force.***

- General Norton Schwartz, USAF Chief of Staff, Jan 2009



AF Energy Goals

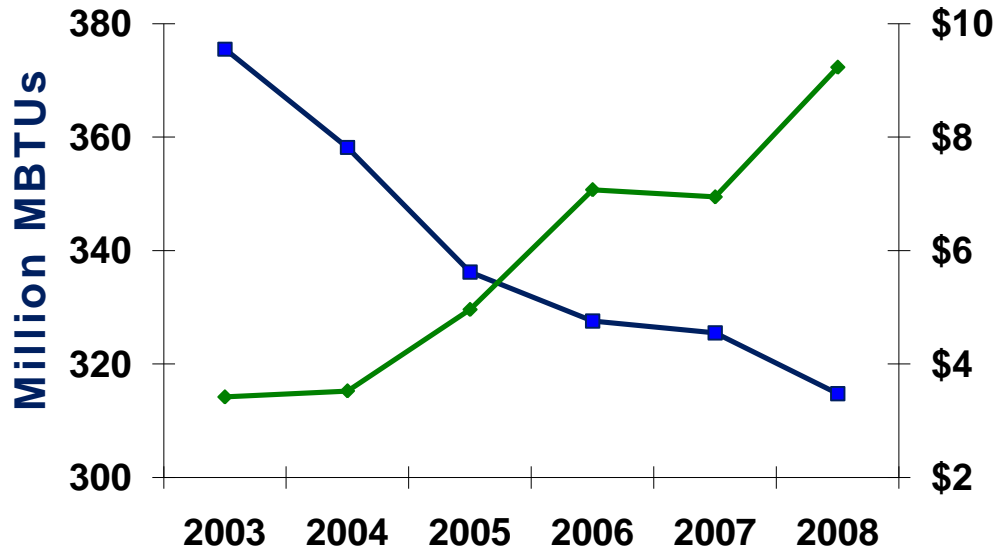
- **Plans \$2.3 B over next six years on energy and water conservation and expanded use of renewable energy projects**
- **Capital investment strategy expected by 2015 to:**
 - **Reduce energy intensity at AF facilities by 30% by 2015**
 - **Reduce potable water usage by 16%**
 - **Increase on-base renewable energy to 3% of all electricity use**
 - **Increase renewable energy to 10.5% of all electricity**



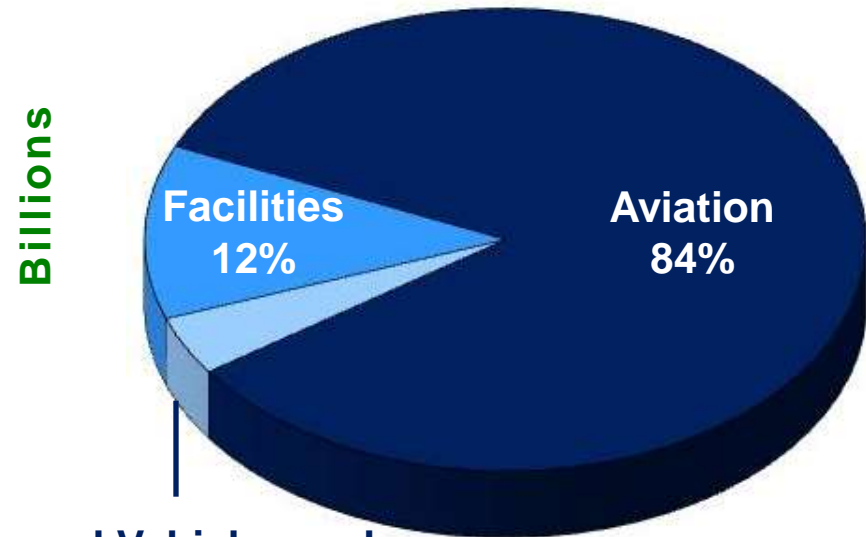
AF Environmental Program – Energy

Over \$9 billion spent for energy in 2008

Energy Cost and Consumption Trends



Energy Cost Breakdown



Air Force is the largest user of liquid fuels in the DoD

Ground Vehicles and
Equipment, 4%

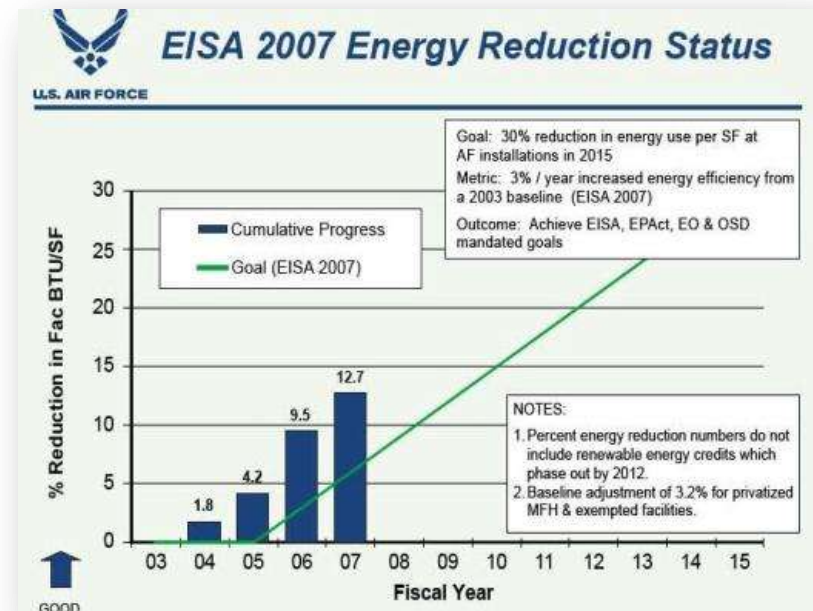
***Energy Consumption is Decreasing
While Costs are Increasing***



AF Environmental Program – Energy

- Air Force Energy Goals:
 - Reduce demand
 - Increase supply
 - Culture change
- AF No. 1 purchaser of green power in fed government
- Met every energy conservation goal since 1975
- Reduced facility energy intensity by more than 30% 1985 – 2005
- Aggressive conservation program exists to meet EISA 2007 and EO 13423 goals; on path to meet 30% reduction by 2015

