



Results, lessons, impacts

Final publishable report



European Farmers and Foresters involved in contributing to an intelligent Energy Network towards the target of 20% reduction in fuel consumption

Efficient20 is an Intelligent Energy project

The project began its activities in May 2010 and came to a conclusion in April 2013.

Efficient20 is coordinated by AILE (France) and involves 12 partners from 9 EU countries

The partners are:

- Association of Local Initiatives for Energy and Environment (AILE) – France
- Ruralnet Limited (Ruralnet) – United Kingdom
- Italian National Body for Agricultural Mechanization (ENAMA) - Italy
- Kuratorium für Waldarbeit und Forsttechnik (KWF) – Germany
- Poland Industrial Institute of Agricultural Engineering (PIMR) – Poland
- Higher Federal Education and Research Institute of Agricultural Engineering and Food Technology
Francisco-Josephinum (FJ-BLT) – Austria
- Energy Agency of the Province of Avila (APEA) - Spain
- Walloon Agricultural Research Centre (CRA-W) - Belgium
- Chamber of Agriculture and Forestry of Slovenia (KGZS) – Slovenia
- Agricultural Institute of Slovenia AIS - Slovenia
- Chamber of Agriculture of Ille et Vilaine – Regional Chamber of Agriculture of Brittany (CRAB) - France
- National Research Institute of Science and Technology for Environment
and Agriculture (CEMAGREF – IRSTEA) - France

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Introduction

With the economic and environmental problems related to the dependency of our society on petroleum products comes an increasing pressure on agriculture viability. Fuel used in farming machinery represents more than a third of the energy consumed in agriculture and fuel costs represent ca. 40% of total costs of the tractor input (with a utilisation rate of 450 h/year). So introducing fuel saving measures can play a significant part in reducing input costs

Despite the importance of diesel in farming energy consumption, there were few detailed references on farming fuel consumption, with three main reasons:

- you can perform a lot of different kinds of work with a tractor, from spraying to ploughing, including transport and small work for animal feeding...
- there is a huge variety of practices, soil and weather conditions that make a lot of difference between two similar farms.
- measuring fuel consumption is a real supplementary work for the farmer, it requires time, method and precision.

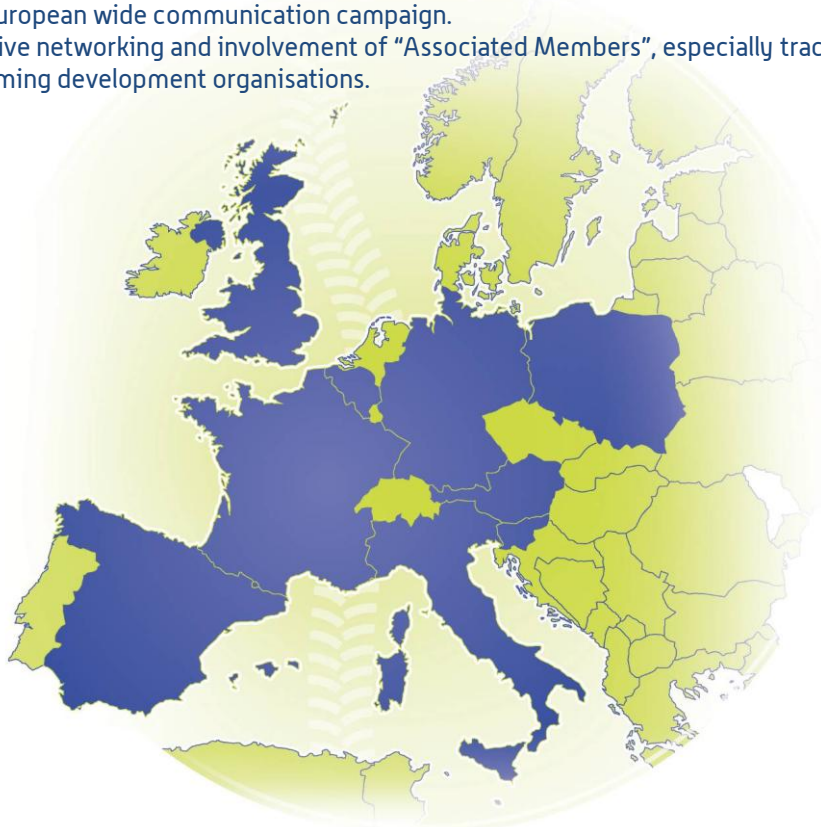
The main objective of the project was to create a network of farming related companies and organisations in order to contribute to the European target of 20% savings in the farming fuel consumption.

Gathering data at European level enables the comparison of various practices and contexts and thus helps to define more precisely the variation factors and incentive levers.

We chose to focus on energy savings because we noticed it is always more difficult to convince end users that savings are as important as renewable energies.

Our project included four complementary tools:

- a collaborative database on fuel consumption
- actions of fuel reduction with farmers' and forester's pilot groups, allowing to share knowledge and create international tools on fuel savings and eco-driving in agriculture.
- a European wide communication campaign.
- active networking and involvement of "Associated Members", especially tractor manufacturers and farming development organisations.



Reducing fuel consumption by 20%, it's possible!

With the economic and environmental problems concerning the dependency of our society on petroleum products comes an increasing pressure on agriculture viability, and for very good reasons: fuel used in farming machinery represents more than a third of the energy consumed in agriculture and fuel costs represent ca. 40 % of total costs of the tractor input (with a utilisation rate of 450 h/a). So introducing fuel saving measures can play a significant role in reducing input costs and improving farm profitability, with environmental benefits at the end. Here are some of the technical achievements of the Efficient 20 project.

What are the main parameters which influence fuel consumption?

While most farmers do their best to work efficiently, there are usually possibilities at a different scale or level that could be studied. It's possible to summarise the influencing parameters in three vertical levels, where every level impacts the following.

The first one is the farm level, where the overall management of the farm logically impacts all aspects of fuel consumption:	
Methods of cultivation are crucial factors The diesel consumption for different crops amounts to 60 – 120 litres/ha depending on the labour intensity.	The number of operations by activity plays a key role. Fuel consumption fluctuates about +/-50 % for the same tasks depending on local conditions (e.g. soil) and users' variability.
The second level concerns the "strategic" management of the machinery, the choices made by the farmer:	
Choosing an efficient tractor (in term of motor's curves, eco-technologies, etc.) Appropriate matching of tractor with machinery	Planning and Combining work/equipment Saving the use of machinery in a rational way
The third level is all about the "tactical" use of machinery, the improvement in use, the way the machinery is set-up, driven and maintained. There are lots of solutions and they can be combined:	
Keeping your Tractor in shape (correct maintenance) Eco-driving techniques	Correct tyre pressures and equipment settings and lots more...

- 1 - Adapted driving: 10% - 20% saving
- 2 - Adapted implement: 5% - 8% saving
- 3 - Adapted implement settings: Up to 30% saving
- 4 - Adapted tyre pressure: 5% - 10% saving
- 5 - Weight management: 5% - 8% saving
- 6 - Engine maintenance: 5% - 10% saving

Various solutions are studied by the project:

- 1 - Optimizing the use of a tractor in the field,
- 2 - Impact of farm structure,
- 3 - Specific measures of soil tillage,
- 4 - Specific measures of forage harvesting,
- 5 - Specific measures of transport,
- 6 - The human factor.



Efficient20's tip: get the training handbook "D3.8 Strategies for saving fuel with tractors" on the project's website:
<http://uk.efficient20.eu/category/resources/>.

Applied approach and methodology

The project aimed at developing a bottom-up approach, allowing field measurements to be collected and interpreted. The aim was also to improve farmers' and farming organisations awareness about fuel savings.



