Chapter 29
Advanced Green Logistics Strategies and Technologies

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Abstract Green Logistics is no longer just a temporary fashion, but a topic that has been discussed by experts for many years. What is new is, on the one hand, the increased social and political awareness and, on the other hand, the transfer of green core statements to entrepreneurial problems. Not least the economic crisis that began at the end of 2008 reinforced the change in attitude towards a more sustainable economy. As a result of the crisis, the cost situation but also the competitive environment has intensified for companies, which are now also concentrating on areas such as waste disposal logistics, which had previously not been taken into account. Concrete climate protection strategies, for example, to prevent CO_2 emissions, are therefore being actively pursued by industrial companies, particularly by companies with high transport volumes. For the transport industry as such, which is strongly affected by rising fuel prices, more efficient transports mean not only a reduction of CO_2 emissions, but also cost savings in economic terms. Accordingly, the *basic* methods and principles of Green Logistics and their relationship to Logistics Social Responsibility and Sustainable Supply Chain Management are outlined in this chapter. The *advanced* part of the chapter describes detailed instruments for Green Logistics strategies and coordination as well as provides a technical overview regarding latest green transportation developments, including a case study regarding green waste disposal logistics. The final *state of the art* part of this chapter discusses Green Logistics strategies as integral part of sustainable business models, including a further case study and further reading advice.

29.1 Green Logistics Methods and Principles (*Basic*)

So far, CO_2 emissions play a most important role in the current discussion on "green" logistics concepts. In this line, the measurement of carbon footprints (CO_2 footprints) is a particularly promising method for calculating CO_2 emissions. There are gener-

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ally two ways to record and measure climate emissions using the carbon footprint: the CO_2 performance of an entire company or that of a single product. The CO_2 performance of individual products is also closely related to the *Product Lifecycle Analysis* (LCA). It describes the entirety of CO_2 emissions released in all phases of a product's production and use (e.g. for the manufacturing, usage and disposal phases). Hence, the LCA is a method of systematic registration, analysis and assessment of the environmental effects of product and service systems (Dobers et al. 2013). The CO_2 emissions of a can of Coca Cola, for example, are calculated on the basis of the cumulated energy consumption over the entire lifecycle of the product, i.e. from the production of the aluminum, the can and the lemonade, to filling, packaging and transport, to cooling in the warehouse, in the supermarket and at the consumers, as well as the final recycling or disposal of the product.

In order to determine how much CO_2 is produced in the areas of procurement, production and logistics the process must be transparent and the measurement verifiable. Only when the "where" and the "how much" of the CO_2 emissions are known, the next step—integrating reduction measures into the (logistics) business strategy—can be taken. For this purpose, software systems have been developed which calculate CO_2 emissions on the basis of specified emission guidelines. Decision support systems thus facilitates strategic and operational decision-making. The overriding goal in the calculation of CO_2 emissions is therefore to create control parameters for the entire company. They serve to improve overall business performance by identifying potential and providing guidance on prioritizing. In this context, it is also possible to communicate a "green" overall performance of the company to the customer in the area of marketing.

29.1.1 Calculation of Logistics Activities' Environmental Impacts

There are many environmental impacts that can be used as environmental indicators to measure environmental efficiency. The environmental impact in the form of CO_2 emissions, probably the environmental indicator which is most often focused on, is ultimately only one of many environmental emissions that can be measured in air, water and soil. For purely pragmatic reasons, however, the presentation of a large number of environmental indicators does not make much sense, since this would lead to a loss of overall transparency. In practice, the following options have been established to reduce the number of environmental indicators and still achieve a meaningful result (Spielmann and de Haan 2008):

- Aggregation of all environmental impacts into one environmental performance indicator;
- The aggregation of certain emissions into an impact category;
- Aggregation of sum parameters (e.g. cumulative energy demand).

In principle, CO_2 emissions can be included in the impact category of greenhouse gas emissions. Greenhouse gases are currently considered to be the most important cause of global warming. In this context, the potentials of other greenhouse gas emissions such as methane or nitrous oxide are converted into CO_2 and shown as CO_2 equivalents. The cumulated energy demand, in comparison, is used to depict resource consumption. It is calculated by determining the energy consumption for all steps of a process and adding them together in a common unit. In road transport, for example, the cumulated energy demand refers not only to fuel consumption, but also, among other things, to energy consumption in the production of fuel or vehicle manufacture and disposal. However, since the cumulated energy demand is dominated by fossil fuels in road transport, it correlates strongly with greenhouse gas emissions (Spielmann and de Haan 2008).

In the academic literature, different approaches and methods for measuring CO_2 emissions in freight transport are described. Depending on how the activities of freight transport are defined, how precise the data base used to describe freight transport is, and the consumption data available for each mode of transport, the results may differ by up to 30% for the analysis of one and the same activity (McKinnon and Piecyk 2009). Based on a study in the context of the British road freight transport by McKinnon and Piecyk (2009), four approaches are shown in Fig. 29.1 as examples of how CO_2 emissions for *Heavy Goods Vehicle* (HGV) transports of a certain weight were determined. It can be seen that a set of key indicators (average distance traveled, fuel consumption, average load weight, etc.) are required for the individual approaches in order to be able to make statements with regard to the quantitative output of CO_2 in a certain period and thus ultimately also to depict the carbon footprint for a transport relation. Figure 29.1 offers a visual presentation of the different methods.

In accordance to the approaches presented by McKinnon and Piecyk (2009), the environmental effects linked with logistics activities cannot be measured directly. Instead, they are estimated through average values using a variety of data sources and software tools (Dobers et al. 2013). Hence, the calculation of CO_2 equivalents in road freight transportation can lead to varying results. Nonetheless, they provide a clear direction for selecting a green transport mode.