Vision
**Make Energy A Consideration
In All We Do**





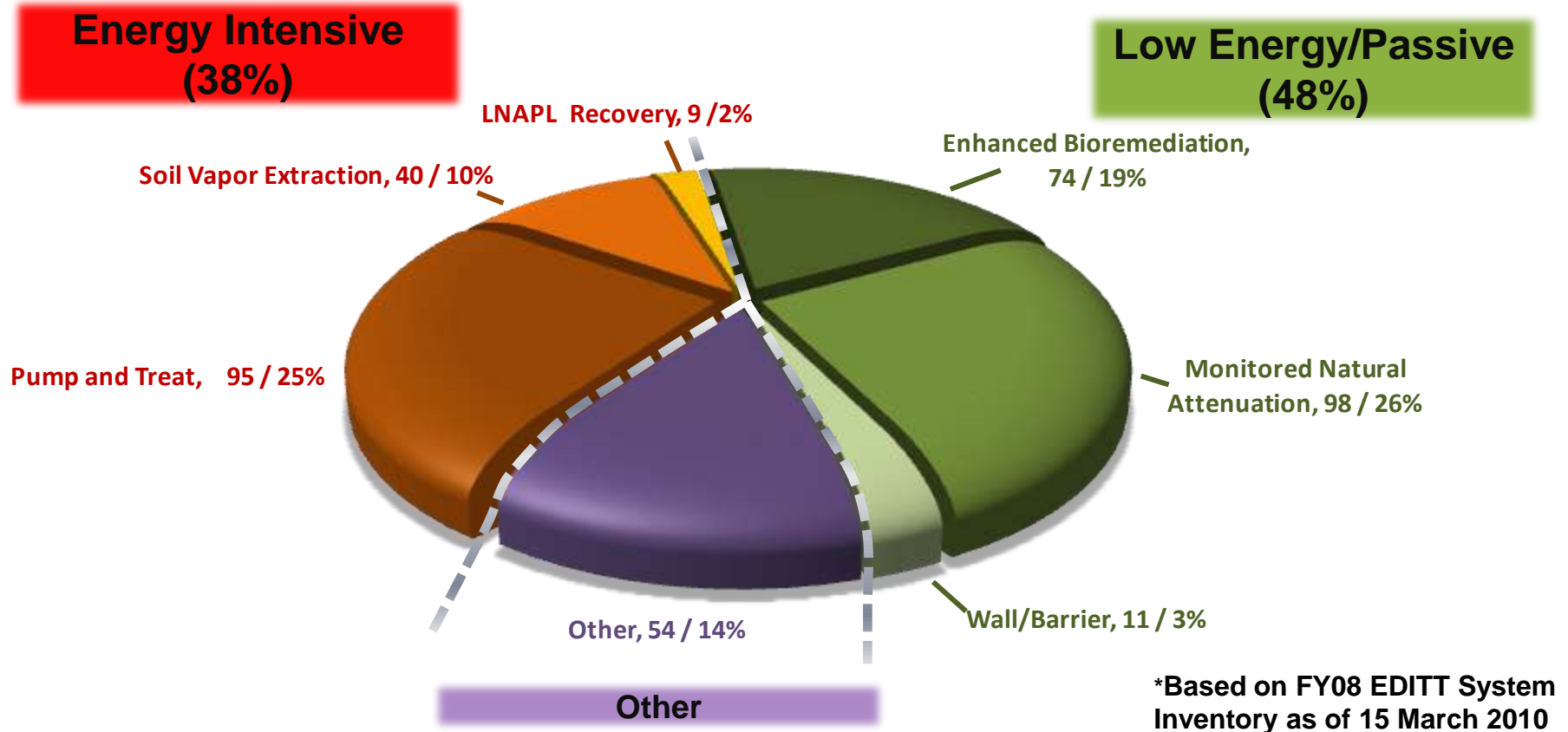
AF Environmental Restoration Program

- **Installation Restoration Program (IRP) – 572 sites in 2010**
 - **6,078 sites closed, response complete, or RIP**
 - **Cleanup of pre-1986 contaminated sites**
 - **Achieve Remedy-in-Place (RIP) by 2012**
- **Compliance Restoration Program (CRP) – 952 sites in 2009**
 - **Compliance cleanup sites (post-1986 releases)**
- **Military Munitions Response Program (MMRP) – 455 open munitions response sites**
 - **Cleanup of non-operational ranges**
 - **Achieve RIP/Response Complete (RC) by 2020**
- **FY10 Budget: \$414M for 648 active projects**