Database creation and set up was one of the main activities in the beginning of the project, to obtain a collaborative and user-friendly tool. The database is available online in 7 languages on <http://efficient20.eu/appfarms/>. Currently the database reaches 2,239 farmer's measurements and 378 expert measurements, with 98 pilot groups, 145 farms and 277 tractor drivers registered.

32 pilot groups were constituted, equipped with fuel monitoring devices and assisted by partners in the recording of fuel consumption. After participating in a training session (34 sessions organised), the farmers and foresters performed 227 comparative tests, where a baseline measurement in normal conditions, is compared to a measurement performed with a fuel saving solution.

Studies and surveys were carried out to complete the knowledge about fuel consumption and means to reduce it: an analysis of existing bibliography, a review of embedded computers, a survey on understanding and comfort of use of recent tractors. Studies were carried out by partners or associated members.

To enhance general awareness about fuel savings in agriculture, a European communication campaign was organised, based on existing farming machinery events. The partners attended 99 events, among which 59 with more than 500 attendees and active participation. During those events, among which several well-known national or international agricultural machinery fairs (ZLF, Royal Welsh Show, SIMA, EIMA, Agro-Show...), the activities carried out by partners were: lectures and speeches presenting the project, the database, documents, technical sessions, demonstration of eco-driving, recruitment of PG's...

To develop closer collaboration with farming organisations and related companies, networking activities were carried out. Contacts with tractor manufacturers and dealers, universities and farming organisations were made and 63 of them became associated members of the network, implementing activities within the project (studies, training sessions, comparative tests, demonstration in fairs...)

The project progresses and achievements were monitored through an evaluation framework which allowed to stick to the planned schedule and to record regularly the results.

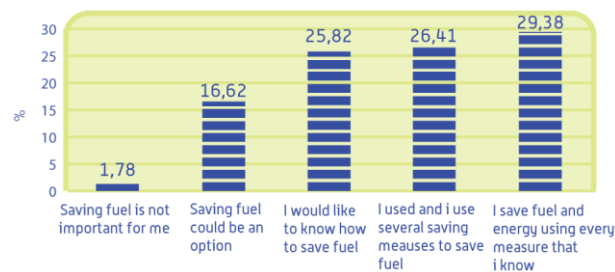


How to help users reduce their fuel consumption

Evaluating the level of knowledge about fuel consumption by users

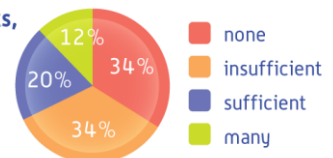
One of the aims of the Efficient 20 Project was to increase the knowledge and to raise the awareness of the farmers on fuel savings in agricultural tasks. This is the reason why a first global evaluation was carried out at the beginning of the project to know precisely the situation. To complete it, a more technical oriented evaluation was made to evaluate the level of understanding by users of new equipment in agricultural tractors and machinery.

One of the most interesting results obtained thanks to the questionnaire analysis was that nearly half of the farmers and foresters surveyed answered that they were wishing to save fuel without knowing how to do it.



This lack of knowledge was probably due to the fact that the amount and availability of practical principles and techniques on eco-driving in agriculture was poor (from professional press, media and manufacturer through manuals or training).

Do you know any guidebooks, which provides guidance on economic operation of machinery and eco-driving techniques in agriculture?



These first results confirmed the relevance of projects such as Efficient20.

This action also identified farmer's low level of motivation (57%) to save fuel, as well as the low level of knowledge and awareness about the importance of adopting fuel saving measures.

Identifying the strengths and the weaknesses of farmers and foresters involved in fuel saving was obviously the first step to define concrete objectives with them!

Adapting the message to motivate the audience

Regarding the results of the questionnaires, it was crucial to adapt to the audience the way to broach fuel consumption and reduction. It was shown that, in the agricultural sector, both motivation and acquisition of new knowledge of participants had to be increased.

For example, motivation actions tried to:

- 1 Highlight the impact of fuel saving actions at different levels: economic, competitive, productive, environmental..., in order to
- 2 Stress the potential improvements and impacts at personal level,
- 3 Identify the fuel consumption per task, in order to reveal how important the fuel cost is within the economic results, making the adoption of measures more attractive [database].

The best way to improve the acquisition of knowledge was with training, courses and journeys. The training courses and actions had to be developed according to the elements marked as more influential in reference to the fuel consumption, in order to optimize the obtained results. The main factors mentioned by farmers were linked to machinery (use, driving style, speed) and to land (conditions and kind).

The organisation of training actions with farmers (the more knowledgeable the better) was a good way to improve their knowledge about the consequences of their actions. Telling the audience about their experience made it easier to adopt saving measures for farmers who hadn't adopted any yet, and it reinforced those who were already applying some measures.

In order to promote this kind of message there are many possibilities:

- 1 Presentation (combined with other activities),
- 2 Visit with experts, manufacturers, research centre,
- 3 Quiz,
- 4 Contest of eco-driving...

Efficient20 tip: get the "D6.4. Analysis questionnaire by country"! Ask the Efficient20 local partners for a copy (see the "useful address" chapter) or visit the project website <http://efficient20.eu/>

Knowing its own fuel consumption: the 1st step towards reduction

Measuring fuel consumption is the first step towards fuel's reduction. To investigate the potential for further savings it is necessary to record the data of the actual situation linking the fuel consumption to each plot and each operation on the farm. This must be performed for each single step, written by hand or electronically on a simple form. Based on that, an overview can be achieved of all the procedures and their corresponding fuel consumption. Therefore a basis for further efficient saving measures is established.

In order to know about the consumption of tractors or other self-propelled machines, users can:

- 1 - Estimate the consumption manually by monitoring refill volumes,
- 2 - Install relevant fuel monitoring instruments like turbines (flow measurements),
- 3 - Use an on board computer that is able to display consumption.

This last solution becomes more important as more and more equipped tractors arrive on the market. The table below gives an overview of currently available tractor models that can provide consumption information (standard or optional, based in the information provided by the manufacturers)

Brand	Model	Current consumption (L/h and/or L/ha)	Total consumption (L)	Average consumption (L/h or L/ha)
Case	Maxxum	•	•	••
	Puma	•	•	•
	Puma CVX	•	•	•
	Magnum	•	•	•
	Steiger	•	•	•
Fendt	Vario 200-300	•	•	•
	Vario 400-800	•	•	•
	Vario 800-900	•	•	•
John Deere	6030 Premium	•		
	7030 Premium	•		
	8R range	•		
Claas	ARION 400-600 CIS	•		
	ARION 500-600 CEBIS	•	•	
	Axion 800 CIS	•		
	Axion 800 CEBIS	•	•	
	Xerion	•	•	
Lindner	Geotrac 84-104		•	•
	Geotrac 114-124		•	•
DeutzFahr	Agrotron TTV	•	•	•
	Agrotron M Profiline	•	•	•
	Agrotron X	•	•	•
Massey Ferguson	MF6400	•	•	•
	MF7400	•	•	•
	MF8600	•	•	•

While some computers feature a wide range of display options, others are only capable of showing current consumption [l/h]. Displays are often not installed at all in the low power machines or are only available at extra cost. The forest machines (John Deere, Komatsu [VALMET], Ponsse) provide in general a wide range of information.

The advanced systems currently available on the market have brought about a significant reduction in the workload and therefore an increase in comfort. Sadly, about 60% of farmers

didn't use on-board computer display information about fuel consumption; they found it too complicated to use. That's why an in-depth training is required before the user can fully utilise all functionalities of the computer. As 70% of farmers welcome assistance from dealers, manufacturers and dealers should provide on-going assistance to answer questions and solve problems. Clearly structured and easy-to follow user manuals also play an important role in this context. This could be a starting point for improvement.