29.1.2 Transport Mode Selection

As described in the last section, it is possible to identify hundreds of emissions into air, water and soil for each transport mode. In addition to emissions such as CO_2, nitrogen oxides, hydrocarbons and particulate emissions, resource consumption indicators can also be used as ecological criteria for the choice of mode of transport. In the following, CO_2 emissions are described as an exemplary ecological criterion for the choice of mode of transport. Figure 29.2 provides a first indication of the CO_2 emissions of individual modes of transport, which shows the energy consumption in the transport sector over the last 40 years. It shows that around two-thirds of the energy and the

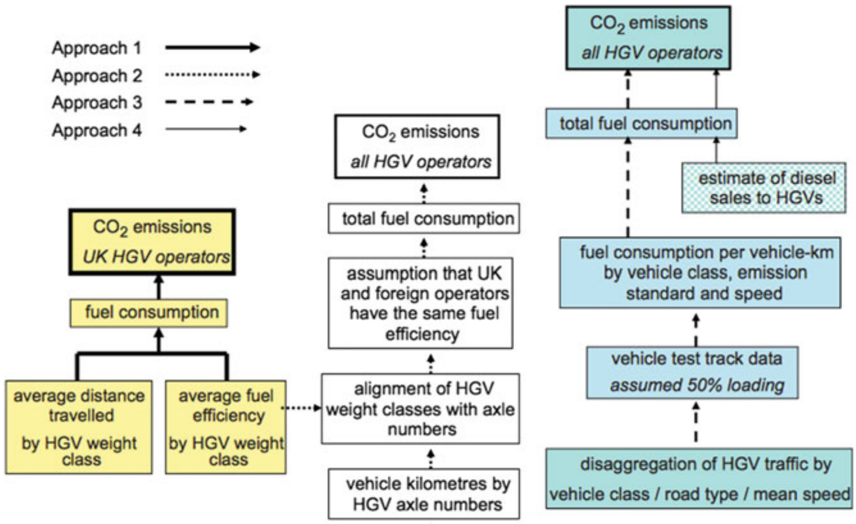

Fig. 29.1 Differing approaches to the estimation of CO_2 emissions from trucks (McKinnon and Piecyk 2009)

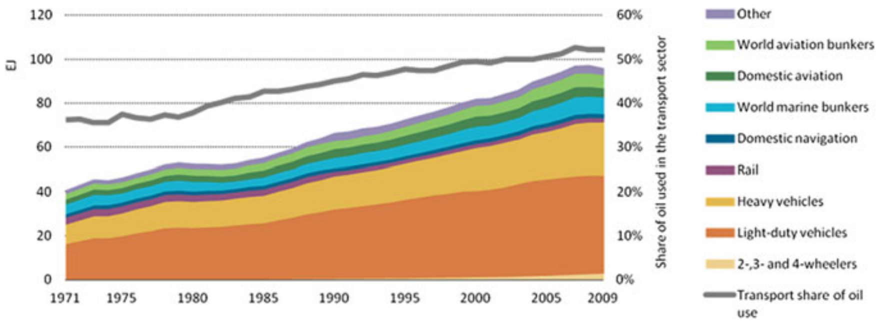

Fig. 29.2 Energy consumption in the transport sector over the last 40 years (http://thecityfix.com/blog/global-calculator-tool-investing-sustainable-transport-critical-combating-climate-change-greenhouse-gas-emissions-ipcc-erin-cooper/)

related CO_2 emissions is used by road traffic. On the other hand, only a slight growth could be seen in water and rail transport.

The large discrepancy between road and air transport on the one hand and water and rail transport on the other can be attributed to the higher specific energy consumption per ton-kilometer (tkm) of trucks and aircraft compared to ships and trains. For example, 0.22 MJ/tkm are estimated for rail transport, whereas 1.59 MJ/km are consumed by semi-trailer trucks, meaning that in order to provide the correspondingly higher energy demand from fossil fuels for road transport, a quantitatively higher CO_2 emission can and must be calculated (Spielmann and de Haan 2008).

However, it is still an oversimplification to record the pure energy demand for the operation of the transport modes alone. In particular, it is imperative to take the energetic upstream chains of transport services, such as the production of fuel or the manufacture and disposal of vehicles into account when calculating energy consumption and thus quantitative CO_2 emissions.

In a nutshell, when planning transport and logistics networks to optimize transports, the described ecological criteria of the choice of mode of transport should be considered. Examining transport management from a purely cost perspective may initially identify road transport as the cheapest alternative, but only by including aspects such as environmental emissions and resource consumption, which are transparently presented using decision support systems, additional economic and ecological potentials can be leveraged. A renewed examination of transport and logistics networks from the point of view of Green Logistics will show that the focus must be on shifting the flow of goods away from trucks to carriers such as rail or inland waterway vessels, as these have a significantly lower energy consumption per tkm (Prestifilippo 2009).

29.2 Relationship to Logistics Social Responsibility and Sustainable Supply Chain Management Literature

The general problem of coordinating interdependent supply chain members in order to maximize the supply chain profitability has been subject of supply chain research for a number of decades (Simatupang and Sridharan 2002). In the last decade, social and environmental issues found their way into supply chain research, emphasizing the importance of cooperation between companies in order to maximize profitability while minimizing environmental impacts and maximizing social well-being at the same time (Seuring and Müller 2008). Compared with the traditional *Supply Chain Management* (SCM), which is usually intended to focus on economic performance, *Sustainable SCM* is characterized by explicit integration of environmental or social objectives which extend the economic dimension to the *Triple Bottom Line* (TBL) as suggested by Elkington (1998).

