

Sustainable Roads -Energy Efficiency in Road Design, Construction & Operation

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Saving energy has been a key objective of the energy policies of both the European Union and the Member States since the first oil crisis in 1973. The Union, in cooperation with the Member States, has made continuous efforts to promote energy efficiency ever since, thus reducing pressure on costs and contributing to the economic competitiveness of the EU.”

(Loyola de Palacio, Vice-President in charge of relations with the European Parliament, Transport and Energy – SAVE 2000 Foreword)

Today, the transport sector accounts for nearly one third of the EU's total final energy consumption with some 80% attributable to road transport alone.

‘Transport accounts for around a quarter of UK domestic energy use and emissions of carbon. The majority of the UK's transport greenhouse gas emissions are carbon dioxide and road vehicles are responsible for 93% of this. In addition to the climate impacts of transport, the heavy dependence of the sector on oil at a time when the UK will increasingly rely on imported oil, carries potential consequences for the security of our energy supply’ – *UK DTI White Paper on Energy – Meeting the Energy Challenge May 2007*

To date the energy consumed in constructing and, maintaining roads and operating traffic has not been considered as a parameter for decision making. However with the increased requirement to understand sustainable projects, basic research and tools are becoming necessary.

SUMMARY

With all of this in mind, an EU wide team Coordinated by Waterford County Council, Ireland including Engineers specialising in Road Design, Energy Evaluation, Geotechnology, and Computer Software Development recently completed a SAVE funded research project to create new energy

evaluation software. This development will now allow Engineers to incorporate the measurement of energy usage into their proposals as well as enable them to analyse the interaction between their designs and the energy used by vehicles on the roads over a design lifetime. The team comprised participants from the Czech Republic, France, the Netherlands, Ireland, Portugal, the UK and Sweden.

This report summarises the findings from that project indicating that changes to the alignment and design of a road that may require higher energy in construction can actually provide long term energy savings over its operational life cycle.

It demonstrates that by careful route choice taking road life cycle into account significant energy savings can be achieved.

The project is now being followed up by an expanded team with new expertise under the EU Project ‘Energy Conservation in Road Pavement Design, Maintenance & Utilisation’ (ECRPD). This project is programmed to run from January 2007 to January 2010.

Building on the work of the earlier project it will be testing sensitivities of the original analysis by taking a broader sample of projects and specifically looking at evaluating energy conservation in pavement manufacture and placement and also at pavement maintenance on existing roads. In particular it is looking at energy saving in road maintenance so as to save energy in vehicle use. It will also add further example projects to form a statistically better basis for comparison.

Particular benefits being sought are: -

- Energy use in existing road pavements in EU25
- Identification of energy use in new low energy materials.

- Identification of energy efficiency in road maintenance

At the time of writing the project is in progress and results will be published in a future Briefing Sheet.

ROAD ROUTES STUDIES

Five proposed schemes, either at the design phase or at early construction phase were selected for inclusion in the project. The road types selected included both single carriageways and dual carriageways. These five schemes are listed below.

1. **Czech Republic:** R43 near Brno, part of Euroroute E461 involving two route options
2. **France:** RD921 Pithiviers and Ferte Saint Aubain involving four route options
3. **Ireland:** N25 Dungarvan Outer Bypass involving five route options
4. **Portugal:** IP5 between Celorico and Guarda involving two route options
5. **Sweden:** National Road 50 through Motala involving one route option.

The route options from France and Ireland were single carriageways while those from the Czech Republic, Portugal and Sweden were dual carriageways

SOFTWARE DEVELOPMENT

The newly developed programme named 'JOULESAVE' is designed to operate in conjunction with 'MXROAD', developed by Bentley, which the team considered to be the most widely used road design software in Europe.

The JOULESAVE programme allows Engineers to quantify the energy requirements for all phases of road construction and to compare the different options in terms of energy use. The data are automatically assembled from the design as it is being developed and are passed to the analysis software for the calculation of the energy required to construct each element of the works.

By interface with the 'VETO' programme, developed by the Swedish National Road and Transport Research Institute (Statens väg- och transportforsknings-institut, VTI), JOULESAVE allows Engineers to analyse how each route option impacts on the fuel usage of vehicles on the road over a design lifetime. Comparisons may then be made between construction energy use and vehicle operation energy use to select the optimum design in terms of overall energy use.