Training sessions handbook and organisation tips

One of the best ways to increase the motivation and the capacity of farmers and foresters is to develop training sessions especially speaking about fuel consumption: eco-driving session.

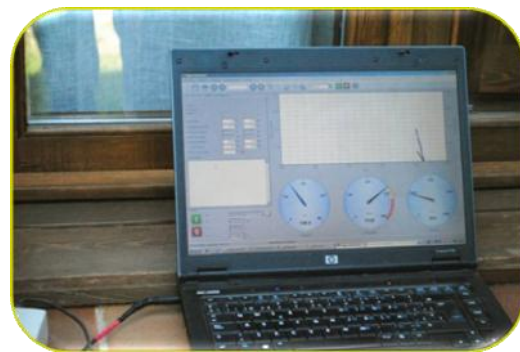
Highlighting the main factors which affect fuel consumption helps to justify each one of the fuel saving techniques

SPAIN



› Tests using equipment to display engine power/torque curve (in-field test-bench)

"Using this special measuring equipment was interesting, because it allowed farmers understanding how an engine works and what the relation between engine speed and energy consumption and power is." (APEA)



France



› Comparative test on ploughing with an on board fuel consumption monitor

"It is important that participants collect their own experience" (AILE)

SLOVENIA



› Folder with explanations are given to participants for the theoretical part of the training session

"Eco-driving session was useful because attendees had theoretical presentation of possibilities for lowering fuel consumption and practical driving part with significant difference in fuel consumption." (Agricultural Institute of Slovenia)



Training sessions lessons learnt

In general the developed eco-driving sessions consisted in a theoretical part and a practical one. The theoretical part normally consists in interactive classroom-based training with the presentation of the possibilities of fuel saving in agriculture on the basis of the "Training handbook [D3.8]" and the Power-Point Presentation. Following topics were discussed:

- introduction (fuel price, cost of ownership of a tractor, benchmarks for fuel consumption)
- characterisation of a tractor engine and gear box,
- effect of engine speed,
- impact of farm structure,
- specific measures in soil tillage,
- specific measures in forage harvesting,
- choice of the optimal transport vehicle,
- measuring the fuel consumption,
- crucial man factor.



In Germany the trainings were focused on forestry

Sometimes the trainers integrate the theoretical part in the practical part of the training session. The practical part of the training session includes activities which aim at showing some examples of fuel reduction by comparison of consumption between situations. This practical part includes the following activities depending on the interest of participants:

- transport with tractor and trailer,
- work with a front-end loader,
- soil tillage – effect of working depth, ballasting, tyre pressure,
- manure spreading,
- checking the state of maintenance at a test bench,
- working with a feed mixer wagon,
- working with harvester and forwarder in forestry.

The fuel savings measures that can be easily tested are the followings:

1. Effect of the state of maintenance at a test bench (dynamometer),
2. Effect of working depth, ballasting, tyre pressure,
3. Effect of driving style,
4. Effect of Eco PTO,
5. Effect of machine adjustment.

It is interesting when participants can test their own way of driving and compare it to the others or to themselves after advice given by the trainer. They are often surprised about the variability in fuel consumption among different drivers under the same conditions, and about the large effect of eco-driving.

Because the economic aspect is important, it is essential that eco-driving does not cause an increase in working time requirement (to avoid increase of labour and machine costs). Thus, practical examples should show that it is possible to keep the same speed with less fuel consumption



The given advice and explanations come from the experience from more than 30 driving sessions organised in 8 different countries gathering together nearly 300 participants during the Efficient20 project.

Pilot groups fuel measurements methods and lessons learnt with monitoring devices

The first step to improving fuel efficiency is to know the diesel consumption for each type of farming activity. Once precise measurements have been done, the users can begin to monitor the effect of changing the way they work.

74 Pilot groups of farmers and foresters across Europe were involved in consumption recordings during the project Efficient20. With the help of local partners, lots of different activities were studied and encouraging results were achieved for various fuel saving solutions.

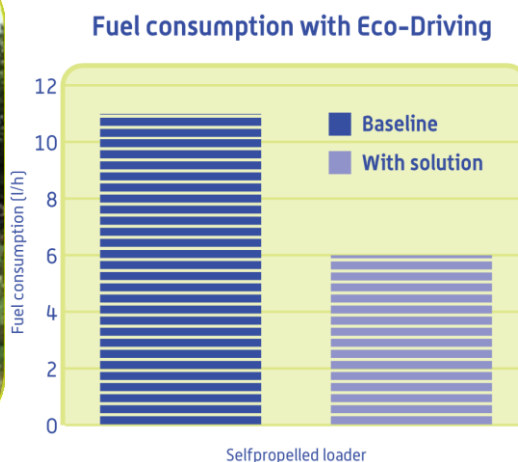
- 1 - Assessment of the initial consumption of the farm,
- 2 - Comparison to standard values,
- 3 - Potential of optimization, personal action plan designed,
- 4 - Implementing the action plan in the farm,
- 5 - Assessment of the final consumption of the farm,
- 6 - Calculation of the consumption reduction achieved.

There are three ways to measure fuel usage:

- Global fuel tank (refueling every time the tractor gets back to the fuel tank)
- Plot measurement
- Instantaneous measure (with electronic devices)

All the data (plot, operation, related consumption, ha realized, km traveled, etc.) are recorded at every step

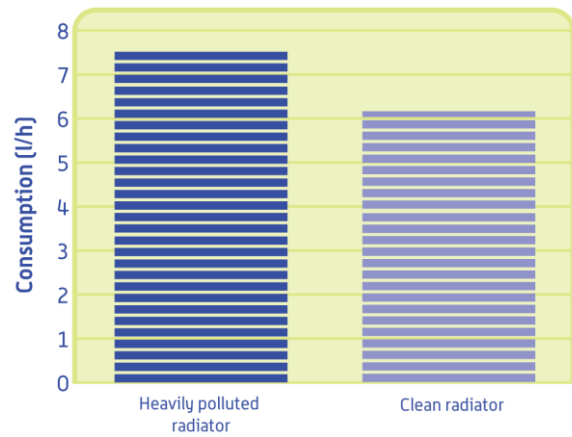
In the farms, the action plan gives the opportunity to observe comparative tests, where an initial consumption measurement (baseline) for a specific activity is followed directly (ideally on the same day and in the same field) by other measurements with tried out fuel-saving techniques (such as driving at the most efficient rpm, adjusting tyre pressures and using ballast to reduce wheel-slip and soil compaction). Here are some examples of comparative tests realised by farmers and foresters from pilot groups:




FRANCE	Pilot group: Farmer, Cuma de Bellevue
Type of work: Manure loading	Tractor/implement: JCB 536 Agri Xtra, 135 ch
Used solution: Eco-driving, between a nervous and smooth driving style respectively carried out in the morning and the afternoon of the same day	Saving: :43% of fuel saved for the same quantity of manure loaded in the same time



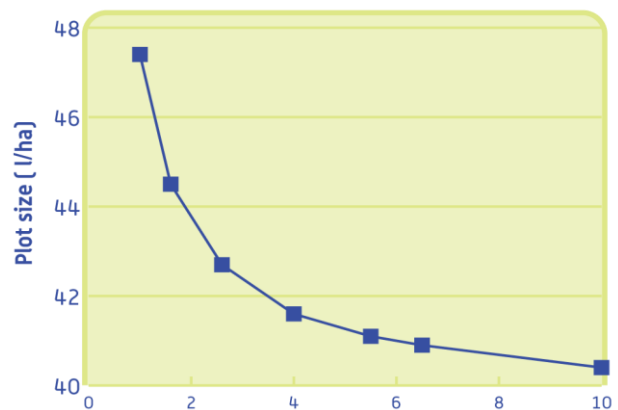
Fuel consumption with clean and heavily polluted radiator