In comparison, the general literature on logistics management encompasses all logistics processes of transportation, warehousing and inventory management (Ciliberti et al. 2008). With regards to the literature on *Logistics Social Responsibility* (LSR), authors already have clustered main categories of sustainable logistics practices, particularly sustainable purchasing, sustainable transportation, sustainable warehousing, sustainable packaging and sustainable reverse logistics (Carter and Jennings 2002; Ciliberti et al. 2008) (see Table 29.1). In the Green Logistics literature, a subset of LSR (Murphy and Poist 2002), logistics service providers (LSPs) should mainly focus on the optimization of their sub-processes from an environmental perspective, e.g. by reducing CO_2 emissions in the transport sector. In recent years, social issues were addressed more intensively in a supply chain context emphasizing the importance of a supply chain wide implementation of *Corporate Social Responsibility* (CSR) strategies (Yawar and Seuring 2017). Accordingly, the Green Logistics practices, besides other logistical sustainable practices, can be seen as an important part of (S)SCM, CSR and the Logistics Management literature.

29.3 Designing Green Logistics Strategies (*Advanced*)

The collection of environmentally relevant information on events within individual processes ("visibility") is fundamental for the development and implementation of a comprehensive green logistics and transportation system. In this area, IT can be of particular assistance in combining procurement, production, distribution and waste disposal logistics with the methods of Green Logistics. For this reason, GDSS will be discussed in more detail below. The second step will focus on optimizing and coordinating transportation processes as well as provides a technical overview regarding latest green transportation developments. In the subsequent section, an IT project will be described, which was implemented in practice and which connects the logistic processes of procurement and waste disposal in particular.

29.3.1 Green Decision Support Systems (GDSS)

The use of GDSS for the sustainable optimization of logistics structures enables decision makers in the industry to carry out evaluations for different logistics strategies. There are currently a multitude of methods and approaches that focus on different sub-areas such as route planning, location planning, network design or warehouse planning. The primary goal of GDSS is to draw up a balance sheet of the energy consumed in the individual processes and the resulting environmental impacts (e.g. CO_2 emissions) in order to assess the impact on the individual ecological effect variables. In this context, however, most approaches are not able to quantify exactly the energy consumption and environmental impact in a particular application, but only to make indirect statements about ecological optimization potentials. In this context, most GDSS work according to the principle that processes are made up of individual components to which certain input and output variables are then assigned. For the calculation of the conversion of energy and material for the modelled processes, related tools usually subsequently use publicly available databases (e.g. the Federal Environment Agency's "ProBas"). In the following step, evaluations can now be carried out by varying the individual material, energy and cost flows according to various factors and evaluating their result variants. As already described, there are different approaches and methods for calculating environmental influences (e.g. in the form of carbon footprints), so that the results of different GDSS tools can lead to different results when considering the same process. It should also be noted that these IT tools described above only carry out static calculations of ecological balance.

Table 29.1 Sustainable logistics practices

Category	Description
Sustainable purchasing	Sustainable purchasing can be defined as "purchasing activities considering social issues advocated by organizational stakeholders" (Maignan et al. 2002). If a company adopts social and/or environmental standards, the purchasing function can be used to transfer them to (sub)suppliers (Green et al. 1996). With regard to social standards, purchasing activities should be related to diversity, human rights and safety topics (Carter and Jennings 2004). The main logistical topics are carrier selection as well as diversity in hiring logistics personnel and motor carriers (Carter and Rogers 2008)
Sustainable transportation	Sustainable transportation is defined "as transportation that meets mobility needs while preserving and enhancing human and ecosystem health, economic progress, and social justice now and for the future" (Ciliberti et al. 2008). Sustainable transportation research is mainly concerned with the economic and environmental dimensions of sustainability focusing on fuel efficiency and emissions reduction from transportation equipment (Feitelson 2002). With regards to the social dimension, safety issues at motor carriers were investigated most (e.g. Crum et al. 1995). Carter and Easton (2011) as well as Hassini et al. (2012) explain this research focus with external stakeholders' pressures such as governmental regulation. See also Chap. 21 of this volume
Sustainable warehousing	Sustainable warehousing mainly covers the activities of proper storing (proper labeling and documentation) of hazardous materials, donation of excess or obsolete inventory to local communities and trainings to operate forklifts in a safe manner (Carter and Jennings 2002; Ciliberti et al. 2008). In comparison to sustainable transportation, sustainable warehousing is a rather small field while the link between inventory holding and transportation efforts is rather neglected from a sustainability point of view (Mejías et al. 2016). Accordingly, Hassini et al. (2012) see inventory management as one of the least investigated categories in sustainable logistics practices
Sustainable packaging	Sustainable packaging can be defined as "packaging that adds real value to society by effectively containing and protecting products as they move throughout the supply chain and by supporting informed and responsible consumption" (James et al. 2005). Although the focus on environmental impacts of packaging has recently moved towards a more holistic view on life cycle impacts (Sarkis 2003), the literature is still dominated by investigating the incurring impacts of using returnable and non-returnable packaging from a single firm perspective (Ciliberti et al. 2008). See also Chap. 13 of this volume
Sustainable reverse logistics	Sustainable reverse logistics deals mainly with the implementation of processes that guarantee the use and re-use of products (Nikolaou et al. 2013, and Chap. 16 of this volume). In line with sustainable purchasing, the use of recycled raw materials is seen as logistical practice with high sustainability potential (Hassini et al. 2012), especially improving the overall environmental and financial performance of a company. Recently, authors are also incorporating social aspects in reverse logistics systems such as equity, diversity, health and safety practices, education and stakeholder engagement (Nikolaou et al. 2013)

These incorporate normal case processes and mainly include average values. In order to take the dynamic effects occurring in practice into account, GDSS tools should be supplemented by simulation tools. Simulation tools such as Siemens' "Plant Simulation" make it possible, for example, to take stochastic effects into account when calculating energy consumption in the waste disposal chain (Hellingrath 2009).