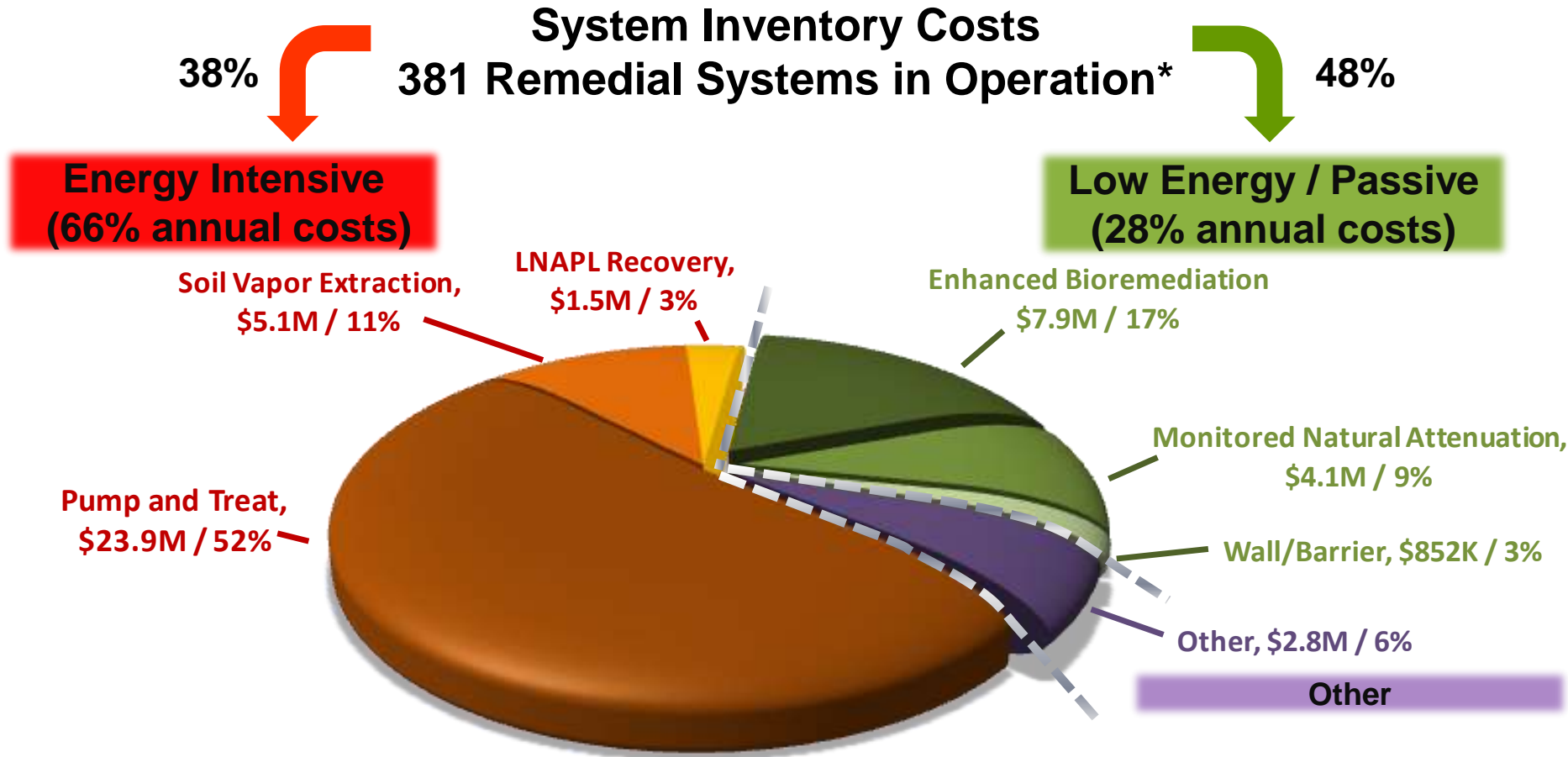
AF Environmental Restoration Program

System Inventory: 381 Remedial Systems in Operation*





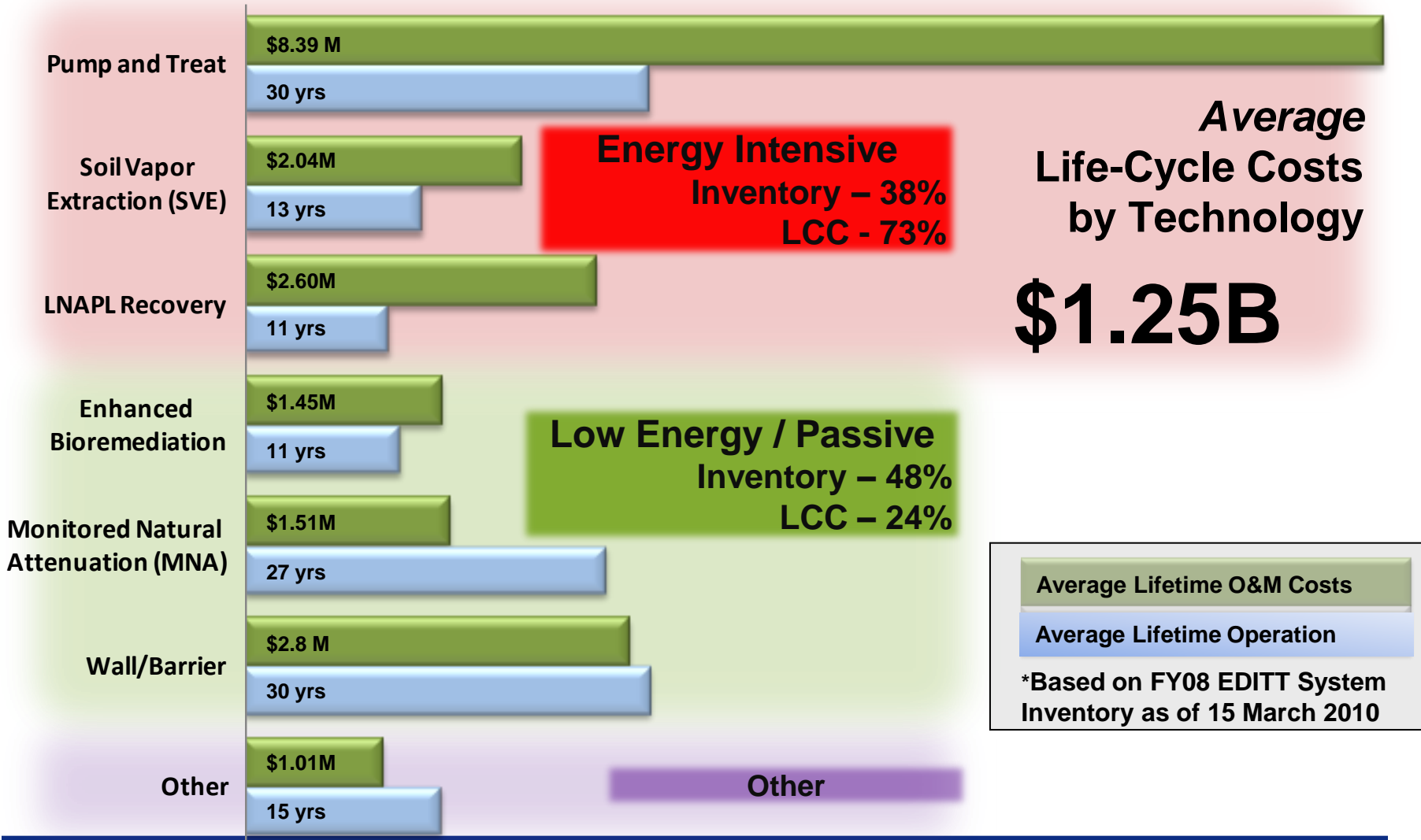
AF Environmental Restoration Program



*Based on FY08 EDITT System Inventory as of 15 March 2010



AF Environmental Restoration Program





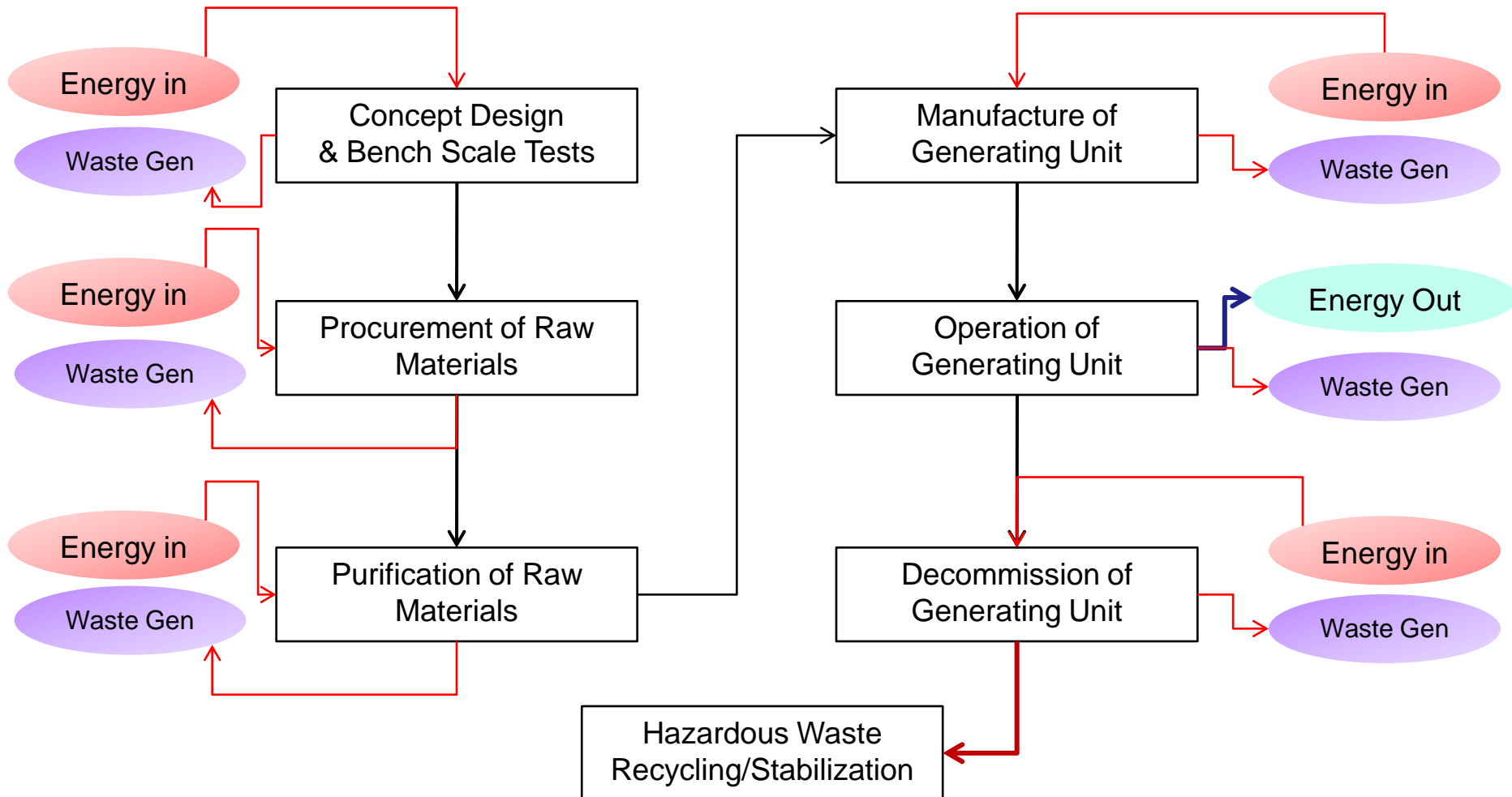
How Green is Green?

- Wind and PV power production systems exhibit low environmental impact during operational stages
- However, potential human health and environmental impacts stem from manufacturing and production processes associated with these technologies
- Life Cycle Analyses (LCA) necessary to fully understand environmental impacts associated with these technologies
 - Evaluate process stage impacts
 - Greenhouse Gas (GHG) Emissions
 - GHG Energy Payback Times (EPT)