 GERMANY	Pilot group: Forestry; Baden-Wuerttemberg
Type of work: Forest harvesting	Tractor/implement: Tractor Steyr 4110 Profi
Used solution: Cleaning of radiator (Engine maintenance)	Saving: Heavily polluted radiator compared to a clean one 20% fuel saving



Fuel consumption



 AUSTRIA	Pilot group: Austrian Farmers AT3
Type of work: Sugar beet harvesting	Tractor/implement: Holmer T3, 260 kW, bunker 25 m ² , 6 rows
Used solution: The increasing plot size from 1.0 to 10.5 ha reduced the working time per ha for turning on the headland.	Saving: The increasing plot size causes a reduction of the fuel consumption from 47.4 to 40.4 l/ha (15 %)


The comparative tests are very useful to give a quick view of the expected benefits of eco-solutions but they also provide a valuable way of convincing farmers and foresters, who much prefer to read about what other farmers are doing than to rely on purely academic research. That's why the project has produced a brochure with detailed accounts of nine different comparative tests achieved in nine different countries, with all the explanations about the different solutions used (implement settings, adapted weight, eco-driving, tyre management, etc.).

These data give the possibility to study the consumption at different scale, from the comparative test on the field (with/without implementing saving action) to the global saving of the farm.

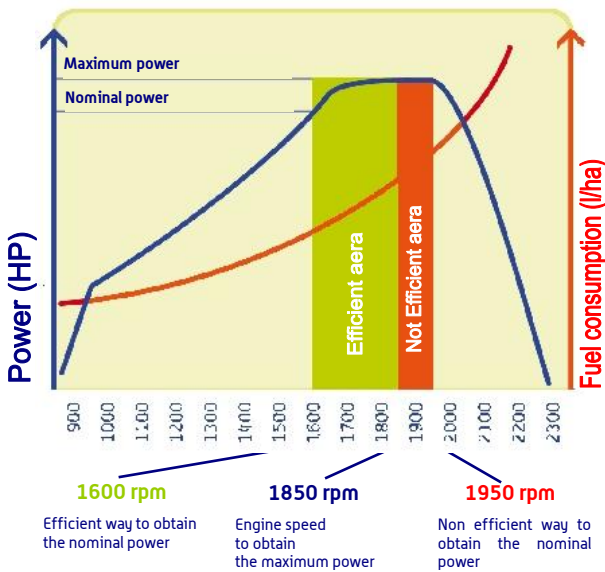
Next pages show two case studies extracted from the Farmer's brochure, "D5.3 Put your tractors on a diet, Fuel-saving achievements from efficient20 farmers". Ask the Efficient20 local partners for a copy in your national language

It is possible to save fuel if you pay more attention to the engine speed than to the noise of the engine

Reducing engine speed: the importance of 400 r.p.m.

 Many farmers drive the tractor according to the engine noise, which usually means working at around 400rpm higher than the level for optimal power and fuel consumption. Reducing the engine speed can give the same power while using less fuel.

This fact is obvious in tractors that optimize the power itself, as they usually work in the range of 1.400 - 1.800 r.p.m. instead of 1.800 - 2.200 which is where farmers are used to drive when they control the engine speed. Systems incorporated in tractors to control the engine speed automatically, try to optimize the fuel consumption to deliver the power needed in each moment, working on the "left" side of the chart that links power with engine speed. However, when farmers control the engine speed themselves, it's normal to drive on the "right" side of the chart. In both cases, the power obtained is the same, but not the fuel consumption.



> Practical course to teach farmers to reduce energy speed, in New Holland Campus.

"Many times you drive in a high engine speed but it's not necessary" "farmers use this stubble cultivator around 20cm" instead of ploughing

This has been explained and practiced in courses (one per agrarian Pilot Group) and in the field, where farmers (from three Pilot Groups: "El Oso", "La Mora" and "Valle Amblés) have obtained interesting results:

	l/h	l/ha	ha/h
Chisel	-5.5%	-6.4%	1%
Cultivator	-14.6%	-7%	-8.2%
Dis Harrow	-12.5%	-12.5%	0%
Fertilizer	-33.3%	-25.9%	-10%
Front loader	-19.9%	N/A	N/A
Moldboard plow	-6.5%	-6.4%	-0.1%
Roller	-16.9%	-16.9%	0%
Seed drill	-15.8%	-15.8%	0%
Sugar harvester	-12.7%	-12.7%	0%
Transport	-32.5%	-17.6%	-18.2%


These savings have been obtained mainly by reducing the engine speed from the speed that farmers were used to work on (1.800 - 2.000 r.p.m.) to the engine speed recommended after courses (1.600 - 1.800 r.p.m.) or even less when the labour is light.

According to the chart results, there is a range of saving potential from 6.5% [hard work like mouldboard ploughing, cultivator] to 26% [light work like fertilizing, seed drill, transport] in terms of litres per hectare. Farmers have to pay attention to engine speed instead of to engine noise. Reducing by 400 r.p.m. from the common engine speed is a good action to reduce the energy consumption, as the tractor provides the necessary power for the job using less fuel. Driving with a lower engine speed is recommended in all situations where the driver can control engine revs. Significant fuel savings across a variety of field and road work are possible.



At ploughing we can reduced fuel consumption on different ways

Ploughing with a lower tyre pressure and lower engine speed of tractor

 Ploughing is one of the most fuel-hungry activities in agriculture, but it can be reduced in several ways. A study carried out by Efficient20 examines how adjusting tractor tyre pressure (according to the type and condition of the ground - highest tyre pressure is used for the road driving, lowest at the field) and using lower engine speed could diminish the fuel consumption.

The presented results are valid for the light sandy soil with adequate moisture for ploughing with tractor Deutz Fahr, Agrofarm Profi Line 420 (power 70 kW/95 HP, maximum power 73 kW/99 HP, constant power range from 1400 to 1700 rpm of engine speed, Powershift transmission, 60 forward gears + 60 backwards gears and a mass of 4660 kg), equipped with the three furrow reversible plough Vogel Noot 950 LM (working width 114 cm, working depth was 21 cm, velocity 7 km/hour, productivity 0,71 h/ha). The results show (graph 1, table 1) that the highest reduction of fuel consumption (up to 25%) could be achieved with lower tyre pressure and lower engine speed of the tractor. Reducing only the engine speed of tractor (from 1800 to 1600 rpm), could reduce the fuel consumption by 8% - 12% (depending on the defined tyre pressure); tyre pressure reduction lead to 15% to 18% fuel savings (depending on the defined engine speed of tractor). Fuel consumption also depends on different working conditions (soil type and moisture, soil compaction, different speed or working depth, etc.).

Through the Efficient20 project, several discussions, seminars, courses and eco-driving demonstrations were held to show farmers possible ways to reduce fuel consumption in soil tillage activities. The measurements, which are shown in this paper, were carried out at the course for fuel saving in Jable, where, among others, three members and the leaders of the two pilot groups participated.

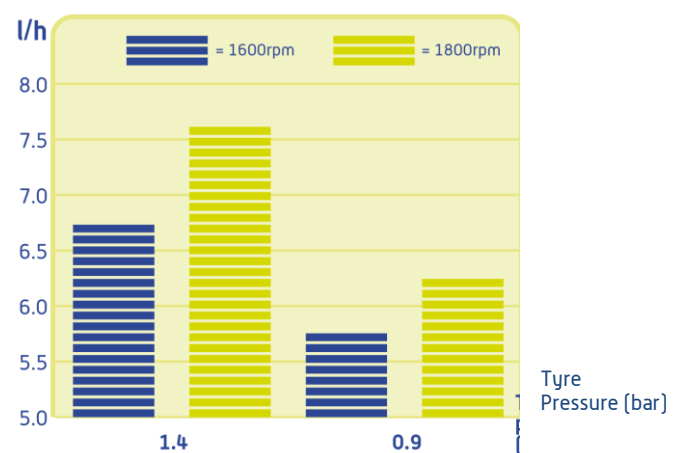
> Participants of course for fuel saving in Jable at 27th July 2012

Rising fuel prices will force the majority of farmers to use a more fuel-efficient mode of agricultural work."