In the field of transport logistics, many companies are already using programs to bundle goods flows, optimize delivery routes and avoid detours. For example, there are route planning systems for this area that enable optimal planning of the duration and route, number of stops to be made as well as the transport loads. Here, planning systems use a variety of static and dynamic models as well as mathematical approximation methods and heuristics to solve the task. The main goal of most models is to minimize the distance travelled. This can be achieved either directly through intelligent routing (*route planning*) or indirectly through denser transport capacity utilization (*loading space optimization*) (Ziegler 1988). This means that energy consumption and environmental pollution can be reduced either by searching for the shortest route or by better vehicle utilization. Detailed information on synchromodal planning that explicitly focuses on bundling and detour avoidance, while multiple transport modes for different route segments are taken into account, can be found in Chap. 21 of this book.

The route planning optimization problem refers often to the "Travelling Salesman Problem" and is frequently found in the academic transport logistics literature. In the simplest case, there is one warehouse (source/sink) and several customers (source/sink). The task is to design the shortest tour which covers all delivery points, starting and ending in the warehouse (Kruskal 1956). However, the usual route planning programs also have other target functions, such as minimizing time and transport costs. In the first case, particular attention must be given to information on current traffic jams, technical road maintenance and the average speed of the vehicle on different sections of the road. In the case of cost optimization, tolls, fuel costs and personnel costs are calculated. From the point of view of Green Logistics, a further objective should be considered, namely the inclusion of energy consumption and environmental pollution from transports, the minimization of which is directly linked to the minimization of the route length and thus also the travel costs.

Automated planning and optimization of vehicle capacity utilization by means of GDSS can be a further mean to achieve increases in the efficiency of transports. Not only can the weight and volume of the transported goods be taken into consideration, but also their geometric dimensions. Consequently, the volume capacity of a vehicle can be better utilized. In this context, the technical configuration of the packaging and container system is important. The related optimization problem in Operations Research is known as the "Container Loading Problem". Usually heuristic methods are used to solve the container loading problem. Softtruck's GDSS "CargoWiz", for example, models the process of truck loading in three dimensions (3D cargo layout). This IT tool has numerous functions, such as manual positioning of one or more load carriers or observing specific sequences of consignments during loading. The aim is to load a larger quantity of goods into a truck (www.softtruck.com) which, however, may be constrained by a maximum weight.

29.3.2 Green Transportation Strategies

Closely related to the transport mode selection is the transport of a transport unit over multiple transport modes. While realizing inter- and multimodal transports, main issues are seen in the handling of load units at transhipment points as well as more coordination efforts than a single mode transport (Dekker et al. 2012). Nonetheless, the building of (inland) container terminal facilitating ship-rail-road combinations, for instance, promotes an enormous reduction of truck kilometres driven and, therefore, reduces the environmental impact. When it comes to multimodal routing, support systems need to take combined transport schedules of road, rail, and ship into account. At the beginning, routing programs supporting inter- and multimodal processes were rare as sufficient data exchange was often missing (Klukuas and Wiedenbruch 2013). In order to avoid an additional data transfer, they argue that further transport route optimization should be facilitated either with a transport schedule check to shift towards alternative transport modes or with the creation of new transport schedules to consolidate cross-company material flows. However, in recent years, considerable progress has been made by means of approaches easing inter- and multimodal transport planning (cf. Mes and Iacob 2015; Heeswijk et al. (2016); Pérez Rivera and Mes 2016). In this line, the cross-company use of logistical infrastructure such as vehicles might support a conversion to alternative technologies (like e-mobility), which currently are too expensive to operate for a single company. Accordingly, an eco-efficient route planning cannot be seen independent from an eco-efficient fleet management focusing on alternative drive technologies and regenerative fuels.

Once a choice about the transport mode(s) has been made, a decision about the equipment needs to be taken influencing transport capacity and speed as well as economic and environmental performance (Dekker et al. 2012). For instance, new equipment might be more energy efficient. However, new investments into eco-efficient technologies tie capital. Therefore, the investments decision depends on the financial return generated by efficiency gains. In this line, fuel choice and the related carbon intensity can also influence the economic and environmental performance. For instance, the use of biofuels based on corn or organic waste have a positive impact on the carbon intensity. More recently, electric vehicles dominate the discussion on alternative drive technologies as they can significantly reduce emissions when electricity is produced eco-friendly. However, electrically driven vehicles still have a limited range and, therefore, are currently seen most promising for city logistics and transport combined with distribution centres close by.

29.3.3 Case Study Green Waste Disposal Logistics

Background

The field of waste disposal logistics includes, most importantly, the core logistic functions of movement (transportation), collection, storage and transshipment as well as information processing related to these functions. From a logistical point of view, however, most waste has properties that do not permit the direct transfer of standard supply concepts. First and foremost, the low value of the materials is decisive, which imposes economic limits on the transport distances and intake radii. Therefore, only the application of cost-saving and sustainable disposal logistics concepts appears to be effective. In the context of the "greening" of disposal processes, the physical logistical processes of waste collection, waste transport, waste transshipment, waste storage and recycling as well as the associated supply processes have to be considered under the aspects of Green Logistics. There are also process-related reciprocal effects in the supply chain between waste disposal and, in particular, procurement which have a decisive influence on material use and downstream disposal processes.

Case Company

REHAU AG+Co, headquartered in REHAU, Upper Franconia, is a family business operating worldwide in the chemical industry. In the area of waste disposal logistics, REHAU works with electronic order catalogs to achieve savings through improved services when purchasing waste disposal services.

Electronic Catalogs at REHAU

Electronic order catalogs are generally used to simplify and harmonize the individual order processing procedures. They are accessible via the intranet for authorized employees to request waste disposal services from an external waste disposal service provider. Required prices and "articles" are negotiated beforehand with the respective supplier by the purchasing department. The classic process, in which the unit that requires the service creates a request and the purchasing department generates the purchase order, is no longer necessary. The unit that needs to order simply selects the desired "articles", transfers them to a shopping cart and sends the order.