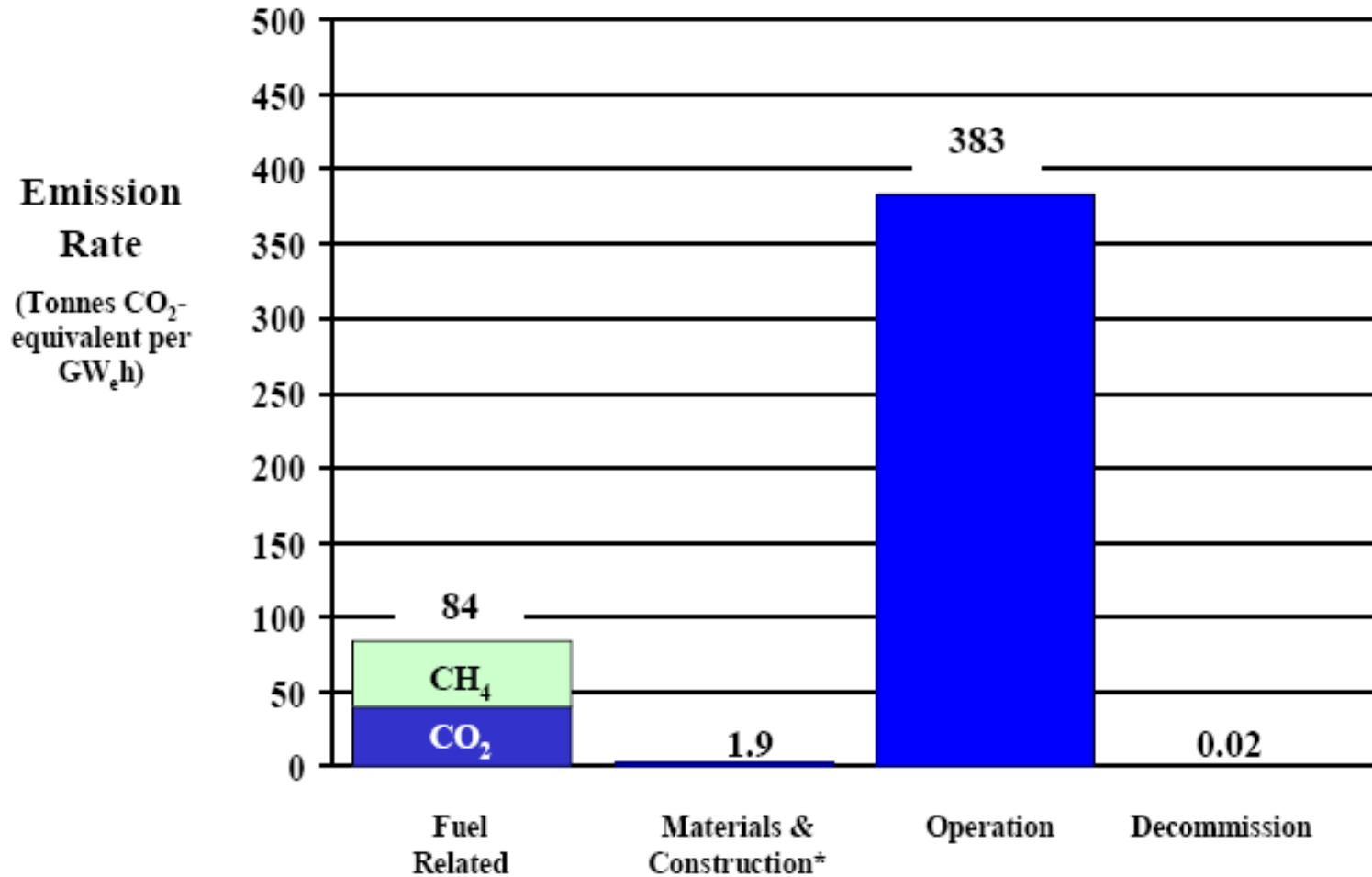


Life Cycle Analysis





LCA GHG Emission for 620MW **Natural Gas** Plant

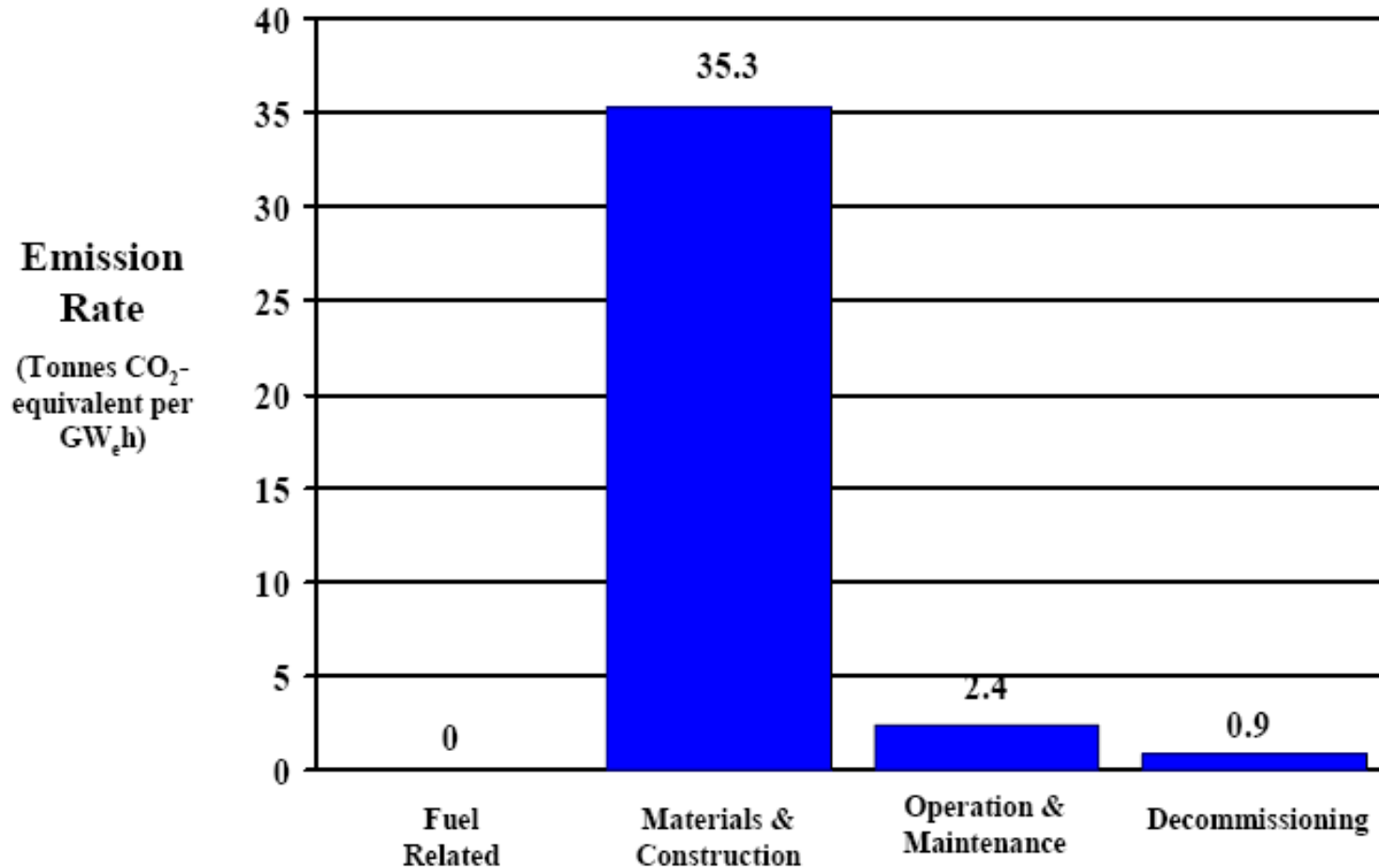


Source: Paul J Mier (2002)