Milan Mihelcic
pilot member

Fuel consumption for ploughing

Fuel consumption for ploughing on sandy soil with a tractor Deutz Fahr, Agrofarm Profi Line 420 (power 70 kW/95 HP) and three furrow reversible plough Vogel Noot 950 LM (working width 114 cm, working depth 21 cm), by comparison with the engine speed of tractor and the tyre pressure.



Reduction of fuel consumption (in percentage) for ploughing with different engine speeds and tyre pressures.

		1800 rpm	1600 rpm
Tyre pressure	1.4 bar	100 %	-11.8%
	0.9 bar	-18.4 %	- 25%



Database functionalities

The Efficient20 partners have designed a database specially dedicated to the consumption studies, where all the pilot groups' data are uploaded, standardized and accessible. The Efficient20 internet database is currently fed by:

74 Pilot Groups

121 Farms

235 members

There are also measurements from other actors of the project (Experts, research centres, etc.). One measurement is one line of the database, but each line can be filled with up to 48 different types of information (tractor/implement full description, timing, surface, speed, settings, etc.), to provide a complete description of the work carried out and fuel consumption achieved.

ID	Date	Member	Farm	Activity	Implement	Fuel	Solution	Worked area
390	10/29/2011	Letihon Olivier	Letihon Marc	Soil tillage	Plough Mounted 5 furrows	28.3	Eco-Driving	1.8
391	10/29/2011	Letihon Olivier	Letihon Marc	Soil tillage	Plough Mounted 5 furrows	27.1	Eco-Driving	1.7
392	10/29/2011	Letihon Olivier	Letihon Marc	Soil tillage	Plough Mounted 5 furrows	30.8	None	1.7
393	10/29/2011	Letihon Olivier	Letihon Marc	Soil tillage	Plough Mounted 5 furrows	29.4	None	1.6

Database Fuel Measurement per activity *	
Harvesting	479
Breeding	27
Transport	129
Soil tillage	883
Fertilization and crop protection	75
Loading	26
Manure and slurry spreading	68
Forest harvesting	321

All the eight activities retained are studied. The number of operations recorded per activity (given below) shows that there are more data for certain activities than others. Some activities give more possibilities for the tests (such as soil tillage and harvesting which are some of the most fuel demanding activities in a farm), or they are maybe more common in the participating farms.

All the fuel saving solutions retained have been tested too, with some very encouraging average results. Some of them are really near to the Efficient20 20% target, especially if we remember that these are stand-alone solutions, and could be used in combination!

Database average fuel saving achieved *



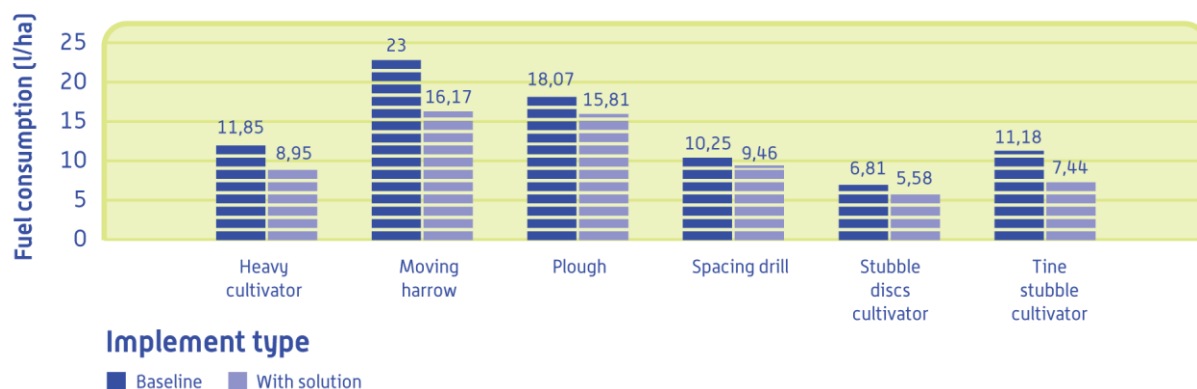
* based on December 2012 database

Each solution regroups different practical actions. For example, the "tyre management" actions are all about tyre pressure and tyre type choices, or "adapt implement's settings" solutions take into account actions like management of the working depth, replacement of used knives, optimisation of the settings of the three point linkers, and much more.

In the “Reports” section, the online database gives some opportunities to study the data from different points of view, through the “fuel consumption by activity”, “fuel consumption by solution” and “fuel consumption by implement” reports.

Filters (on “activity”, “country”, “unit to display”, etc.) support further analysis. Here is an example for the fuel consumption achieved across all “soil tillage” operations where the “adapt implement’s settings” solution was used. Six types of soil tillage implements are concerned and in some cases a 20% fuel saving is reached (example: “Moving harrow” presents a 30% reduction).

Fuel consumption by solution - adapt implement's settings (december 2012)



> The database now shows its full potential with more than two thousand operations registered!

Using the database enables to:

1. Compare chosen fuel usage with data recorded by other farmers carrying out similar work,
2. See fuel savings being achieved through applying various fuel-saving techniques,
3. See the impact of changing the way of working on fuel savings.

The National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA), as one of the French partners of the project, is leading a scientific data analysis of the database measurements. This study in two steps (by implements, by solutions) will lead to European references. Analysis aims to study fuel costs of agricultural operations, not only in terms of fuel consumption but also considering the working capacity (ha/h) in other words, in terms of integrated (global) efficiency. Here is a first attempt of analysis and reflection made with the database in August 2012 for the “plough” activity with comparison between the baseline, the “Eco-driving” solution and the “Tyre management” solution.

Solution	Tests	Power of tractors (hp)	Tested area (ha)	Working capacity evolution [%]	Fuel reduction [%]
None	115	153	600	/	/
Ecodriving	28	162	170	-4	-19
Tyre management	9	162	23	0	+2

“Power of tractors”, “Working capacity evolution” and “Fuel reduction” are average results.

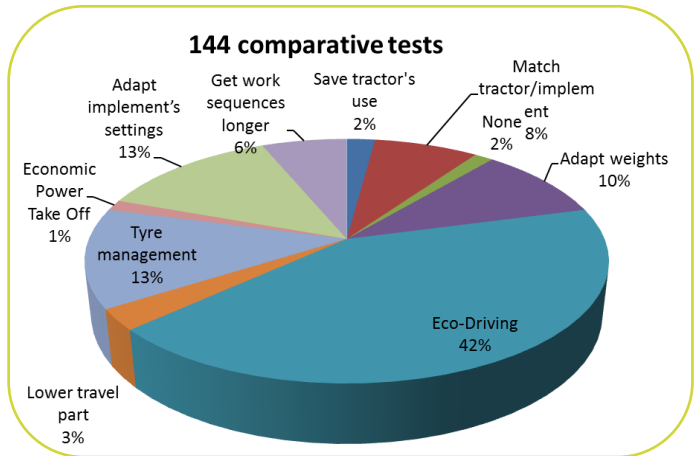
We can see that the “Eco-driving” solution gives good fuel savings and the 20% saving objective seems to be nearly achieved in this case, but the working capacity does not seem to be improved. Due to high variability in the results of the “Tyre management” and low number of tests, there are difficulties for results interpretation. Nevertheless, the database feeding is still going on and Efficient20 is working to demonstrate that solutions with global efficiency exist. “Work costs less and is faster”, that’s what we call a global efficient activity; when the fuel saving management leads to an efficient work in every way you see it (and it’s finally what the farmers and foresters are interested in).