Developing Electronic Order Catalogs in the Context of Green Logistics

The use of electronic catalogs brings with it a number of advantages in the context of Green Logistics, which go beyond the purely organizational savings effects. Firstly, collecting individual waste quantities and types in an Enterprise Resource Planning (ERP) system can be regarded as significant progress, since it is now possible to carry out an informative potential analysis of the internal waste flows including waste handling and storage with the help of the Green Logistics procedures. Secondly, it is also possible to connect the electronic catalogs to the ERP system of the waste management service provider, for example via an Electronic Data Interchange (EDI) or Web-EDI interface. The individual waste disposal orders would no longer be submitted by fax/email, but directly transmitted by data exchange. This enables the waste management service provider to optimize route plans and consolidate volume flows with the aid of the available actual and plan data. In this context, however, it would first be necessary to compare the costs of introducing the EDP solution with the "green" savings potential.

Lessons Learned
REHAU's work on this topic has shown that the combination of various organizational and technical methods can achieve effective results in reducing CO_2 emissions and thereby reducing energy and resource consumption in the area of waste disposal logistics, which can also lead to positive monetary effects. Ultimately, the question must be asked when and to what extent companies and policymakers will implement the measures described above on a nationwide basis and what contribution research can make in this respect. For example, the measurement of CO_2 emissions in the form of the carbon footprint of individual products and companies is a suitable source of information for assessing the different processes within the supply chain. In the future, it is foreseeable that legal framework conditions in particular will change and become more stringent with regard to compliance with "green" guidelines, so that it will no longer be a question for companies as to whether introducing sustainable processes is necessary or not. The German Closed Substance Cycle and Waste Management Act (KrW-/AbfG) has already had an impact on the area of waste disposal logistics. Companies should now start examining their disposal logistics processes in order to avoid losing valuable competitive advantages.

29.4 Green Transport Technology Developments

In line with designing strategies and concepts regarding the implementation of Green Logistics with industry, retail and logistics service providers, also technological advances are imminently relevant for transport processes. For *road transportation* the engineering innovation field provides the most new options as depicted in the following Table 29.2. For *rail transportation,* current research is addressing the question of how to provide renewable electricity production to electrical rail lines as well as the question of how to convert diesel traction routes to hybrid-electric systems—in combination with increased intermodal freight services by improving hubs and nodes for e.g. combined road-rail transportation (Pinto et al. 2017). For *water transportation*, ship technology development is approaching the area of hybrid-electrical propulsion systems in order to replace diesel engines in the long run for inland waterway as well as seafaring cargo ships. Additionally, slow steaming strategies are providing signifi-

Table 29.2 Green road transport technology advances

Technology	Description	Citation and sources
LNG (Liquified Natural Gas)	LNG is used for standard trucking operations, with expected GHG reduction potentials of up to 15%, more for other emission classes and particulate matter; main hindrance: reliable supply structure for LNG fuels	Thunnissen et al. (2016) Sustainable fuels for the transport and maritime sector: a blueprint of the LNG distribution network. In: Zijm H, Klumpp M, Clausen U, ten Hompel M (eds) Logistics and supply chain innovation. Cham, Springer International, pp 85–104
Electricity (renewable sources)	Electricity-powered trucks are on the rise and available for nearly all load-classes—though cargo-load and battery weight restrictions will make cargo transportation efficient mainly for light trucks in the near future; ecological objectives are only achievable if applied electricity is actually drawn from renewable sources (wind, solar, bio)	Klumpp et al. (2013) Total cost and sustainability analysis for electric mobility in transport and logistics. In: Blecker T, Kersten W, Ringle CM (eds) Sustainability and collaboration in supply chain management—a comprehensive insight into current management approaches. Eul, Köln, pp 17–28
Power-to-gas	Renewable electricity from solar, wind or bioenergy sources may be converted to methane and used like existing LNG; main problem in this case is the steady supply flow into the existing gas fuel infrastructure for vehicle supply	Vo et al. (2017) Use of surplus wind electricity in Ireland to produce compressed renewable gaseous transport fuel through biological power to gas systems. Renew Energy 105:495–504
Hydrogen	Hydrogen combustion engines are technologically feasible and very clean emission-wise; a problem is the network infrastructure change and investments for hydrogen fuel delivery and supply as well as the required renewable production (solar, wind, bio) of the fuel volumes	Najjar (2013) Hydrogen safety: the road toward green technology. Int J Hydrog Energy 38(25):10716–10728

cant environmental benefits in sea shipping (Gudehus and Kotzab 2012). For *airborne transportation*, the two most important technical improvements address greening the combustion fuel (“biofuels”; Moran 2017) used or applying hybrid-electrical engines with solar and/or battery support as for example in development by Rolls-Royce, Siemens and Airbus with the E-Fan project aircraft (Hollinger 2017). These technology developments are complemented by and are interacting with two important further trends in transportation: First, *co-modality and intermodal cooperation* is a major action field within applying green transport technologies. Second, automatization and *autonomous driving* are advancing technologies closely connected to greening transportation especially in the road transportation segment (Olson 2016) but also in airborne transportation (Heerkens 2017).

