Supplementary Material B – Information on policies affecting material efficiency in G7 countries and China

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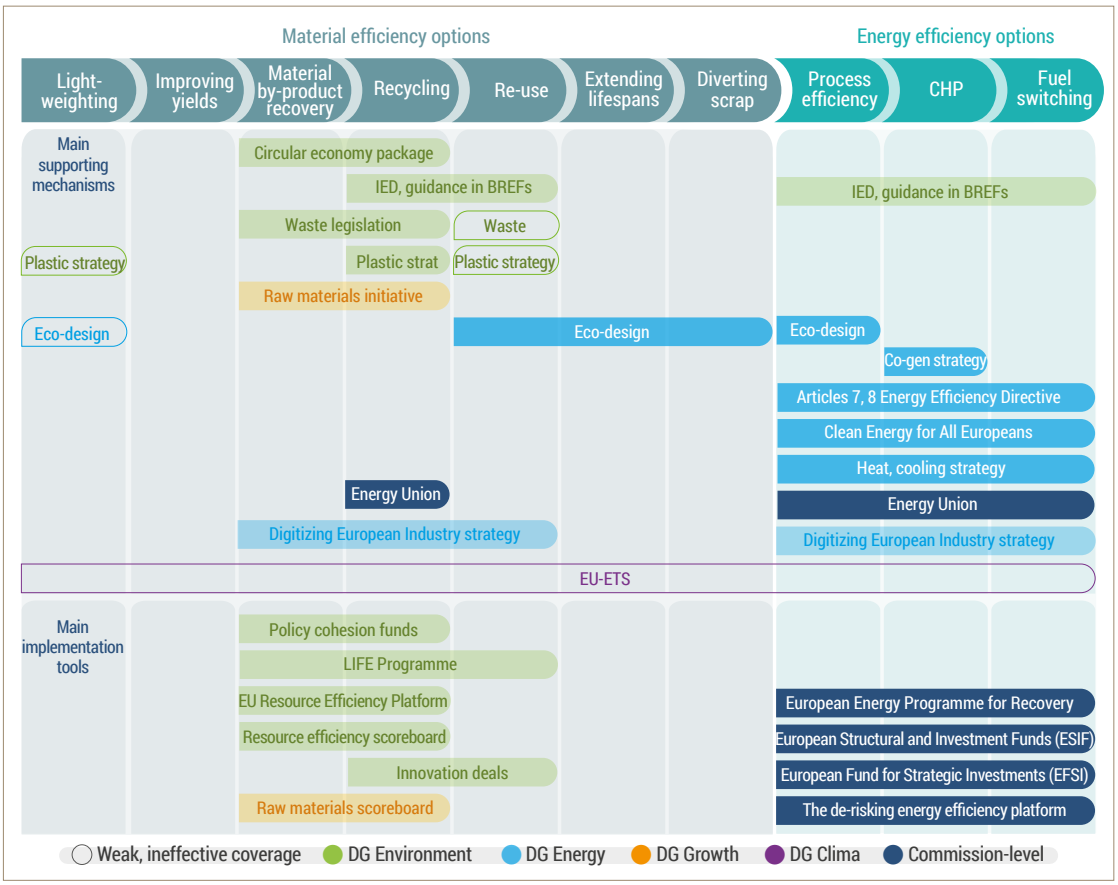
S1. Summary of material efficiency policies in the G7 and China

S1.1. European Union

The EU has established a wide variety of policies that encourage or mandate material efficiency strategies to varying degrees. Figure 1 summarizes the policy development architecture within the EU for specific material and energy efficiency policies as analyzed by Hernandez et al (2018).

Figure 1. European Union Key Policy Review for various technical measures in material and energy efficiency (Hernandez et al., 2018)



Source: Hernandez et al., 2018.

The Waste Framework Directive (2008/98/EC) is a key part of EU policy that provides with details on how waste should be handled. The directive provides general principles including the polluter pays principle, the waste management hierarchy, and extended producer responsibility all of which aim to reduce the environmental impact of waste while simultaneously increasing resource efficiency through reuse, recycling and recovery. According to a study by Deloitte, all EU Member States have transposed the Waste Framework Directive (2008/98/EC) into national legislation providing a common set of principles for waste management across EU-28 according to the waste hierarchy (Deloitte, 2017). In 2018, the directive was amended to improve its robustness and identify gaps that need to be addressed.

The EU Circular Economy action plan is a second important element in EU policy toward material efficiency. The action plan was adopted in 2015, aiming to boost jobs, growth and investment for developing a resource efficient economy (European Commission, 2019a). In March 2019, the European Commission published a comprehensive report on the implementation of the Circular Economy Action Plan and according to that report the 54 action plans have been completed while further work is being carried forward. The report presents the

main achievements and statistics identified by the monitoring indicators under the Action Plan.

The EU's 2020 strategy is also a significant example of policy that includes material efficiency. The EU 2020 strategy is an agenda for growth and jobs for the current decade (European Commission, 2010). It is organized around 5 headline targets and a series of flagship initiatives. The resource-efficient flagship initiative is a collective growth strategy for EU countries to shift towards sustainable growth and a low-carbon economy via resource-efficiency by 2050 (European Commission, 2010). It outlines a set of measures including waste minimization, alternative material use, raising the productivity of agriculture, conserving water and energy, reducing raw material use, green building, clean transportation, environmentally sound technologies all while promoting a circular economy. Progress on the EU 2020 strategy related to climate change and energy is measured through a series of headline indicators focussed on GHG emissions, renewable energy and energy efficiency (Statistical Office of the European Communities, 2016).

Similarly, the 2018 circular economy package includes a monitoring framework[1] to track progress at EU and national levels. It consists of ten key indicators which encompass a range of aspects of the circular economy such as production & consumption, waste management, secondary raw materials and economic aspects (investments, jobs and innovation etc.). This framework further augments the existing Resource Efficiency Scoreboard and Raw Materials Scoreboard, which were previously developed by the Commission (European Commission, 2018).

The summarized listings below focus on material efficiency in building construction and transportation in G7 countries (Germany, France, Japan, Italy, United Kingdom, Canada, and the United States as well as China).