Efficient20’s tip: get access to the internet database, sign up on the project’s website:
<http://efficient20.eu/appfarms/>

Comparative tests analysis

144 comparative tests were performed by the 30 pilot groups supported by the project partners. The breakdown of those tests with related fuel saving solution is shown in the graph below.

Among the 144 tests, 6 were found aberrant, meaning that the values were not consistent and we were not able to find an explanation, 7 were found unsuccessful, meaning that the group wanted to test a solution and finally consumption was higher than baseline. For example, they tested a solution with more front weight and noticed it was not appropriate. Or they managed to reduce fuel/h but fuel/ha increased, which is an inefficient solution because the surface to work remains the same.



The tests that did not give the expected results teach us that:

- Sometimes theory does not fit to the field reality
- It is really important to have monitoring devices in the tractor to check if good practises have the expected effect. The spreading of on-board computers clearly displaying instantaneous and cumulative consumption is a real challenge

The next paragraphs analyse the 131 remaining tests.

Farming (Loading, breeding and manure spreading) and Forest activities

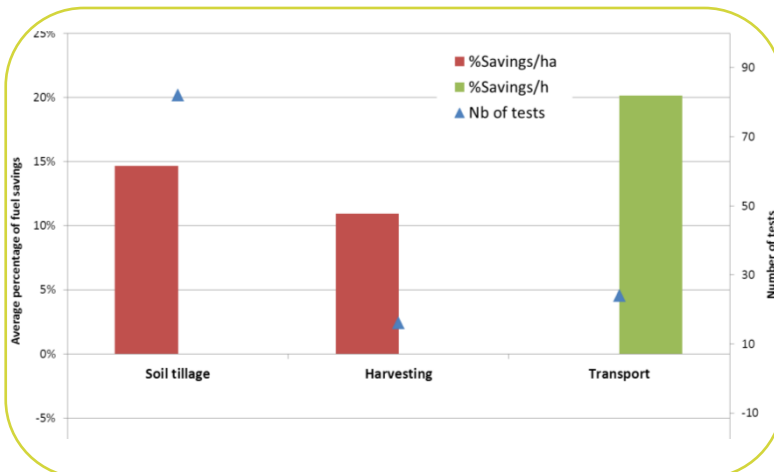
There are not enough tests to conclude on a general trend: there are less than five tests by activity. But the results of individual tests show that it is possible to save 10% fuel with eco-driving.

These activities are not often cited by farmers as fuel saving potential but nevertheless, savings can be achieved.



The 3 main activities show an effective decrease in fuel consumption.

Soil tillage, harvesting and transport gather respectively 82, 16 and 24 tests. The average fuel saving per hectare is shown in the graph below. This is the main indicator of the project's results.



Comparison tests run for soil tillage show an average saving of 15% in fuel/ha.

Comparison tests run for transport show an average saving of 20% in fuel/h.

Soil tillage

The 86 tests run show that fuel savings from 15 to 20% are possible both per hectare and per hour. This is a really encouraging result, as soil tillage is one of the most energy demanding operation.



Eco-driving is studied in 31 tests. Among them, 5 lead to more than 10% decrease in working speed, which means that the farmer saved fuel but spent more time. But for the 26 remaining (84%), the working speed is equivalent or better. For 5 tests, it is even possible to have a significant increase in working speed, leading to a better fuel/h ratio, but a better efficiency of the operation. The eco-driving measures in soil tillage must therefore be encouraged widely.

The appropriate management of weights leads to interesting fuel savings (5 tests among 10 show more than 10% savings). Except for one test, the change has low impact on working speed.

Harvesting

The 16 tests run show a limited yet positive possibility of savings, but mainly linked to infrastructure changes (lower distance to harvested plots, increase plots' size)

In fact, eco-driving is limited with the harvesting machines (combine and forage harvesters) which have to be run with a specific engine speed.

Eco-driving in transport

All 15 tests run for eco-driving show a good efficiency for fuel savings. 13 tests are above 15% savings. The tests can be split into 2 categories:

- Gear or engine speed adjustment with no modification of speed (7 tests)
- Speed reduction: 8 tests. Although farmers were reluctant to run those tests at first, they were amazed to see that reducing the speed for only 5 km/h could lower the consumption by 30%. Finally, they found it worthwhile.



Tyre management



For tyre management, the results are not homogenous. A small number of tests leads to a diminution of working speed, which means that the farmer saved fuel but spent more time.

5 of the tests in soil tillage lead to fuel savings higher than 20% per hectare, and 6 tests lead to a significant raise in working speed, by reducing slipping.

However, always for soil tillage, 5 tests show low efficiency (no significant reduction of consumption). We were not able to make further interpretation of those results, because the detailed conditions of the tests were not available.

Anyway the meaningful tests allow recommending widely the adjustment of tyre size and pressure during the heavy soil tillage activities. This adjustment is also interesting to avoid soil

compaction and gain working speed.

Efficient20 tip: get the D 3.7 "General report on Pilot Group Fuel reduction". Ask the Efficient20 local partners for a copy or go to the project website <http://efficient20.eu/>

Statistical method used for measurements

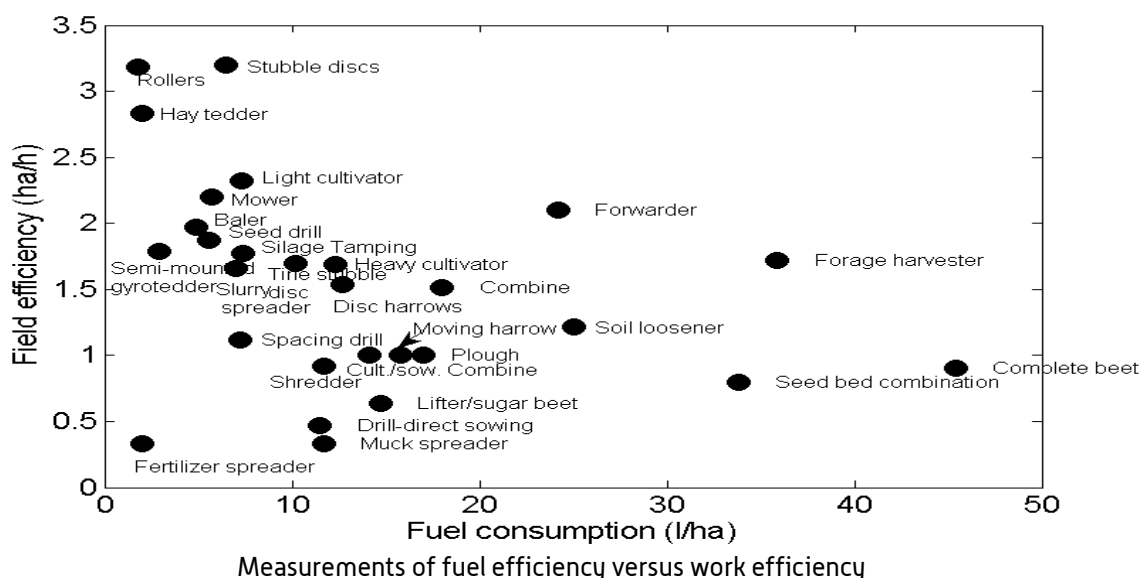
Two indicators were proposed to characterise the tractor efficiency. Fuel consumption is used to establish fuel need with regard to the cultivated area. It is associated to the productivity indicator dealing with the corresponding time budget for tractor's activities. The database firstly gives a picture about the farm, tractors fleet, methods of measurement and operations.