*Includes replacement parts



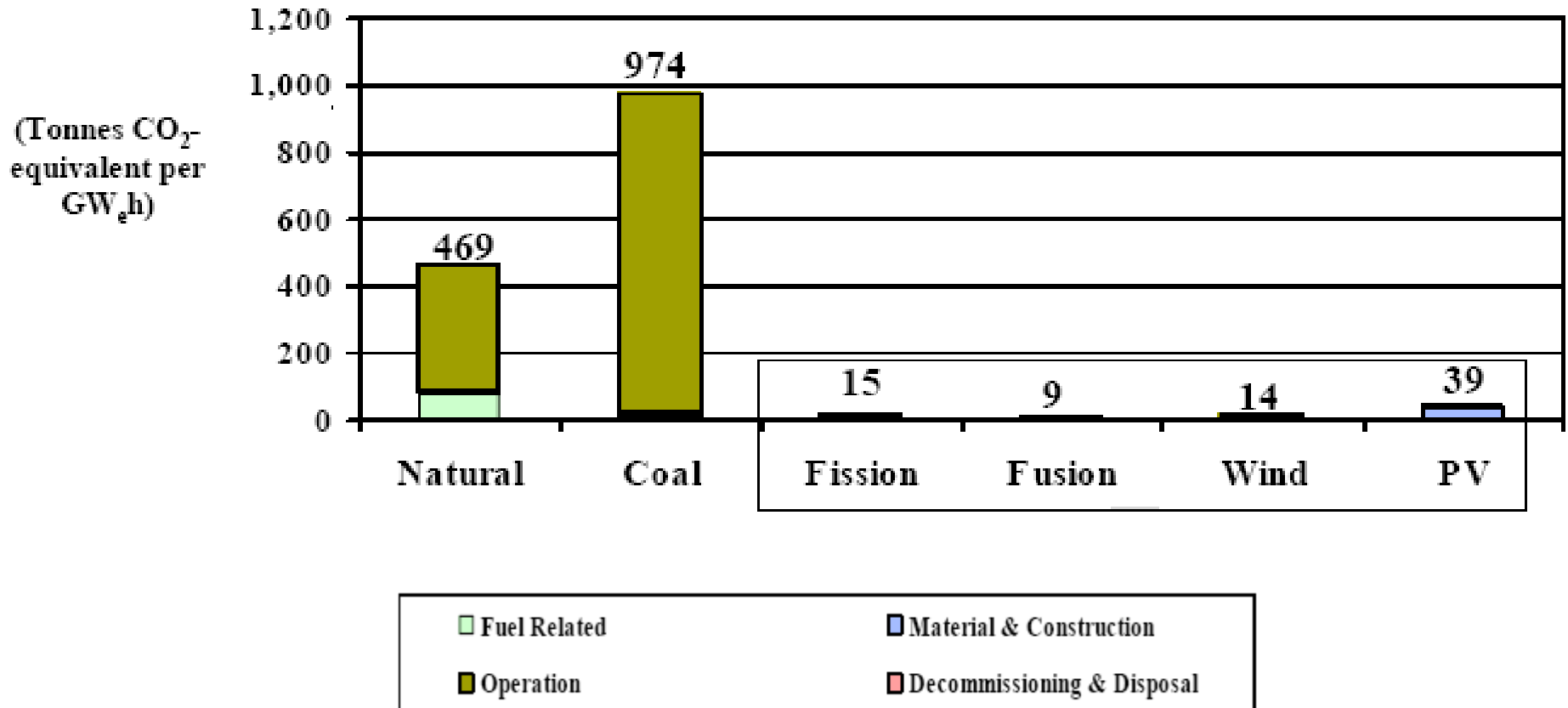
LCA GHG Emission for 8KW PV System



Source: Paul J Mier (2002)



GHG Emission Rate per GW



Source: Paul J Mier (2002)



- **LCAs** for wind turbine systems **relatively limited**
- Available studies commonly bring to light **dominant influence of material production** on environmental performance of wind turbine technologies
- LCC results: **payback duration varies** significantly based on **location, location, location**
 - 41% sites displayed payback < 10 yrs
 - 63% sites displayed payback < 15 yrs

Wind Turbine LCA References

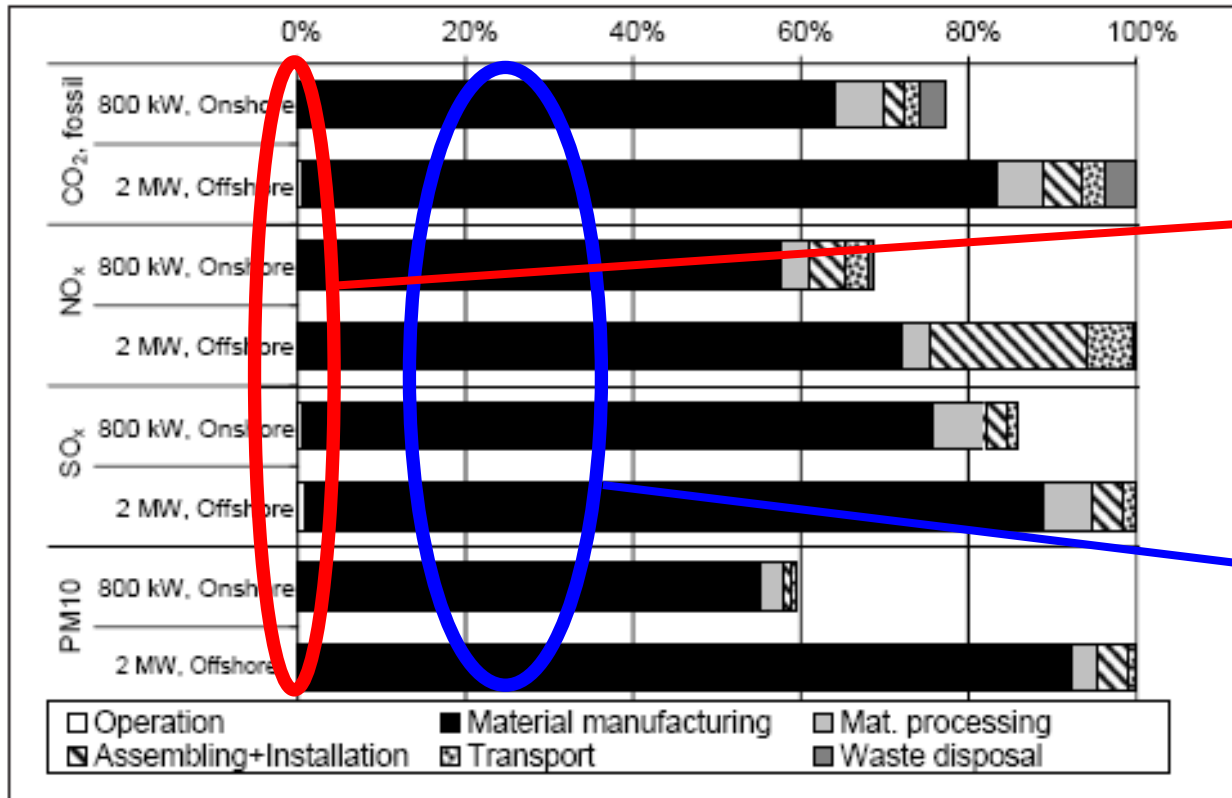
Jungbluth *et. al.*, *International Journal of Life Cycle Assessment*, 10, 24, 2005