S1.2. Germany

Germany has a voluntary building certification program, the DGNB. This program provides assessments for buildings and urban districts for new, existing, and renovation building projects and promotes resource extraction and responsible construction and consumption with waste reduction and prevention strategies (The DGNB System: Global Benchmark for Sustainability, 2002). Projects can earn bronze, silver, gold and platinum ranking similar to the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) certification program (discussed in the main text of the present report). Other policies related to material efficiency include the German Energy Concept, the Energy Efficient Construction Program, the Heating Cost Ordinance, the German Government Raw Material Strategy, New Lightweight Materials for Automotive Industry, and End of Life Vehicle Disposal. The building and construction policies address reuse and recovery of materials, increased use of recycled materials, limitation of the use of hazardous materials, and reduction of the use of materials such as steel and glass. They also include economic incentives for the implementation of material efficiency methods in building projects. The Energy Efficient Renovation Program offered by the kfW Bank Group provides loans and grants for retrofits and installing energy efficient components. The Energy Efficient Construction Program also provides loans but for new buildings to surpass building standard regulations (Amecke et al., 2013). The German Resource Efficiency Program (ProgRess II) follows an integrated perspective on energy and material efficiency (*German Resource Efficiency programme (ProgRess II): Case Studies,* 2017). ProgRess II includes a series of circular economy targets including a significant increase in the percentage of recycled aggregate used as concrete aggregate relative to the total volume of recycled mineral construction materials by 2030 and a significant increase in the percentage of recycled material in the manufacture of gypsum board by 2030 (Federal Ministry for the Environment and Federal Ministry for the Environment, 2016)

In transportation, Germany's material efficiency strategy focuses on material production and material recovery. The New Lightweight Materials for Automotive Industry initiative focuses on for adapting lightweight materials and electronics for

1 https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework

electric vehicle production (Germany Trade and Invest, 2014). Arena2036 focuses on R&D for a lightweight design, construction, and ergonomics. The Open Hybrid LabFactory carries out R&D in new material production (metals, plastics, textiles) to make vehicles more environmentally friendly for mass production (Germany Trade and Invest, 2014). The Regulation on the Disposal, Return and Environmentally Sound Disposal of End-of-life Vehicles outlines targets for reuse and recovery at least by 85% by weight (2006) and 95% by 2015, increased use of recycled material in manufacturing, and reduction of hazardous substances in the development of the vehicle. (German Federal Ministry of Justice, 2012).

The government aims to achieve a building stock that is nearly climate-neutral by 2050. This will entail reduction of GHG emissions and primary energy demand in buildings by 80 percent relative to 2008 levels (Federal Ministry of the Interior, Building and, 2019). The built environment stakeholders have recommended the integration of whole life carbon criteria into European policy (WBGC 2019). This is in line with the German National Sustainable Strategy which is to boost efficiency while adhering to the standards and requirements of buildings (Federal Ministry of the Interior, Building and, 2019).

S1.3. France

France has also made efforts to reduce waste through economic incentives, banning of products, and setting of recovery, reuse, and recycling targets. The French Energy Transition for Green Growth Act 2015 seeks a 30% increase in material productivity by 2030 along with a reduction of GHG emissions by 40% by 2030 relative to 1990 levels and 75% by 2050; to cut final consumption 30% by 2030 relative to 2012 levels and 50% by 2050, half of landfill waste by 2050; efforts to bring 500,000 homes into compliance by 2017 thermal standards, and tax credits for individuals that conduct home improvement energy and material efficiency projects (Planete Energies: France, 2015). The Act aims to achieve a 7% reduction in household waste and increase recycling rates to 60% by 2025 and outlaw obsolescence (Planete Energies: France, 2015). To achieve a circular economy, France has enacted several laws including those which ban single-use plastic bags and ban plastic cups, glasses, and plates (Planete Energies: France, 2015).

In addition, the Road Map for the Circular Economy aims to progress towards 100% recycled plastics by 2025 and to reduce the material intensity of the French economy (DMC/GDP) by 30% by 2030, compared to 2010. This target is similar to the resource productivity target set by the Energy Transition Act for Green Growth. (Aoki-Suzuki et al., 2019).

The building construction and transportation sectors are a particular focus of the Environment law (de l'Environnement, Law No. 2009-967 of 3 August 2009). While many of the targets address energy and GHGs, material efficiency-related targets include 75% increase of industrial waste recycled by 2012, reduction of municipal solid waste generation to 5 kg per year per inhabitant 2008-2012, 15% reduction of waste incinerated and stored by 2012 and 50% reduction of paper use by 2012 (Fritsche et al., 2013).

S1.4. Japan

Japan has established several laws for construction material and automobile recycling as part of its effort to create a sound material-cycle society (SMCS). Use of 3R strategies – reduce, reuse, and recycle – waste reduction and resource productivity are a focus of the SMCS. In the 1960s-70s, Japan enacted a series of laws establishing the foundations of the SMCS: The Act on Emergency Measures Concerning the Development of Living Environment Facilities (1963), the Waste Management Act (1970), and the Revision of the Waste Management Act (1976). In the 1980s-90s, various laws were enacted to manage hazardous substances, introduce proper waste management and recycling methods, and establish basic laws for the protection of the environment from industrial wastes and dioxins (Japan Ministry of the Environment, 2014). More recently, Japan has emphasized its SMCS and 3R measures to enhance further efficiency related to small home appliances, construction and building, and automobile manufacturing.

The Japanese Construction Material Recycling Act requires a series of key mandates on demolition and recycling of buildings as described in the main

text of the present report. The Law for the Recycling of End-of-Life Vehicles targets the materials in vehicle production that are landfilled as automobile shredder residue as described in Box 6 in the main text of the present report. Complementing the Automobile Recycling Act is the End-of-life Recycling law which aims to increase air bag recycling to 85% and shredder dust recycling to 70% (Togawa, 2015).

S1.5. Italy

In 2016, a significant step was taken to integrate environment related issues in the economy through the introduction of an environment bill annexed to the financial law of 2014 called 'Collegato Ambientale'. In 2017, Italy's National Sustainable Development Strategy (NSDS) was approved and provides concrete activities based on the sustainable development goals (SDGs) on the five dimensions of the 2030 Agenda: "People, Planet, Prosperity, Peace and Partnership" (European Commission, 2019b). The NSDS recognizes circular economy and resource efficiency as fundamental pillars within the 'prosperity' dimension. In conjunction with the adoption of NSDS, Italy also published "Towards a Model of Circular Economy for Italy - Overview and Strategic Framework" in 2017 which provides a general perspective of the Italian government on circular economy, resource efficiency, sustainable material management, also with regard to their interaction with a low-emission economy (European Commission, 2019b).

In July 2018 a public consultation was launched on a monitoring framework for resource efficiency and the circular economy prepared by the Ministry of Environment, the Ministry of Economic Development and the (ENEA) National Agency for New Technologies, Energy and Sustainable Development and a final report on that was produced in December 2018 (European Commission, 2019b). The Italian Circular Economy Network has published a report on the performance of Italy of the circular economy and resource efficiency.

To advance green public procurement (GPP), Legislative Decree n. 50/2016 containing the new Italian Public Procurement Code (PPC) entered into force in 2016 making GPP mandatory in Italy. Italy adopted a national action GPP plan in 2013. The Ministry of the Environment established the minimum environmental criteria which serve as a reference point for the use of GPP by contracting authorities. The national law n. 221 of December 2015, so-called Collegato Ambientale, makes GPP mandatory (Article 19).