The median European farm has 120 ha and consumes about 15,000 litres of fuel per year. Using multivariate analysis, it is shown that the measurement method affects efficiency indicators and that a "by implement" analysis is the best way to explain variance of records. Using examples, we discussed about the difficulties in defining a reference case to quantify the "eco-solution" effects on fuel consumption. Therefore, "eco-solution" tests are added to the reference sample and are used to analyse setting effects on fuel consumption. Then, reference fuel consumption and productivity are computed for a large list of implements.

Details describing the usual practices are given for the implements that have a lot of operation records. This gives a tool for advisers to discuss about the representativeness of field measurements and comparative tests. Then, comparisons are carried on to extract the influence of settings on fuel consumption and productivity. This allows quantifying impacts of soil, engine power or speed on the fuel consumption and time of use.

Results also give some quantitative elements about the increase of fuel costs and their related productivity gain when engine power is increased. At the end, an annual balance of fuel and time budget is presented and shows how to use results for assessing the benefits of some logistics "eco-driving" solutions. The transport effects are presented for light and heavy works, quantifying fuel and fuel increase with longer distances.

This database about the European agricultural practices for mechanised work is designed to study and optimise the operational parameter settings during tractor's activities but further work is needed to facilitate data feeding and increase accuracy of reporting.



Efficient20 tip: get the D 2.5 "Data base analysis report" Ask the Efficient20 local partners for a copy or go to the project website <http://efficient20.eu/>

Review of scientific bibliography

Harper Adams University, an associate member of Efficient20, investigated how fuel efficiency could be improved in agriculture, providing signposts for future research and development, with the objective of informing agricultural equipment manufacturers, dealers and agricultural support organisations.

To establish which topics should be considered as priorities, each one of the practices and technologies were scored according to 2 criteria:

- the fuel efficiency improvement they could offer, estimated from the literature reviewed when possible or calculated by the author (score from 0 to 10),
- the other improvements they could provide to agriculture, sorted in 13 categories, among which, for example emissions reduction, time saving or improved food security. This led to a scoring of one point for each improvement a technology or practice could offer. These scores were based upon the author's opinion (score from 0 to 13).

Moreover, an estimation of when the topic would be commercially introduced and when it would become commercially normal has been carried out. Table below shows the scores attributed to technologies and practices and the priority obtained.

Area	Technology / Agricultural Practice	Fuel Efficiency Improvement	Other Improvements	Score (Max 23)	Priority
Diesel Engines	Emission Control	0	1	1	31
	Piezo Injectors in Common Rail Diesel Engines	1	2	3	24
	Stop Start Technology	2	1	3	23
	Engine Power Management	2	2	4	19
	Catalyst in Petroleum Diesel	1	0	1	30
Alternative Fuels	Biodiesel	4	4	8	15
	Fuel From Pyrolysis	N/A	3	3	28
	Hydrogen Fuel Cells	10	4	14	4
	Hybrid Vehicles	5	3	8	14
	Electric Vehicles	10	3	13	6
Changing Farming Practices	Precision Agriculture	9	7	16	1
	Controlled Traffic Farming (CTF)	7	5	12	7
	Direct Drilling & Minimum Tillage	9	5	14	5
	Hydroponics & Vertical Farming	10	5	15	2
	Field & Tractor Course Design	4	4	8	13
	Energy Independent Farms	10	4	14	3
Precision Agriculture	GIS Mapping	0	3	3	25
	Yield Monitoring	1	2	3	26
	N-Sensor	2	4	6	17
	GPS	0	2	2	29
	Autosteer Systems	3	6	9	12
	Site Specific Nutrient Mapping	1	3	4	20
	Auto-boom Technology & Variable Rate Application	5	6	11	8
	NDVI	2	4	6	18
Other	Contour Mapping	5	4	9	11
	Varying Machine Size	N/A	4	4	21
	Machine Maintenance	3	4	7	16
	Implement Speed	N/A	1	1	32
	Lightweight Materials	N/A	3	3	27
Forestry	Change to Energy Production	N/A	3	3	22
	Harvesting Methods	6	4	10	10
	Active Woodchip Drying	9	1	10	9

In conclusion, the farming practices of precision agriculture, controlled traffic farming (CTF), direct drilling and minimum tillage, energy independent farms (EIF), hydroponics and vertical farming were established as priority topics for research and development. As were the technologies of hydrogen fuel cells, electric vehicles, automatic boom and variable rate application. Fuel efficiency improvement in the priority topics was high, ranging from a 20% fuel efficiency improvement in automatic boom technology and variable rate application, to an improvement in fuel efficiency of over 100% in hydroponics and vertical farming when compared to current arable farming. The priority topics ranged from being commercially normal practices from the present with direct drilling and min-till, to fifteen years or more in the case of hydrogen fuel cells, CTF and EIF.

Efficient20 tip: get the D 3.1 "Current and future agricultural practices and technologies which affect fuel efficiency" " Ask the Efficient20 local partners for a copy or go to the project website <http://efficient20.eu/>

Embedded computers

The aim of the task was to draw a clearer picture of the comfort of use and understanding of new on-board equipment for reduction of fuel consumption. For this purpose a detailed review of embedded computers on tractors and forest machines and a survey among farmers were carried out.



The review of embedded computers focused on the various available methods for presenting information (display, terminal etc.) and the possibilities for evaluating fuel consumption (average consumption, total consumption, etc.) on tractors and forest machines. All analysed manufacturers offer a range of on-board computers or terminals for their tractors. While all units provide the same basic functions, there are notable differences in the available special display functions.

Source John Deere: John Deere, Mannheim

However, a comparison of the availability of different computers in various model ranges shows, that on-board computers are often not installed at all in the low power machines ("small models") or are only available at extra cost. Some information systems also differ in the options available for displaying fuel consumption information. While some computers feature a wide range of display options, others are only capable of showing current consumption [l/h]. Although the specific operator requirements are the decisive factor in this case, there are certainly some advantages in including a small number of "standard functions" (l/h, l total, average consumption). The technological effort required to adapt the system would also be relatively low. There are some fundamental differences between forest machines and agricultural tractors with respect to on-board information systems. For example, the computer is an integral component of the harvester.

The computer controls and monitors all operational data such as length of processed timber, diameter and piece numbers or harvest volumes. The situation is somewhat different in forwarders. A large proportion of these machines are ordered without computer software. In these cases, the forwarder is shipped with a standard fuel gauge. However, the on-board computer allows the operator to monitor important displays concerning fuel consumption. In addition to the standard values of total and average consumption, the specific harvester computer also displays consumption per cubic metre and trunk. Current systems also generate extensive reports containing operational and production data as well as information about the condition of the machine. An in-depth training is required before the user can fully utilise all functionalities of the computer.