CONSTRUCTION ENERGY

The energy used in the construction of roads is obtained by breaking down the works into their

constituent items. The energy values are then calculated for each item in terms of off-site materials (the energy required to produce materials such as aggregate, concrete, bitumen, etc.) and in terms of on-site placement (the energy required to excavate, transport, lay, etc.). These values are then used by the JOULESAVE software to calculate the total energy required for the construction of each road design option. The figures given below are based on the five proposed schemes considered in the study (i.e. the two single carriageways and the three dual carriageways) and show the range of energy values calculated for the construction of each road type.

Road Type	Energy Used during Construction (TJ/km of road)
Single Carriageway	6.31 to 8.17
Dual Carriageway	22.57 to 33.41

(Note: 1 TJ = 1×10^{12} Joules)

The higher values associated with the dual carriageway reflect the additional off-site materials works and the additional on-site placement works involved in constructing a wider road type

VEHICLE OPERATION ENERGY

Forecast traffic volumes and vehicle types expected to use the road need to be determined for input into the VETO programme.

Major aspects of the road design, such as horizontal and vertical geometry, that would impact on vehicle fuel usage are analysed so that the vehicle fuel usage over the road's lifetime may be calculated for each route option. This is achieved by importing the geometric design data via JOULESAVE into the VETO programme.

The figures given below are based on the five proposed schemes considered in the study (i.e. the two single carriageways and the three dual carriageways) and show the range of energy values calculated for the two main vehicle types traveling along the different routes.

Road Type	Energy Used during Operation (MJ/km of road per vehicle)
Single Carriageway Car	1.75 to 1.85
Single Carriageway Truck	7.83 to 8.56
Dual Carriageway Car	1.77 to 1.98
Dual Carriageway Truck	8.00 to 9.84

(Note: 1 MJ = 1×10^6 Joules)

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The higher values associated with the dual carriageway reflect the increase in vehicle speeds traveling along a wider road type.

OVERALL RESULTS OF POSSIBLE ENERGY SAVINGS

The table below provides details of the results of all of the route option analyses for each of the five proposed schemes

Route	Road Type	Length (km)	Construction Energy (TJ/km)	Total Vehicle Operational Energy 2010 -2009 (TJ/km)
Czech 1	Dual	16.73	33.41	365
Czech 2	Dual	16.00	22.79	516
France Est	Single	13.45	6.90	69
France G Est	Single	16.60	6.31	113
France West	Single	12.53	7.00	109
France G West	Single	12.79	7.73	125
Ireland 1	Single	12.57	7.63	136
Ireland 2	Single	12.37	7.82	134
Ireland 3	Single	11.43	8.17	134
Ireland 4	Single	11.45	7.78	142
Ireland 5	Single	13.13	7.07	175
Portugal 1	Dual	15.60	30.02	821
Portugal 2	Dual	15.90	29.88	710
Sweden	Dual	5.70	22.57	191

The right hand column in the table above takes into account the various traffic volumes and types associated with each of the five proposed schemes.

A typical, mid-range set of values is shown in the case of Ireland. From these it can be seen that the Total Vehicle Operation Energy consumption per kilometer over the scheme lifetime may vary from 125 TJ to 175 TJ. This shows that by expending an additional 0.56 TJ/km during construction, possible savings of 50 TJ/km or 29% may be realised during operation. If the same assessment is undertaken for the remaining proposed schemes then savings of: 151 TJ or 29% appear in the options for the Czech Republic, 47 TJ or 42% for France and 111 TJ or 14% for Portugal.

CONCLUSION

The above assessment shows that by proper analysis at design stage, Road Engineers could help to contribute significantly to an overall reduction in energy consumption. For example, in the case of the two options of dual carriageway in the Czech Republic, a possible saving of 151 TJ/km over its 16.73 km represents 2,526 TJ over its 20 year lifetime. This saving approximates to 2.43 TJ per week, which is well in excess of the energy required to launch the US Space Shuttle into a typical 300 km altitude orbit.

Such energy savings are of major significance especially when it is considered that the case above is just one example of possibly one hundred or more of similar road schemes that are planned throughout the EU each year.

Although much research work has already been undertaken as part of this project, the team believes that in the light of the results, further and more rigorous assessments are warranted given the enormous scale of the energy values involved. Such further assessments may include an examination of the various Member State national standards for horizontal and vertical geometry, road surface friction and possibly speed limits, all of which contribute towards overall efficiency. This research could have the potential to make a major impact on energy efficiency in road transport.

Full results of the IERD Project can be found at http://www.nra.ie/Publications/DownloadableDocumentation/RoadDesignConstruction/file_3619_en.pdf and details of the ECRPD Project can be found at <http://www.ecrpd.eu>.

PROJECT PARTICIPANTS

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