S1.6. United Kingdom

The UK Resource Security Action Plan, developed in 2012 in response to concerns about the availability of some raw materials, identifies and reduces waste in common construction materials such as timber, lead, copper, steel, iron, glass, and cement. The Plan also examines rare earth metals, lithium, cobalt, chromium, and other metals in the production of automobiles and parts (DEFRA, 2012). The Plan focuses on the security and efficient use of materials rather than scarcity and provides a framework for business action to address resource risks, and establishes measures to facilitate partnerships between government and businesses to address resource concerns (European Environment Agency, 2016).

Similar to the German building certification program, BREEAM in the United Kingdom identifies waste reduction strategies in construction and operation and maintenance of the buildings (BREEAM, 2011). The UK also has a significant number of products and businesses registered in the EU Ecolabel scheme. As of September 2018, the UK had 110 products and 2620 licenses registered in the EU Ecolabel scheme providing an indication of the country's circular economy transition (European Commission, 2019b). Green Public Procurement (GPP) in the UK is conducted through 'greening government' commitments which are not legally binding but rather based on political and administrative commitments. At the moment, GPP, encompassing 12 major products groups with approximately 60 products, is set at two levels - mandatory minimum and voluntary best practice. The GPP targets are embedded as 'government buying standards' in procurement contracts. (European Commission, 2019b).

In 2018, the UK committed in its 25 Year Environment Plan to ensure resources are

used more efficiently and product lifetime's are increased in order to minimise waste and environmental impacts. Through the promotion of reuse, remanufacturing and recycling, UK aims, by 2050, to double resource productivity and work towards eliminating all avoidable waste (European Commission, 2019b).

S1.7. Canada

Many resource efficiency policies in Canada are initiated at a subnational level where the focus has been on waste reduction and, more broadly, the 3Rs as with, for example, the Ontario Circular Economy Act. In November, 2018 ministers in Canada endorsed a nationwide waste reduction goal to reduce disposed waste to 490 Kg per person by 2030 and 350 Kg per person by 2040, which is a 30% and 50% reduction respectively from the baseline of 706 Kg in 2014 (Canadian Council of Ministers of the Environment (CCME), 2019). Similar to the United States, Canada also several voluntary, industry-driven initiatives. A notable example of this is the significant uptake of LEED certification. According to a report published by the Canada Green Building Council (Canadian Council of Ministers of the Environment (CCME), 2019), as of January 2019 there are 4025 LEED certified projects and 700 LEED V4 registrations.

The Government of Canada, provincial, and territorial governments are working together to develop and implement increasingly stringent model building energy codes, starting in 2020, with the goal that provinces and territories adopt a "net-zero energy ready" model building code by 2030 (Energy and Mines Ministers' Conference et al., 2017; Environment and Climate Change Canada, 2016). In addition to developing a code for new buildings, the Government of Canada has also committed to developing a code for existing buildings (i.e., a retrofit code) by 2022, which will outline requirements for renovations (Energy and Mines Ministers' Conference et al., 2017). Another effort to promote resource efficiency is the Green Construction through Wood Program which aims to encourage greater use of wood in construction projects in Canada (Energy and Mines Ministers' Conference et al., 2017). For improvement of resource efficiency in the transportation sector, initiatives such as the Ontario ELV recycling law and vehicle waste disposal guide have helped Canada achieve satisfactory rates of recycling and reusing (Ismailos and Touchie, 2017). Similarly, the Province of British Columbia has industry-driven initiatives such as Vehicle Dismantling and Recycling Industry Environmental Planning Regulation (VDRIEP). The initiative requires individual operators or industry associations to develop environmental management plans that demonstrate how they will comply with environmental protection standards.

Through the Greening Government Strategy, the government intends to reduce GHG emissions and increase the resilience of assets, services and operations in order to adapt to climate change. Commitments on various issues include real property, mobility, green procurement, adaptation to climate change, and performance measurement in green buildings for a low carbon economy. Some of the government's aims include using 100% clean energy by 2025, ensuring 80% zero emission vehicles by 2030, diversion of 75% of federal operational waste, and 90% of construction waste by 2030 (Lukiwski, 2019).

S1.8. United States

Material efficiency policy in the United States is shaped by the Resource Conservation and Recovery Act (RCRA) and its amendments. The objectives of RCRA are to protect human health and the environment and to conserve valuable materials and energy resources. In an effort to rethink waste policy, the U.S. Environmental Protection Agency (EPA) published "Beyond RCRA: Waste and Materials Management in the Year 2020" (The RCRA Vision 2020) in 2002. This policy initiative recognized the need for society to shift from waste management to materials management. In 2009, EPA published "Sustainable Materials Management: The Road Ahead," that laid out the case for a life cycle approach to materials management in order to effectively and efficiently use materials, minimize negative environmental impacts and unintended consequences of actions. It provided recommendations to government for engaging in sustainable materials management.

Specific state regulations such as those proposed in California classifying of auto shredder residue (ASR) as a hazardous waste have the potential for material efficiency GHG dividends. The law creates disincentives for shredding of material from recycled vehicles since hazardous waste classification has higher disposal fees. This creates incentives for salvaging more material and increasing efficiency in recycling (Regulation of Auto Shredder Residue in California, 2014). California's Buy Clean Law requires contractors to disclose GHG emissions of the materials they will use for proposed projects on state infrastructure including concrete and steel. Environmental product declarations (EPDs) are used to ensure compliance and need to be submitted with an application for bid (Buy Clean California, 2017).

Like many US states, Massachusetts has a solid waste plan with waste reduction and recycling targets. Its 2010-2020 Solid Waste Master Plan (Massachusetts Department of Environmental Protection, 2013) includes a short-term goal of 20% annual reduction in solid waste disposal by 2020. The long-term goal is to reach "zero waste". This would require an 80% reduction in residential and business waste (Massachusetts Department of Environmental Protection, 2013). To reach these two goals, Massachusetts is implementing a variety of strategies for recycling, composting, organics diversion, regional and local recycling markets, municipal waste combustors, construction, and material diversion and market development, stimulating greater reuse, improving existing facilities, and funding local campaigns (Massachusetts Department of Environmental Protection, 2013). Another example is the State of Oregon 2050 Vision for Materials Management for Sustainable Materials Management for further strengthening the state's Solid Waste Management Plan.[2] This effort seeks to reduce environmental impacts by managing materials on a lifecycle basis.

S1.9. China

While material efficiency policies in China date back to the late 1970s (Zhu et al., 2019), the Chinese government made an explicit mention of material efficiency and a circular economy for the first time in 2005 and in subsequent five year plans (FYPs). The most recent is 'Development Strategy and Immediate Action Plan of Circular Economy' (2013) with targets for 2010–2015 in the 12th five-year plan:

- Resource productivity 15% higher than 11th FYP
- The total value of the recycling industry to reach 1.8 trillion Yuan.
- >72% of industrial wastes reused in other processes
- 70% of waste products are recovered

Targets for 2015–2020 are a mixture of aspirational and more defined targets centered on incorporating 3Rs into a range of industrial processes:

- Resource productivity to increase by 15% from 2015 level
- Over 75% of national industrial parks to implement CE policies
- Over 50% of provincial industrial parks to implement circular econony (CE) policies
- Value of recycling industry at US$450 billion.
- Promote the share of green buildings in newly built buildings of cities and towns reaching 50% by 2020
- Promote the share of public transport in motorized travel in big and medium-sized cities reaching 30% by 2020.