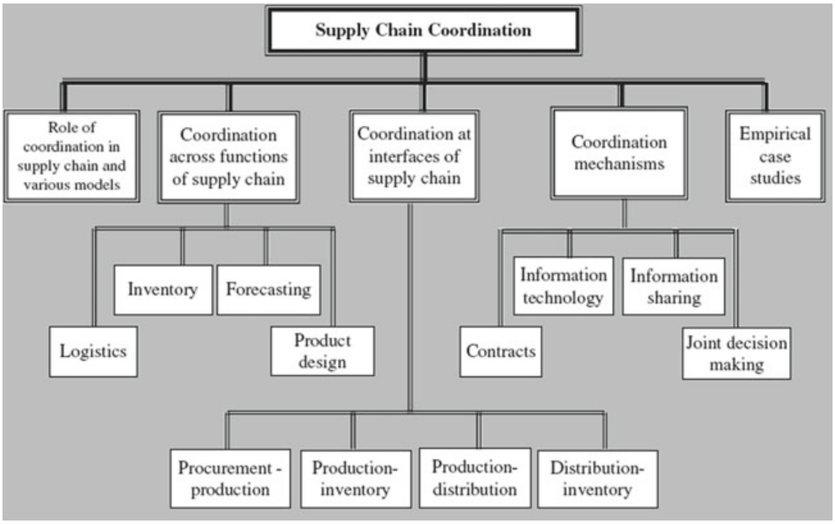

Fig. 29.3 SCC classification model (Kanda and Deshmukh 2008)

29.5 Supply Chain Coordination

To realize Green Logistics strategies, it is necessary to embed Green Logistics practices in the stream of *Supply Chain Coordination* (SCC) as coordination and planning between several entities of a supply chain. Skojett-Larsen (2000) defines SCC as coordinated collaboration between several companies in a network to share opportunities and risks, using an integrated planning based on a common information system. Similarly, Simatupang and Sridharan (2002) see SCC as a collaboration of independent companies to operate more efficiently than if operations are planned and carried out separately. Consequences of insufficient SCC are accordingly imprecise demand forecasts, low capacity utilization, shortages or surplus materials and a deficient service level (Ramdas and Spekman 2000). Moreover, the literature highlights how effective relationships can help manage potential supply chain risks (e.g. Scholten and Schilder 2015). In this context, Kanda and Deshmukh (2008) provide an SCC classification model where the relevant coordination functions, interfaces and mechanisms can be identified for the research problem. In matters of SCC mechanisms, they distinguish between contractual coordination, coordination through information technology, coordination by information sharing and joint decision making (see Fig. 29.3). Considering Green Logistics practices, the coordination mechanisms of pricing and emission trading contracts as well as information sharing and joint decision making are most promising (Dekker et al. 2012).

When it comes to pricing mechanisms and emission trading, prices are adapted in accordance to available capacities and demand. In this line, consumers have a financial incentive to switch to a more sustainable alternative if the true costs of logistics, e.g. in the form of CO_2 certificates, are taken into account. The carbon emission trading scheme introduced by the European Union (EU-ETS) intends to coordinate the market as companies can buy emission rights on the market and reflect these costs in their sales prices. When it comes to information sharing and joint decision making, again GDSS play a major role. In the short- and mid-term, a good planning of transport and warehouse capacities as well as inventories reduces environmental impacts (Dekker et al. 2012). In a mid- to long-term horizon, collaboration generally tackles the strategic integration of technical and logistical processes (Vachon and Klassen 2008) and, therefore, might influence the environmental performance of a supply chain positively.

29.6 Sustainable Business Models (*State of the Art*)

So far, business models have been extensively discussed and defined in the literature (Zott et al. 2011). Linked to the strategy and innovation literature, the business model approach describes the ways in which a business creates and delivers value to their customers through designing value creation, delivery and capture mechanisms (Osterwalder and Pigneur 2002, 2009). The elements of business model design generally include features embedded in the product/service; determination of the benefit to the customer from consuming/using the product/service; identification of targeted market segments; confirmation of the revenue streams and design of the mechanisms to capture value (Teece 2010). Focusing on conventional business models, four main business areas were identified while creating business models: in particular the value proposition, for which customers are willing to pay; the relationships with the customers; the infrastructure and network of the partners; as well as financial aspects (cost and revenue structures) (Ballon 2007).

The business model perspective can be linked to the context of sustainability and has received a growing interest among scholars in recent years (Stubbs and Cocklin 2008), since it highlights the value creation logic and allows for new governance forms such as cooperatives, public private partnerships or social businesses (Schaltegger et al. 2016). Accordingly, Schaltegger et al. (2016) define the role of a business model for sustainability as: "*it helps describing, analyzing, managing, and communicating (i) a company's sustainable value proposition to its customers and all other stakeholders, (ii) how it creates and delivers this value, and (iii) how it captures economic value while maintaining or regenerating natural, social and economic capital beyond its organizational boundaries*". Hence, the existing business model definitions have been aligned with the TBL approach to not only foster economic, but also social, and environmental value creation (Seuring and Müller 2008). Extending the conventional business frameworks in accordance to the TBL, Boons and Lüdeke-Freund (2013) define the key parameters in sustainable business models as:

- value proposition of products and services should focus on ecological, social and economic value;
- overall infrastructure and logistics of the business guided by the principles of sustainable supply chain management;
- interface with customers enabling close relationships between customers and other stakeholders to improve co-responsibility in production and consumption;
- equal distribution of economic costs and benefits among all actors involved.

Broadening the systems' scope further, Neumeyer and Santos (2017) see business models as part of the whole entrepreneurial ecosystem, particularly dependent on the stakeholder's social network. In the last years, authors started to consolidate the literature on sustainable business models by introducing sustainable business model archetypes. Here, Bocken et al. (2014) distinguish nine different sustainable business model archetypes, particularly fostering maximization of material and energy efficiency, creation of value from waste, substitution with renewable and natural processes, delivery of functionality rather than ownership, adoption of a stewardship role, encouraging sufficiency, repurposing for society and environment, as well as the development of solutions that are easily scalable. However, Lüdeke-Freund et al. (2016) see research in the field of sustainable business models still rather limited, in particular with regard to empirical analyses. Moreover, industry and branch specific sustainable businesses need to be analyzed to access business model elements and archetypes supporting the management of voluntary social and environmental activities in certain environments. Thus, this chapter discusses Green Logistics strategies as integral part of sustainable business models.