Nalukowe *et. al.*, 2006

LaPuma et al., Analysis of Wind Turbines Using Monte Carlo Simulation



Wind Turbine Process Stage Contributions



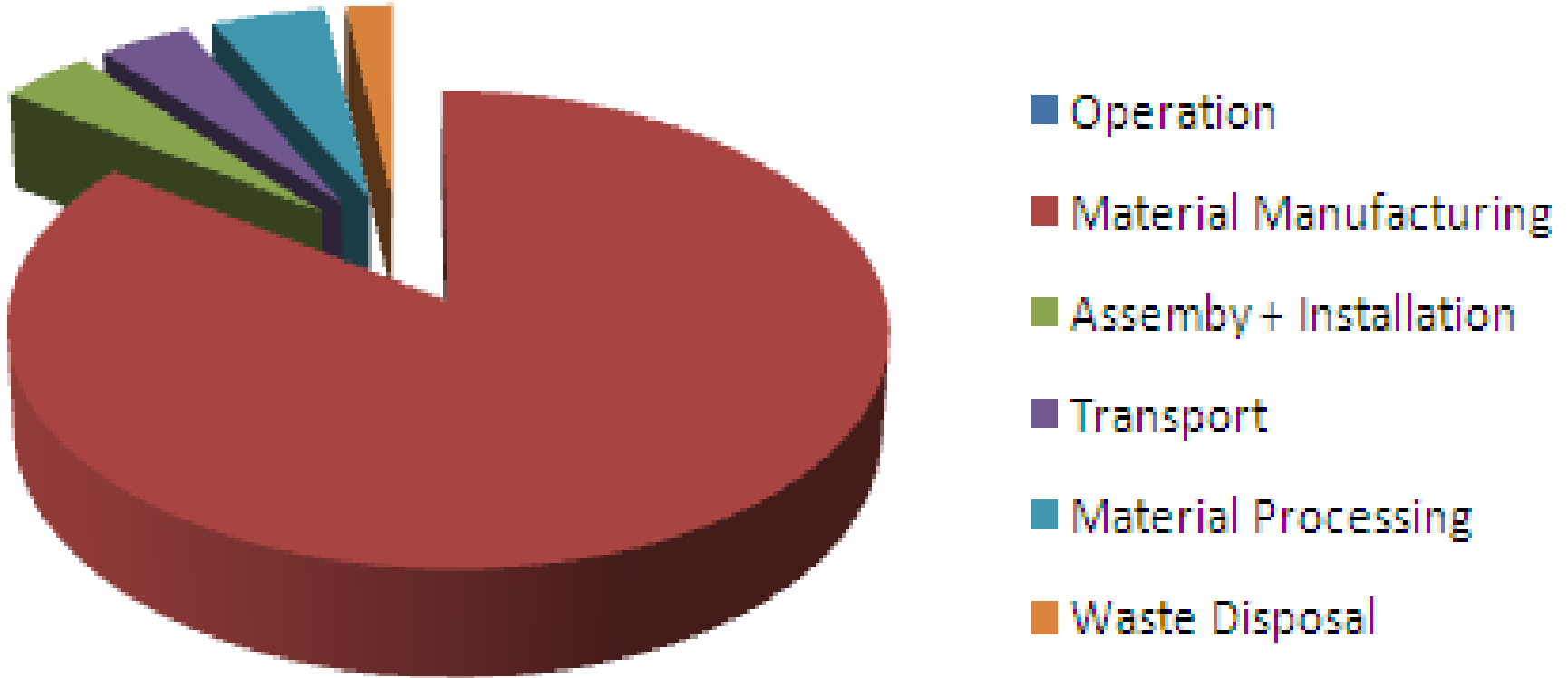
- **No notable impacts** owing to **system operation** stage
- **Greatest impacts** owing to **material manufacturing** process stage

Fig. 8: Share of process stages for the European 800 kW onshore and the 2 MW offshore wind turbines for selected air emissions