2 https://www.oregon.gov/deq/mm/Pages/Waste-Prevention-Strategy.aspx

S2. Examples of building codes and standards related to material efficiency

MATERIAL	MATERIAL EFFICIENCY STRATEGY	POLICY/STANDARD -DIS/ENABLER	SOURCE	DESCRIPTION
Concrete	Use 'Supplementary cementitious materials' (SCM); Reduce carbon intense cement content in concrete.	Minimum Cementitious Materials Content (ACI 329.1T-18 Tech Note)	American Concrete Institute	Aims to minimise cement utilisation through adequate use of supplementary materials to ensure long term durability. Enables the use of innovative products with lower environmental impacts
Wood	Substitute wood for steel as structural supports in buildings	Wood First Act (2009) Building Codes (2018)	Government of British Columbia, Canada	Both Wood First Act (2009) and Building Codes (2018) aim to maximise wood utilisation in residential buildings Wood First Act (2009) stipulates the use of wood as the primary building material in all new provincially funded buildings Building codes allow for the construction of six storied wood framed residential buildings. (Expected to increase to twelve stories in 2020)
Building Design and Construction	Maximise material efficiency through design	Designing for material efficiency in building projects. Code of practice for Strategic Definition and Preparation and Brief (BS 8895-1:2013)	British Standards Institute	The code provides recommendations by which both design and project team can achieve maximum material efficiency through design and how the process is implemented through various stages of Plan of Work
Building Materials	Diverting construction waste to secondary markets	Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings (ANSI/ASHRAE/USGBC/IES 189.1-2014) International Green Construction Code (IGCC 901) *mandatory provision of model code*	American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, US Green Building Council, Illuminating Engineering Society, International Green Code Council	Stipulates that a minimum of 50% of nonhazardous construction and demolition waste material generated prior to the issuance of the final certificate of occupancy will be diverted from disposal in landfills and incinerators by reuse, recycling, repurposing, and/or composting. Includes mandatory provisions related to the human health and environmental impacts of materials. It includes requirements for construction waste management; the extracting, harvesting and manufacturing of materials; refrigerants; the storage and collection of recyclables and discarded goods, and the mercury content levels of lamps
	Optimise level of reused or recycled materials	Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings (ANSI/ASHRAE/USGBC/IES 189.1-2014) International Green Construction Code (IGCC 901) *Prescriptive and Performance-based provisions of model code*	American National Standards Institute, American Society of Heating, Refrigerating and Air-Conditioning Engineers, US Green Building Council, Illuminating Engineering Society, International Green Code Council	Requires that buildings comply with the mandatory provisions and either the prescriptive provisions or the performance-based provisions. The latter provisions must be met in addition to the mandatory provisions and offer a simple compliance approach that involves minimal calculations. Prescriptive provisions of model code include provisions for "recycled and salvaged material content, regional materials, biobased products and multiple-attribute product declaration/certification" Performance-based provisions of model code include provisions for "life-cycle assessment that address performance metrics, procedures and reporting"

S3. End-of-Life Vehicles legislation in EU, Japan, China and US as of 2019

	EU	Japan	China	US
ELV law or regulation	Directive 2000/53/EC of the European Parliament and Of the Council of 18 September 2000 on end-of life vehicles (enforced in 2000) (European Commission, 2007)	Law for the Recycling of End-of-Life Vehicles (enforced in 2005) (Government of Japan, 2006)	Management measures for end-of-life vehicle recycling (enforced in 2019 replacing 2001 law) (State Council Order No. 715) Management Requirements for Harmful Substances and Recoverable Utilization Rate of Automobiles (declared in May 2015 by Ministry of Industry and Information Technology)	Clean Air Act – Sec. 608 & 609 Clean Water Act - National Pollution Discharge Elimination System (NPDES) – 33 USC Sec. 1251 et seq.
Management system background	Measures for increasing ASR (Smink, 2007) Measures for abandoned automobiles Environmental measures for dismantling sites	Lack of final disposal sites (Japan Ministry of Economy, Trade and Industry, 2002) Illegal dumping of ASR (Sakai et al., 2007) Effective use of resources (Sakai et al., 2007)	Low comprehensive utilization efficiency of resources (Yang et al. 2019) Measures for illegal assembly (Zhao and Chen, 2011) Effective use of resources (Sakai et al. 2013) Measures for recycling economy (Sakai et al. 2013)	Strict implementation of regulations (Jody et al., 2007) Environmental conservation measures associated with ELV recycling
Parties responsible for recycling costs	Automobile manufacturers and importers (if the recycling incurs cost), users	Users	No regulation (traded as a valuable secondary resource)	No regulation (traded as a valuable secondary resource)
Target automobile	M1, N1	All vehicles (including buses, trucks, etc.), with the exception of two-wheeled vehicles	M1, M2, M3, N1, N2, N3	No regulation
Recycling target	By January 1, 2006: Reuse + Recovery: 85 % Reuse + Recycle: 80 % By January 1, 2015: Reuse + Recovery: 95 % Reuse + Recycle: 85 % (European Commission, 2010)	Airbag: 85 % ASR: 70 % (from 2015 onwards) 50 % (2010 to 2014) 30 % (2005–2009) (Government of Japan, 2006)	No specific goals (Effectiveness of the recovery rate: 90%) (Azmi et al 2013)	No specific goals (95 % of ELVs enter the recycling route, of which 80 % of the materials are recycled) (Kumar and Sutherland, 2009)
Information management	Issuance of Certificate of Destruction (CoD), monitoring of target values by the government	Electronic manifest system	Issuance of ELV collection certificate (The State Council of the People's Republic of China, 2012)	Information collection management by recycling industry groups
Regulatory provisions	Based on the subsidiarity principle and the principle of extended producer responsibility (Smink, 2007) Regulation to prohibit inclusion of heavy metals (mercury, cadmium, hexavalent chromium, lead) Domestic laws are being enforced but the manner of operation varies with country.	Automobile manufacturers and importers take responsibility for the recycling No target for the recycle rate/recovery rate regarding the total automobile weight. Thermal recovery is recognized in ASR recycling.	Established with the aim to regulate the recycling activities of scrapped motor vehicles, protect the environment, promote the development of circular economy, and ensure the safety of road traffic (Article 1). The "Five Assemblies" ((engine, steering, transmission, axle, and frame) dismantled from ELVs and qualified for remanufacture may be sold to capable remanufacturing enterprises (Article 12 and 13). Stringent requirements on storage, dismantling site, dismantling equipment and facilities as well as dismantling standards, especially environmental protection requirements Relaxed market entry threshold but strengthened supervision on daily operation of ELV recycling with severe administrative penalties for non-compliance. Regulation to prohibit inclusion of heavy metals (mercury, cadmium, hexavalent chromium, lead, polybrominated biphenyls and polybrominated biphenyl ether).	There is no regulatory system that directly manages ELV on the national level [5] Under the Anti-Car Theft Act (1992), information on vehicles collected by recyclers is managed by the National Motor Vehicle Titling Information System. The Automotive Recycling Association operates an information website for related regulations to attain stricter compliance. [37] (Favier et al., 2018)