29.6.1 Sustainable Business Model Framework

A sustainability business model can be conceptualized in different ways such as a narrative of sustainability practices; a description of features, attributes, and characteristics; as well as a list of necessary and sufficient conditions (Stubbs and Cocklin 2008). Within the frameworks given in the literature, the extended sustainable business conception developed by Upward and Jones (2016) is presented now. In this line, Table 29.3 describes the related sustainable business model elements. Moreover, the case of NETs.werk Hörsching will illustrate the single business model elements particularly focusing on Green Logistics services in the last mile.

Table 29.3 Sustainable business model elements

Business model elements	Description
Value proposition	The value proposition of a company is decisive for a customer's buying decision. Here, products and services build a bundle covering the needs of a specific customer segment (Osterwalder and Pigneur 2009). Following Schaltegger et al. (2016), the value proposition has to create, deliver and capture both environmental or social and economic value through offering products and services. Hence, a sustainable value proposition must identify trade-offs between product and service performance and social and environmental effects (Boons and Lüdeke-Freund 2013). In the literature, authors see a link between the (sustainable) business model of a firm and its innovation activities for creating value. Further key activities focus the access to markets, the perpetuation of customer relationships and the achievement of positive revenue streams (Osterwalder and Pigneur 2009)
Customers	The customer interface can motivate customers to take responsibility for their consumption behavior and for the company's stakeholders (Boons and Lüdeke-Freund 2013). Thus, the customer interface enables close relationships with customers and other stakeholders to be able to take responsibility for the production and consumption systems (Schaltegger et al. 2016). In order to approach the customer interface individually, customer groups are segmented by differentiating between different customer characteristics. Business models can either target a specific customer segment or produce for mass markets (Boons and Lüdeke-Freund 2013). Moreover, a company operating on multi-sided platforms (multi-sided markets) serves different customer segments dependently, if applicable (Osterwalder and Pigneur 2009)
Financial aspects	Value creation is linked with the use of resources and, consequently, linked with costs. In this context, sustainable business models are described as a shift from purely monetary-oriented paradigms of value creation (Lüdeke-Freund et al. 2016). Therefore, the comparisons of cost structures between similar business cases are essential to gain insights in how a business creates and delivers value to its customers (Osterwalder and Pigneur 2009). The cost and revenue structure reflects accordingly the distribution of economic costs and benefits among actors in the business model and accounts for the company's environmental and social impacts (Maas and Boons 2010). Following Stubbs and Cocklin (2008), shareholders often have to accept lower returns on investment in the short-term such that the company can directly invest profits into structural changes to support social and environmental improvements

(continued)

Table 29.3 (continued)

Business model elements	Description
Infrastructure	The company or its network partners need to have access to key resources as a prerequisite for value creation. These key resources can be generally distinguished in physical resources, financial resources, human resources and intangible assets (Osterwalder and Pigneur 2009). This perspective is relevant as sustainable innovations may require changed terms of competition and collaboration among the actors engaged in the supply chain (Boons and Lüdeke-Freund 2013). Generally, four types of partner networks can be distinguished. If companies do not compete directly, they can build strategic alliances. If they do so, companies can agree on strategic partnerships. To develop new business cases, joint ventures form an independent company where partners share the financial risks. Most commonly companies collaborate in a supplier-buyer relationship (Osterwalder and Pigneur 2009)
Environment	Sustainable business models treat nature as a stakeholder and promote environmental stewardship (Stubbs and Cocklin 2008). In this line, renewable resources should be used instead of non-renewable resources, or natural resources generally should be used within the limits of ecosystem carrying capacities and the ability to regenerate after interference (natural capital). Here, technological innovations should minimize and eventually eliminate non-recyclable waste and pollution. Related terms such as clean technologies are also used for innovations that have a superior environmental performance (Hart and Dowell 2011; Boons and Lüdeke-Freund 2013). Hence, reduced consumption, and especially the avoidance of damaging ecosystem services, is in the core of sustainable business models to reduce the environmental footprint of the actors (Stubbs and Cocklin 2008). Ecosystem services affected or as part of a value chain are being made visible and accountable (as far as possible)
Society	The importance of incorporating a stakeholder approach is increasingly understood in sustainable SCs and sustainable business models (Seuring and Müller 2008; Lüdeke-Freund et al. 2016). For instance, the stakeholder approach requires that a company engages suppliers in its sustainable supply chain management tackling social issues (Boons and Lüdeke-Freund 2013; Seuring and Müller 2008). Hence, SC governance might help to develop approaches to advance business models into platforms for multi-stakeholder integration and value creation (Lüdeke-Freund et al. 2016)

29.6.2 Case Study NETs.werk Hörsching

Background

The food cooperation NETs.werk is an association with the mission to facilitate sustainable consumption patterns (http://hoersching.netswerk.at). To do so, NETs.werk runs an e-food online platform to distribute locally produced organic food from small farmers in the Linz region in Austria. So far, customers order once a week via an online shop and pick-up their order at one of the NETs.werk branch offices by themselves. To drive the environmental performance in the last mile, NETs.werk started collaboration with a local LSP to offer a direct delivery service operated by electric vehicles. In this line, it is intended to acquire new customers, increase the service quality and decrease CO_2 emissions by avoiding single consumers' car rides and bundling the goods flow.

Value Proposition

Besides the organic products itself, the value proposition accordingly includes a local and sustainable delivery service allowing an expansion of the consumers' catchment area. Key activities to run the NETs.werk distribution network are the processing of the customer orders, the temperature-controlled transportation of the goods as well as the management of the returned packaging.