Source: Jungbluth et.al 2004



Wind Turbine Process CO₂ Contributions



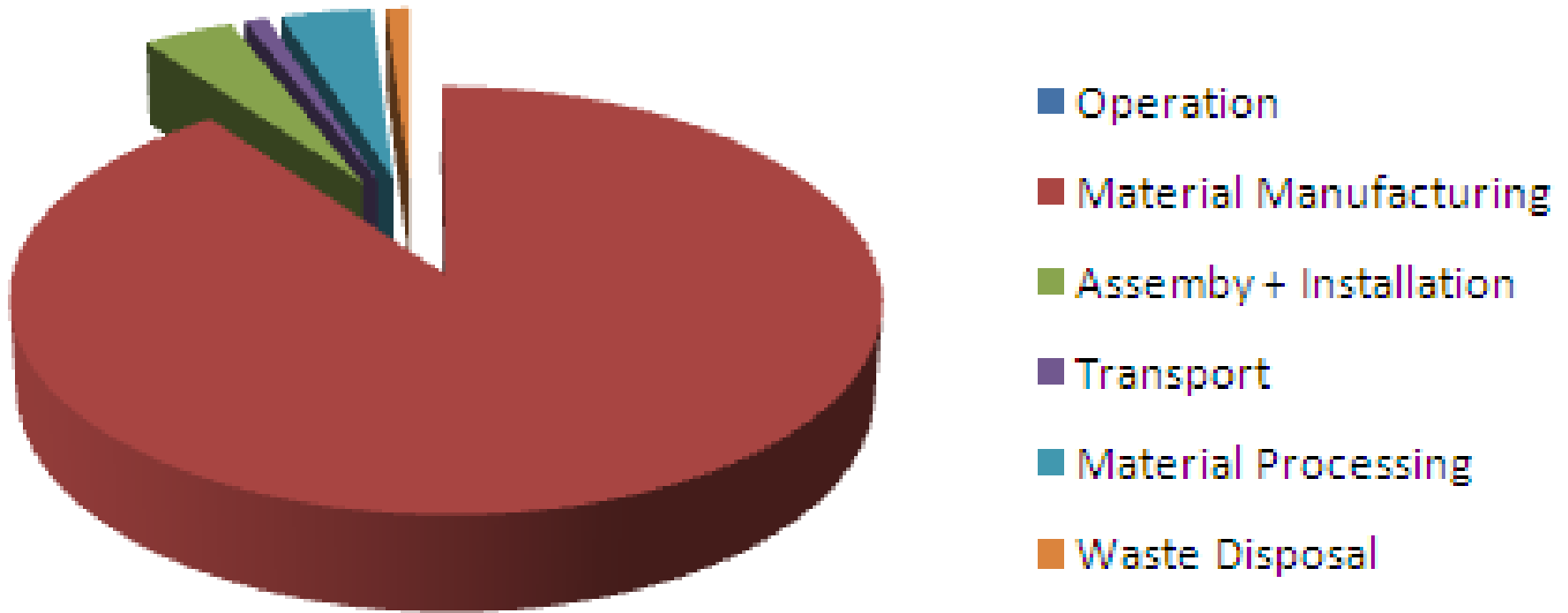


Wind Turbine Process NO_x Contributions





Wind Turbine Process SOx Contributions





GHG Emissions and EPT for Wind Turbines

- Taking manufacturing process stages into account Jungbluth *et. al.* reported GHGs emitted by subject systems as 11 g/kWh for on shore and 13 g/kWh for off shore systems (values significantly lower than conventional fossil fuel production technologies)

Source: Jungbluth *et. al.*, 2004

- AWEA reports typical GHG emission EPT for wind turbines is few months (3-8) depending on average wind speeds at a site

Source: AWEA, 2002





LCA for Solar Systems

- Installing photovoltaic solar panels will cost more than one saves on electricity bills before panels have to be replaced (Bizzarri, Morini)
- Available studies commonly bring to light dominant influence of raw material purification and production on environmental performance of PV technologies

PV System LCA References

Jungbluth *et. al.*, *International Journal of Life Cycle Assessment*, 10, 24, 2005

Alsema and de Wild-Scholten, *Material Research Society Symposium Proceeding*, 2006

Fthenakis *et. al.*, *Environmental Science & Technology*, 42, 2168, 2008

Bizzarri, et al., A Life Cycle Analysis of roof integrated photovoltaic systems 2009



GHG Emissions and EPT for Solar Systems

- Life cycle-based estimates GHG emissions of PV systems ranged from 20-55 g CO₂ equiv/kWh
- CdTe systems typically lower estimated emissions than silicon based systems based on energy input differentials during manufacturing
- Reported GHG EPTs for solar systems have ranged from 1.5 to 3 years

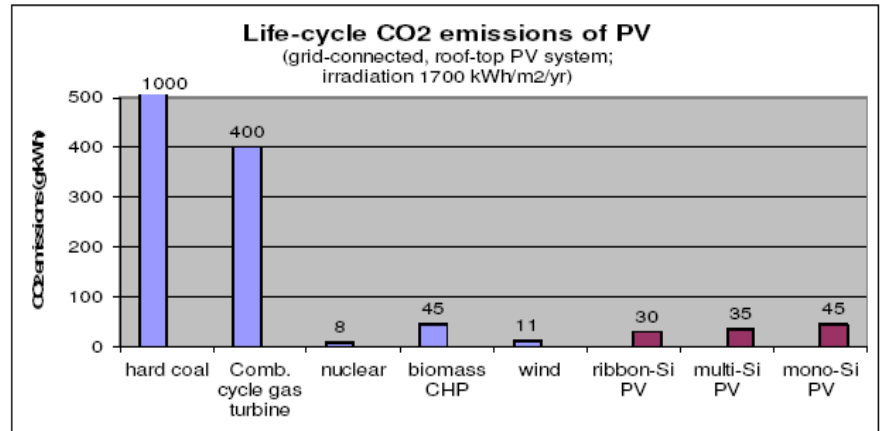


Figure 7: Greenhouse gas emissions of PV systems based on three silicon technologies, compared to a number of other energy technologies. The PV systems are installed on a roof-top in S-Europe (irradiation 1700 kWh/m²/yr) and have a 30 year life time. N.B. The emission from a coal-fired power plant (1000 g/kWh) exceeds the Y-axis maximum ! (Sources: Coal, CC gas, nuclear, biomass and wind data derived from Ecoinvent database [6])

Source: Alsema and de Wild-Scholten 2005
Fthenakis et al., 2008



- Wind and solar power production systems **exhibit low environmental impact during operational stages**
- **Environmental impacts stem from manufacturing and production** processes associated with these technologies
- LCA derived **environmental impacts** estimated for wind turbine and solar systems **significantly less than those offered by fossil fuel-based** technologies
- **Cost** of wind and solar generation systems **may not be recovered prior to end of useful life span**
 - AF alternative energy tool
- Are moving in right direction – **just not there yet**
- Solar power does not free us 100% from of energy dependence



co-contributors:

Mark Heaston, AECOM

Dave Woodward, AECOM

Manish Joshi, P.E, AECOM

Contact Dr Javier Santillan
Javier.santillan@us.af.mil
210-395-8437