M1, 4-wheeled vehicles with seating capacity of nine or less, including passenger vehicles; M2, seating capacity of nine or more, vehicle weight under 5,000 kg; M3, vehicle with seating capacity of nine or more, vehicle weight over 5,000 kg; N1, freight vehicle with maximum load capacity under 3,500 kg; N2, maximum load capacity of 3,500 kg or more, freight vehicle weight under 12,000 kg; N3, freight vehicle with maximum load capacity of 12,000 kg or more

Source: Updated from Sakai et al. (2013)

S4. Inventory of construction and demolition waste policies

This table presents a compilation of all policies related to management of construction and demolition waste found in the literature review conducted for the policy chapter of the present report.

POLICY INSTRUMENT	POLICY/ STANDARDS/ PLANS	DESCRIPTION	MATERIAL EFFICIENCY GOAL	CHALLENGES[3]
Waste reduction/ prevention/ avoidance/ minimization targets/goals	Sweden Waste Prevention Plan (Deloitte, 2017)	Sweden Waste Prevention Plan aims to decrease waste generation per built square meter by 2020 compared to 2014 (Deloitte, 2017)	Reduce generation of waste; Promote more efficient use of construction materials; Prevent emissions from unnecessary production, transport, recycling, disposal of construction materials & waste; encourage on-site recycling/reuse to avoid transportation emissions; encourage use of prefabrication, modularity, designing out waste (Deloitte, 2017)	Lack of benchmark data; wastage rates not widely used or calculated; policies tend to focus on recovery rather than reduction (Hobbs, 2011)
	Wales construction sector plan (Deloitte, 2017)	Wales construction sector plan includes target of reducing C&D waste managed off site by 1.4% annually (Deloitte, 2017)		
Raw material reduction targets/goals	Slovenia Resolution on National Environment Protection Programme (OJ RS 2/2006) (Deloitte, 2017)	Slovenia Resolution on National Environment Protection Programme (OJ RS 2/2006) sets goal of reducing excavation of mineral raw materials for construction purposes from 8 tons/capita to 5.5 tons/capita (Deloitte, 2017)	Reduced use of virgin/primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials; drive market demand for recycled/reused construction materials; closed material loop	Rare policy choice; data requirements; complicated by global trade; may face tradeoffs w/quality & energy efficiency; need for certification or standard of recycled/reclaimed materials
	Portugal Decree-Law 73/2011 (Deloitte, 2017)	Portugal Decree-Law 73/2011 (Deloitte, 2017) - target of incorporating at least 5% recycled materials in public construction		
Waste recovery targets/goals	EU Waste Framework Directive (2008/98/EC)	EU Waste Framework Directive (2008/98/EC) - 70% preparing for reuse, recycling and other recovery of construction and demolition waste by 2020	Prevent emissions from landfilling C&D waste; recover value of C&D waste. Indirectly reduce use of virgin/primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials; closed material loop	Recovery or diversion from landfills typically include both high and low value uses of materials (from reuse to backfilling to incineration); C&D waste is only sometimes targeted separately but more often is part of general solid waste targets/goals – CA (Florida Department of Environmental Protection, 2019)
	Massachusetts Waste Recycling Goal	Massachusetts 50% C&D Waste Recycling Goal		
	California Recycling Goal	California 75% Recycling Goal (*California's New Goal: 75% Recycling*, 2012)		
Landfill tipping fee/ tax	Netherlands Environmental Taxes Act (Brewer and Mooney, 2008)	Netherlands Environmental Taxes Act made landfilling more expensive than recovery alternatives (Brewer and Mooney, 2008)	Provide financial disincentive to landfill C&D waste; incentivize sorting and recovery of C&D waste; prevent emissions from landfilling C&D waste. Indirectly reduce use of virgin/ primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials; closed material loop	Illegal dumping or transportation to neighboring jurisdictions; need for alternative processing facilities and end-use markets for recycling/reuse
	Denmark Waste Tax	Denmark Waste Tax imposes different rates for recycling (none), incineration, landfilling		
Landfill bans	Netherlands Waste Substances Decree	Netherlands Waste Substances Decree bans all recyclable waste from landfills (Brewer & Mooney, 2008)	Prevent landfilling of C&D waste; recover value of C&D waste; encourage sorting of C&D waste; prevent emissions from landfilling C&D waste. Indirectly reduce use of virgin/ primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials; closed material loop	Unintended consequence of illegal dumping without adequate enforcement or transportation to neighboring jurisdictions; need for alternative processing facilities and end-use markets for recycling/reuse
	Massachusetts Solid Waste Management Regulations (310 CMR 19.017)	Massachusetts Solid Waste Management Regulations banning asphalt pavement, brick, concrete, metal, wood, gypsum board from landfills (Brantwood Consulting, 2016)		

3 Unless otherwise noted, challenges described in this column refer to the policy instrument generically, not the examples provided in second and third columns.