Customers

Customer target groups are people who work full-time and have limited time for grocery shopping (e.g. young and employed parents) as this segment needs to plan their shopping activities and is often sensitive towards health and sustainability related issues. Future customer segments are expected in business-to-business supply of restaurants, kindergartens and nursing homes for elderly people. Although the customer interaction while ordering is automated, NETs.werk intends to build a personalized customer relationship via the drivers of the electric vans to offer additional customer services such as a claim and retour management. To avoid anonymity and increase the transparency of the local farmers' production network, courtyard parties will be organized regularly and a rating system at the online platform will be installed.

Infrastructure

Key partnerships of NETs.werk are the local farmers and Schachinger Logistik, a local LSP, who can combine the afternoon business-to-customer food deliveries with a business-to-business parcel delivery service in the morning. Hence, the LSP is able to decrease operational costs per delivery by increasing the usage of the electric vans. In general, important key resources in the distribution network are the existing logistical infrastructure (such as trucks and warehouses) as well as the information and communication technology (ICT).

Financial Aspects
To operate this infrastructure, main variable costs are related to energy consumption of the electric vehicle, driving and picking personnel and running the online platform while fixed costs are mainly related to investments into logistical and ICT infrastructure. To cover these costs, revenue streams are generated by charging the customers partially with delivery costs and co-financing the delivery service from the product margin.

29.7 Integrating Green Strategies in Logistics Service Providers' Business Models

Following Boschian and Paganelli (2016), the alignment of logistical actions between necessary agents in the supply chain, particularly shippers, LSPs and infrastructure managers, defines successful and innovative logistics business models. In this context, the business models of shippers and LSPs are categorized by means of their service range and structure (Köylüoglu und Krumme 2015). A popular classification scheme of logistics business model archetypes is the 1PL–5PL scheme (Merkel and Heymans 2003). Hence, the integration of green strategies is discussed in line with the 1PL–5PL logistics businesses.

1PL (**Single Service Provider**): Single service providers execute a single logistics service, as e.g. a freight carrier (transportation) or stock keeper (warehousing). Accordingly, single service providers should concentrate on methods to decrease the environmental impact of their logistical assets (e.g. using HGVs with cleaner drive engine technologies).

2PL (**2nd Party Logistics Provider**): The 2nd party logistics provider executes all classical logistics functions of transportation, handling and warehousing which is the typical business model for freight forwarders, ocean carriers and parcel services. As they operate different transport modes, the selection of the best modal split becomes an important instrument to increase the environmental performance of their logistical activities.

3PL (**3rd Party Logistics Provider**): The 3rd party logistics provider extends the classical logistics function with neighboring logistics services such as cross docking, inventory management and packaging design. In this line, 3rd party logistics providers are often globally acting companies that contract with their customers "at eye level" (Wolf and Seuring 2010). Hence, they have the opportunity to implement more advanced Green Logistics strategies such as GDSS to optimize transport mode, route and capacity usage.

4PL (**4th Party Logistics Provider**) **and 5PL** (**so-called Lead Logistics Provider**): The 4th party logistics provider provides comprehensive supply chain solutions to coordinate and integrate all supply chain members using e-business and

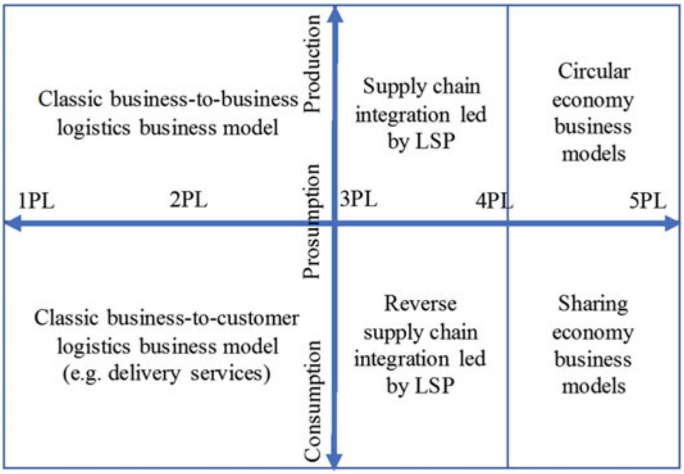

Fig. 29.4 Mapping logistics businesses in the supply chain

ICT applications such as EDI. 4th party logistics providers are often specialized consulting companies not carrying out any operations (so-called non-asset-owning service providers). In contrast, lead logistics providers carry out certain operations by owning or buying the necessary physical logistics infrastructure. Accordingly, coordination mechanisms of pricing schemes as well as information sharing and joint decision making are relevant to achieve greener supply chain configurations.

Mapping logistics businesses in a wider entrepreneurial ecosystem, classical and future Green Logistics business models can be derived and clustered in accordance to their supply chain position (upstream, downstream) (see Fig. 29.4).

Hence, future research steps might include the concrete integration of consumer-centred businesses such as circular and sharing economy solutions in the service portfolios of LSPs to further green the supply chain. In this context, Gruchmann et al. (2016) as well as Melkonyan et al. (2017) already investigated sharing economy solutions as a promising strategy for LSPs to facilitate sustainable consumption patterns and lifestyles. However, more empirical research is still needed to explore how LSPs can facilitate sustainability in such business environments.

29.8 Further Reading

In order to provide further insights into the development and implementation of green logistics the following sources can be of help to dig deeper:

Basic level: For an international perspective on waste disposal and greening supply chains in India see the case study by Ramasubramaniam and Chandiran (2013).

Advanced level: (i) From a political point of view the EU Commission provides a good insight into green transport developments with the 2011 Transportation White Paper (European Commission 2011). (ii) For an innovative application of carbon footprinting in Asian rail cargo see for example Tsai (2017). (iii) For a regional insight to green transportation in China see for example Li (2017).

State-of-the-art-level: (i) For the interaction of transport technology and corridor/infrastructure policy in the European Union see for example Georgopoulou et al. (2014). (ii) Regarding the interaction of green transport with co-modality and autonomous driving see for example Fagnant and Kockelman (2015).

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