POLICY INSTRUMENT	POLICY/ STANDARDS/ PLANS	DESCRIPTION	MATERIAL EFFICIENCY GOAL	CHALLENGES[3]
Mandatory recycling (depending on the definition of "recycling," this policy can effectively be considered a landfill ban)	Japan Construction Material Recycling Law	Japan achieved C&D recycling rates of 99.5% for asphalt concrete, 99.3% for concrete, 94.4% for wood 10 years after Construction Material Recycling Law was enacted (Government of Japan Ministry of Land, Infrastructure, Transport and Tourism, 2012)	Prevent landfilling of C&D waste; recover higher value of C&D waste; encourage sorting of C&D waste; prevent emissions from landfilling C&D waste. Indirectly reduce use of virgin/primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials; closed material loop	Illegal dumping or transportation to neighboring jurisdictions; need for alternative processing facilities and end-use markets for recycling/reuse
	Vermont Act 175	Vermont Act 175 banned certain projects from landfilling drywall, clean wood, asphalt shingles, metal, plywood, oriented strand board and required recycling of these materials (Vermont Department of Environmental Conservation, 2019) Increase in diversion of C&D waste from 2014 to 2016 attributed to VT Act 175 (Vermont Agency of Natural Resources, 2017)		
	City of Madison, Wisconsin Recycling Ordinance	City of Madison, Wisconsin Recycling Ordinance requires 70% recycling rate for concrete/ steel support buildings, requires recycling of clean wood, clean drywall, shingles, cardboard, metal for wood frame buildings and renovations. Increase in diversion of overall waste partially attributed to City of Madison C&D Recycling Ordinance (US Environmental Protection Agency, 2017)		
Mandatory waste management planning	Ontario Regulation 102/94	Ontario Regulation 102/94 requires submission of C&D waste reduction work plan	Encourage design thinking for C&D waste planning; encourage sorting and recovery of C&D waste; minimize landfilling of C&D waste; prevent emissions from landfilling C&D waste	Uncertain impact especially if plans simply must be prepared and submitted without follow-up, verification, or documentation (International Council for Research and Innovation in Building and Construction, 2011) Ontario example-inspections revealed 90% noncompliance 12 years after passage UK Site Waste Management Plan Regulations (2008-2012) requiring plan was repealed due to perceptions of ineffectiveness (Deloitte, 2017)
	Norway Planning and Building Act	Norway Planning and Building Act requires submission of construction waste management plan before building can start and final report including documentation of disposal quantities		
	Vermont Act 250	Vermont Act 250 requires submission of C&D waste management plan		
Mandatory waste audits	Ontario Regulation 102/94	Ontario Regulation 102/94 requires waste audit	Encourage sorting and recovery of C&D waste; minimize landfilling of C&D waste; prevent emissions from landfilling C&D waste; reduce recovery stream contamination	Uncertain impact especially if audits simply must be prepared rather than submitted and independently verified (Hobbs, 2011) Ontario example-inspections revealed 90% noncompliance 12 years after passage
Source separation requirements	Norway Planning and Building Act	Norway Planning and Building Act requires at least 60% source separation	Encourage sorting and recovery of C&D waste; minimize landfilling of C&D waste; prevent emissions from landfilling C&D waste; reduce recovery stream contamination	Space constraints, need for matching alternative processing facilities and end-use markets for recycling/ reuse
	Denmark Waste Separation Circular	Denmark Waste Separation Circular requires source separation for demolition projects (Brewer and Mooney, 2008)		
Standard/ certification for recycled/ reused materials	Netherlands Building Materials Decree	Netherlands Building Materials Decree applied same quality standards to reused/recycled materials as primary materials	Ensure confidence in and drive market demand for recycled/ reused construction materials. Indirectly reduce use of virgin/ primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials	Testing for performance, traceability

POLICY INSTRUMENT	POLICY/ STANDARDS/ PLANS	DESCRIPTION	MATERIAL EFFICIENCY GOAL	CHALLENGES[3]
Building/zoning codes	CalGreen Code	CalGreen Code requires construction waste management plan and 65% recycling/reuse diversion rate for new construction of nonresidential bldgs. (California Building Standards Commission (CBSC), 2017)	Prevent emissions from landfilling C&D waste; sort and recover value of C&D waste; reduce the use of virgin/ primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production, transportation, and disposal of virgin materials; closed material loop. Indirectly encouraging longer lifespan and improved resilience to natural disasters by ensuring minimum quality and performance of buildings	Uncertain impact on material efficiency since codes often rely on green building standards; tend to focus on energy performance, safety, health; offer alternative compliance.
	Connecticut building code	Connecticut building code requires at least LEED Silver or equivalent for major commercial buildings (Matisoff et al., 2016)		
	Boston zoning code	Boston zoning code requires large buildings to be LEED certifiable (Beauregard et al., 2014)		Limited impact of Boston zoning code due to lack of documentation/ verification
Green building standards	LEED v4 Materials & Resources credit category	LEED v4 Materials & Resources credit category - prerequisite (C&D waste plan) and credits (multiple diversion streams & reduction, building reuse, life cycle impact reduction, recycled products) (USGBC) *LEED certification policies*: US government buildings (federal agencies, 24 states, 30 counties, 170 cities) and commercial buildings (60 cities) (Alberta Government, 2006; Matisoff et al., 2016) have certain point systems for certifications San Jose green building policy for large buildings requires at least LEED Silver (City of San Jose, 2019)	Prevent emissions from landfilling C&D waste; sort and recover value of C&D waste; reduce the use of virgin/ primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production, transportation, and disposal of virgin materials; drive market demand for recycled/reused construction materials; closed material loop; encourage use of lifecycle analysis. Indirectly encouraging longer lifespan and improved resilience to natural disasters by ensuring minimum quality and performance of building	Uncertain impact on material efficiency since LEED, BREEAM, GM are Total Quality Assessment (UN Habitat) systems based on points awarded for ecological, economic, and social aspects. Certification levels for LEED, BREEAM, GM don't necessarily reflect ME – points/credits could be for other sustainability categories (Odeleye and Menzies, 2010). Heterogeneity both within and across green building standards and flexibility of certifications make outcomes difficult to evaluate (Matisoff et al., 2016). Certification itself or incentives can involve trade-offs.
	BREEAM Waste section	BREEAM Waste section promotes effective waste management through credit system		
	Singapore Green Mark (GM) Scheme Materials and Waste (Resource Stewardship)	Singapore Green Mark (GM) Scheme Materials and Waste (Resource Stewardship) – points for sustainable construction, embodied carbon, waste management plan (BCA) GM certification policies: minimum certification required under Building Control (Environmental Sustainability) Regulations (Qian et al., 2016), gross floor area (GFA) & cash incentives		
Deconstruction requirement	Portland Deconstruction Ordinance requires deconstruction for older or historic houses	Portland Deconstruction Ordinance requires deconstruction for older or historic houses	Prevent landfilling of C&D waste; sort and recover high value of C&D waste; prevent emissions from landfilling C&D waste. Indirectly reduce use of virgin/primary construction materials; increase use of recycled/reused construction materials; prevent emissions from production of virgin materials; closed material loop	Space constraints; need for matching alternative processing facilities and end-use markets for recycling/ reuse; requires more upfront labor, time, and money
Deposit-refund permits	City of Vancouver Green Demolition Bylaw	City of Vancouver. "Demolition permit with recycling and deconstruction requirements	Ensure compliance with other policies; measure impact and outcomes through data collection	Requires more administrative resources; need for matching alternative processing facilities and end-use markets for recycling/reuse
	City of San Jose Green Building Deposit	City of San Jose Green Building Deposit (City of San Jose. "Private Sector Checklist") - deposit refunded with documentation of LEED certification		
	City of San Jose C&D Deposit	City of San Jose C&D Deposit (City of San Jose. "Building Permit Holders) - deposit refunded based on documentation of recycling/ reuse/donation rate achieved (75%)		

S5. Resource taxation background and rationale

There is a conceptual difference between traditional royalty payments and corporate taxes made by companies to governments and virgin materials taxes (VMTs), which are more explicitly environmentally-oriented: that is, royalties and corporate taxes are fiscal taxes are levied and collected for redistribution towards societal services. In contrast, environmental taxes are intended to cover the mitigation of adverse environmental externalities associated with the targeted economic activity and especially to induce behavioral change to avoid paying them. Put simply, fiscal taxes will always be necessary but (ideally) environmental taxes should yield very little revenue once a sustainable, material efficient economy is attained. They are, therefore, inherently different or, as Söderholm (2011) puts it, 'based on economic efficiency criteria the designs of fiscal and environmental taxes, respectively, will typically differ a lot, and an efficient environmental tax may be a very inefficient fiscal tax.'

Others argue that the distinction between the rationale for royalties and for virgin material taxes is more complicated. In this view, royalties were created to compensate the government (now the citizens of a country) for the extraction of a non-renewable resource. This compensation, in theory, should fully compensate the government for the extraction of a non-renewable resource and environmental degradation associated with the extraction. Recycled metals are not charged royalties as the government has already been compensated for the extraction of a non-renewable resource. Furthermore, many countries impose some form of a reclamation fee, held by a third party, on mining operations to ensure that funds will be available in the future, even if the company goes bankrupt, to undertake mine-site remediation. If indeed royalties actually function to address resource and environmental impacts, opponents of VMTs may ask if VMTs are necessary.

Regardless of whether royalties are simply sources of revenues for governments or motivated and implemented in practice to compensate for resource depletion and environmental impacts, a basis for the design and magnitude of VMTs is needed. By placing an appropriate level of taxation on the use of virgin materials in economic activities, it is hoped that markets and actors will be encouraged or pushed to seek means of recycling and reuse of materials, employing substitute materials or engaging in technological innovation (Söderholm, 2011, 2006). In terms of material efficiency, then, the overall aim of virgin materials tax is to reduce or even halt, via the associated economic disincentives, the demand for and supply of virgin resources and materials. This is in order to both reduce overall environmental burden and stimulate markets for circular uses of existing materials. Accordingly, assessing the efficacy of a VMT might entail monitoring changes in primary commodity extraction and processing on one hand, and levels of material substitution, recycling and reuse on the other.

VMTs present an opportunity to tax materials at the beginning of the product lifecycle rather than attempting, as is predominantly the case in current environmental policy, at the point of waste generation or emission. The underlying logic is that costs are passed from the start through to the end of the supply chain associated with that given material. It is important to note that VMTs are not aimed at primary extraction companies but rather at the users of the virgin material once the material is in first product usage. Hence they have direct material efficiency objectives.

Some of the criticism of VMTs stems from the calculation mechanism for the taxation and whether or not it can adequately capture the full extent of impacts across the supply chain. Accordingly, Bigano et al. (2016) warn that VMT 'is still a very rough instrument' arguing that:

> The same natural resource can be extracted and processed for its "first industrial use" using different technologies, which entail different external costs. Moreover, every unit of material employed in goods' production can be either disposed or re-used, and this means again different environmental impacts… [And]… externalities. Thus, the number of externalities associated with one single unit of the same material can vary considerably, and taxing all units of the

same material with the same rate turns out to be inefficient and counterproductive, as it also fails to incentivize both the adoption of greener technologies and the re-use of materials.

A second limitation for VMTs arises from disparities between different localities in the globalized economy. That is, 'a policy that simply shifts [virgin] material resource use or environmental impacts from the EU [for example] to other parts of the world does not address global environmental justice nor realities of complex international value chains' (Ekvall et al., 2016).

In addition to concerns about the shifting of the environmental burden, if strong VMTs are introduced, there are also concerns about the applicability of such taxes for different materials. Indeed, due to the current status quo of incomplete knowledge and experimentation with different greener production processes, there is no guarantee that the substitute material or process which VMT are supposed to encourage might be more environmentally benign than the one whose use that the tax originally intended to reduce. These challenges, it should be noted, are not unique to VMTs. Many raw/virgin materials are largely price inelastic, something which, along the cost of recycling, may make a VMT ineffective until it is very high (Tiemstra, 2002). In fact, Söderholm (2006) raises the issue of the fairness of VMT on initial producers: is the extraction of raw materials inherently the issue of discussion, or is the excessive demand and inability and ineffectiveness in circulating materials? Dresner et al. (2006) suggest that communication and trust between policymakers and the public are essential in order to gain traction on promoting issues such as material efficiency, especially through taxation, that is 'invisible, abstract, large-scale and long-term.'

Credit: Victor Garcia/Unsplash

S6. Green procurement policies in the European Union

The European Union has an extensive set of directives and policies related to green government procurement which are summarized in this section.

European Union Directives and Policies Related to Green Government Procurement , 2016

Legislation/policy	Relevance
Treaty on the Functioning of the European Union	Provides the basis for EU procurement regulation and sets out fundamental principles
Directive 2014/24/EU on public procurement and repealing Directive 2004/18/EC	Public sector procurement directive
Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sectors and repealing Directive 2004/17/EC	Utilities sector procurement directive
Directive 2014/23/EU on the award of concession contracts	Concessions directive (applies to both public and utilities sectors)
Europe 2020: A strategy for smart, sustainable and inclusive growth COM (2010) 2020	EU strategy which sets specific targets to be achieved by 2020. GPP is mentioned as one of the measures to achieve sustainable growth and in the Innovation Union, Resource-efficient Europe and Energy 2020 initiatives
Public procurement for a better environment COM (2008) 400	Provides guidance on how to reduce the environmental impact caused by public sector consumption and how to use GPP to stimulate innovation in environmental technologies, products and services.
Staff Working Document accompanying COM (2008) 400 SEC (2008) 2126	Provides useful guidelines for public authorities on the definition and verification of environmental criteria, tools for stimulating GPP and examples for a number of product groups. It also offers legal and operational guidance.
Closing the loop - An EU action plan for the Circular Economy COM/2015/0614 final	Identifies GPP as a key component of the circular economy, the need to address issues such as durability and reparability in GPP criteria, and for the Commission to support GPP implementation.
Pre-commercial Procurement: Driving innovation to ensure sustainable high quality public services in Europe COM (2007) 799	Sets out a methodology for the procurement of research and development services that are exempt from the directives
Directive 2012/27/EU on energy efficiency	The Energy Efficiency Directive requires central government authorities to only purchase highly energy-efficient products, services and buildings. Annex III of the Directive sets out the approach which applies to each product/service sector.
Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles	The Clean Vehicles Directive sets mandatory GPP requirements for road-transport vehicles, relating to emissions and energy consumption
Regulation No 106/2008 on a Community energy-efficiency labelling programme for office equipment	The Energy Star Regulation sets mandatory GPP requirements for office equipment purchases
Directive 2010/31/EU on the Energy Performance of Buildings	The EPBD provides indicators and thresholds for energy efficient con-struction, including future mandatory requirements for nearly zero buildings
Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products	The Energy Labelling Directive requires certain products (e.g. air conditioners, dishwashers, lamps) to be labelled with a standard-ised energy class. These classes are currently subject to revision un-der a proposal from the Commission.
Regulation No 66/2010 on the EU Ecolabel	The EU Ecolabel and EU GPP criteria are harmonised to the extent possible
Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products (recast)	The Ecodesign Directive provides the main EC framework for the development of environmental criteria for energy- related prod-ucts
Regulation No 1221/2009 on the voluntary participation by organ-isations in a Community eco-management and audit scheme (EMAS)	The EMAS Regulation provides reference to how EMAS may be tak-en into account in public procurement
Regulation No 995/2010 laying down the obligations of operators who place timber and timber products on the market	The Timber Regulation provides a framework for ensuring legality of timber available on the EU market
Directive 2012/19/EU on waste electrical and electronic equipment (WEEE)	Directive providing for the separate collection, treatment and re-covery of waste electrical and electronic equipment, and setting relevant design requirements
Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)	Sets requirements for manufacturers, importers and distributors of electrical and electronic equipment regarding hazardous sub-stances identified in the Directive, and rules regarding the CE mark-ing.
Regulation (EC) No 1907/2006 concerning the Registration, Evalua-tion, Authorisation and Restriction of Chemicals (REACH)	Manufacturers are required to register the details of the prop-erties of their chemical substances and safety information in a central database.
Directive 2009/28/EC on the promotion of the use of energy from renewable sources	Sets mandatory national targets for share of electricity from re-newable sources, rules on guarantees of origin and sustainability criteria for biofuels and bioliquids.
Directive 2008/98/EC on waste (Waste Framework Directive)	Sets the basic concepts and definitions related to waste manage-ment and lays down waste management principles such as the "polluter pays principle" and the "waste hierarchy."

Source: *Buying Green Handbook, 3rd Edition.pdf*, n.d.

S7. Opportunities to leverage energy-saving potential of Material Efficiency in EU energy and climate policies

Hernandez et al. (2018) propose a set of actions in the European Union to make material efficiency a more significant component of EU energy and climate policies.

Degree	Type	Description	Leader	Example
Before 2020				
Minor	Informational	Incentivise the adoption of ME by providing information on the energy-saving potential of ME	MS, EU Comm	Include ME actions within the "indicative list of examples of eligible EE improvement measures", as portrayed in Annex III of the 2006/32/ec procedure.
Minor	Technical / informational	Improve trust on embodied-energy metrics	Experts	Develop more transparent methods through which to allocate resources or emissions to specific products/activities. Sankey diagrams, for example, could improve visibility of scale and structure of data.
Interm	Informational	Clarify conflicts between energy and material use	MS, EU Comm, Experts	Engage with academics or external consultants to conduct a report on this for industry and other sectors
Interm	Technical/ informational	Incentivise the development of industry standards for ME	MS, EU Comm	These are currently being jointly developed by Environmental Citizens Organisation for Standardisation and European Environmental Bureau.
Interm	Informational	Introduce ME into public agenda	MS, Experts	(Smith, 2017) suggested that creative and entrepreneurial partnerships between researchers and media professionals could raise public awareness about ME – which would increase pressure on governments/ the EU, and help re-frame "the relationship between environmental change, material consumption and everyday life".
Before 2030				
Minor	Informational	Provide standard definition for embodied energy in the EED's guidance documents	MS, EU Comm, Experts	
Minor	Informational	Include appropriate indicators to incentivise the energy-saving potential of ME	MS, EU Comm	Include producer-oriented metrics in the publication of the next RE and CE monitoring frameworks, using guidance from previously-developed LCA-type indicators.
Interm	Informational	Incentivise multi-stakeholder-level and industry-led initiatives	MS, EU Comm	For example, the German government has encouraged the development of "sector-specific aids, methodologies and information such as RE checks and process systematisation tools to assist manufacturing [firms]" with RE projects – currently led by Center for Resource Efficiency
Interm.	Technical	Develop more examples of specific options to reduce energy use by reducing material use	Experts	Fund research projects that investigate energy-saving potential for ME in industry, e.g. through the Horizon 2020 programme or through projects like SPIRE (2017).
Interm	Informational/ technical	Collaborate with industry/multi-stakeholders to develop digital platforms that encourage ME	MS, Experts	Get involved in large-scale projects to investigate ME; e.g. SPIRE is working on a project titled: "Process Decision Making: integration of life-cycle assessment and costing tools for process decision making" as part of the Digital Single Market initiative (?).
Interm.	Informational	Incentivise the training on the resource efficiency management of production	MS, Experts	Germany is a good example: VDI ZRE has developed information material (e.g. resource checks, process chains, a best-practice data base and a cost calculator), as well as tailored qualification seminars on resource efficiency.

MS: Member state; EC, EU Comm: European Commission

S8. Cross-sectoral and cross-national reports related to material efficiency

Title	Author or Institution	Year	Reference
Material efficiency in clean energy transitions	International Energy Agency	2019	International Energy Agency, 2019
2018 global status report: Towards a zero-emission, efficient and resilient buildings and construction sector	International Energy Agency & United Nations Environment Programme	2018	Abergel et al., 2018
The weight of cities –Resource requirements of future urbanisation	International Resource Panel	2018	Swilling et al., 2018
The circular economy–A powerful force for climate mitigation: transformative innovation for prosperous and low-carbon industry	Material Economics	2018	Enkvist and Klevnas, 2018
Mission possible	Energy Transitions Commission	2018	Energy Transitions Commission, 2018
Environmental potential of the collaborative economy: Final Report	European Commission, DG Environment	2018	Rademaekers et al., 2018
Shaping the economy of sustainable development: An overview of national policies favoring resource production and consumption	UN Environment Programme	2018	Akenji, Lewis et al., 2017
Circular economy in the built environment: Opportunities for local government leadership	StopWaste and ARUP (Ellen MacArthur Foundation)	2018	StopWaste and Arup, 2018
Resource efficient use of mixed wastes: improving management of construction and demolition waste	European Commission, DG Environment	2017	Deloitte, 2017
Environmental impacts and potential of the sharing economy	Nordic Council of Ministers	2017	Skjelvik et al., 2017
Policy guidance on resource efficiency	Organisation for Economic Cooperation and Development	2016	OECD, 2016
Study on the energy saving potential of increasing resource efficiency	European Commission	2016	Mehlhart et al, 2016
More from less –material resource efficiency in Europe	European Environmental Agency	2016	European Environment Agency, 2016
Local governments and the sharing economy	One Earth	2015	Cooper et al., 2015
Total carbon study	Ecological Building Network	2015	Ecological Building Network, 2015
Resource efficiency in the building sector	ECORYS	2014	ECORYS, 2014
Factor X: Policy, strategies and instruments for a sustainable resource use	Angrick, M., Burger, A., & Lehmann, H.	2013	Angrick, 2014
Roadmap to a resource efficient Europe	European Commission	2011	European Commission, 2011
EU resource efficiency perspectives in a global context	European Commission	2011	Van der Berg et al, 2011
Measuring material and resource productivity	Organisation for Economic Cooperation and Development	2008	OECD, 2008

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