Source Fendt: Agco GmbH, Mannheim

Efficient20 tip: get the D 3.3 "Detailed review of embedded computers". Ask the Efficient20 local partners for a copy or go to the project website <http://efficient20.eu/>

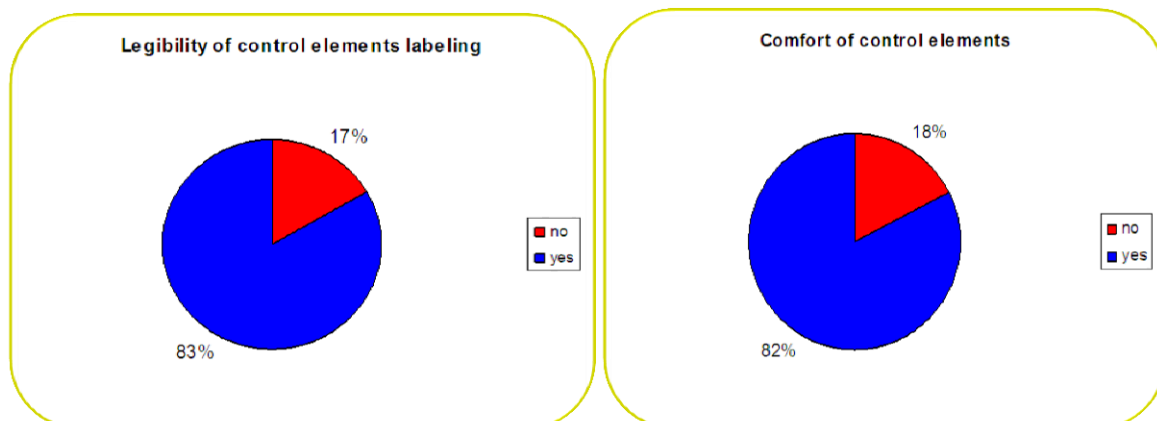
Farmers have a good global knowledge of new equipment and positively evaluate their comfort of use

In 2011, 228 farmers answered a survey about their use of modern tractors. In 2013, 244 farmers answered a similar questionnaire.

The main aim of these surveys analysis was to assess the knowledge and comfort of use of available on-board equipment for reduction of fuel consumption offered by manufacturers of machinery and tractors.



The results show in general, that farmers positively evaluate the comfort of use of new equipment and have quite a good level of understanding of them. In comparison with survey from year 2011, improvements are identified in 21 questions. Worse results are identified in 8 cases. A general improvement in the area of information concerning the principles of eco-driving and fuel savings has been observed from 2011 to 2013. Percentage progress is $(+21-8)/29*100 = 44,83\%$. This coefficient is much higher than the project objective of 10% [According to the project performance indicator – “Rising of 10% in farmers’ and foresters’ understanding and use of the monitoring devices and labels”].



In 2013, farmers better evaluated information given in instruction manuals and trainings offered by manufacturers/dealers. In 2013, farmers also assessed more positively the progress in ergonomics of tractor’s control elements. The farmers registered a growing number of offered eco-driving courses. There was a greater willingness to upgrade qualification among farmers. The level of accepting and applying simple eco-driving methods like adapting tyre pressure and ballasting increased. However, the knowledge of optimal range of engine revolves did not improve and a decline in level of using the information displayed on tractor computer was observed.

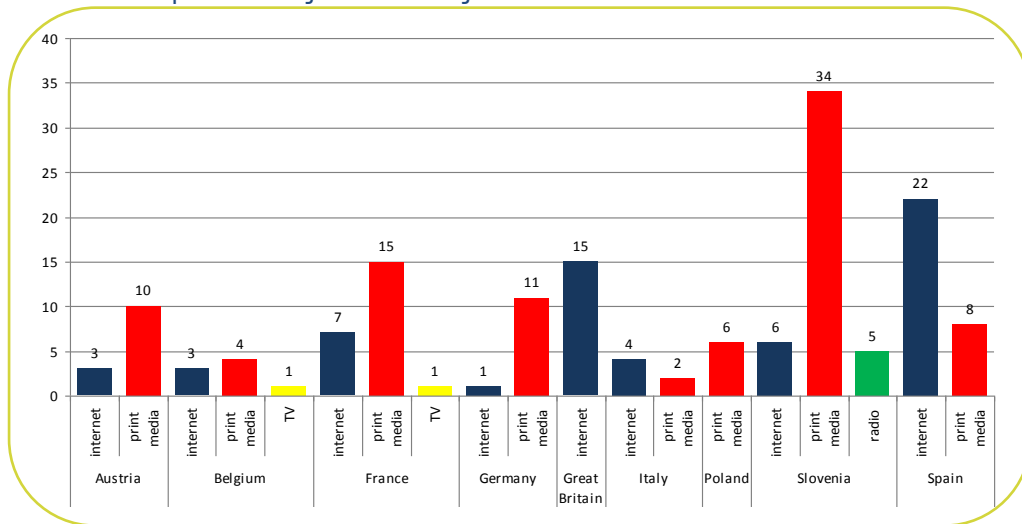
Efficient20 tip: get the D 32 “Questionnaire” and D3.4 “Questionnaire analysis”
Ask the Efficient20 local partners for a copy or go to the project website <http://efficient20.eu/>

Communication campaign: organisation and success stories

Media coverage

During the implementation of the project there were 158 items of media coverage in all the partners' countries. The content of the articles/videos/radio shows was connected to the project Efficient 20 and instructions on how to reduce the fuel consumption.

Number of articles published by media and by countries



Events

The project's goal about the events was more than fulfilled. The project partners were present on 87 events like fairs, courses, annual meetings/gatherings, shows, trainings, etc.

On the events there was almost 3 million visitors among who 159,000 visited the project's stands, presentations and demonstrations.

The events were attended in all the project partners' countries

Austria	27	Germany	9	Poland	9
Belgium	7	Great Britain	8	Slovenia	3
France	15	Italy	1	Spain	8





Austria – Inter Agrar 2012



UK –Cereals 2012



Spain – Expo Bioenergia



France– Mécatraction



Poland – Eko Las 2012



Germany – ZLF 2012



France – Salon aux champs 2011



Austria – Austrofoma 2011



And UK - Staffordshire Rural Hub 2011
Her Royal Highness, Princess Anne met farmers participating in the Efficient20 fuel-saving project

Networking activities



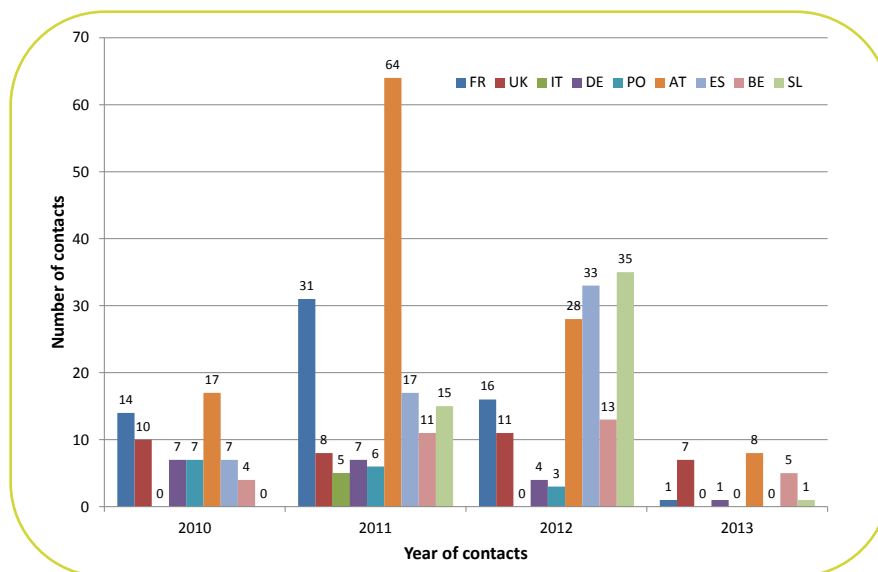
Join us to the EFFICIENT20 Network! This European project (9 countries represented), deals with fuel savings in agriculture and aims at reducing tractor fuel consumption thanks to eco-driving, better use of tractor's gear, improved maintenance...

Active networking is very important for wider recognition of project and transfer of project results to public and target groups. For this reason we prepared a strategy to start with active networking for all project partners. All project partners made contacts and agreements with different target groups.

Template of agreements

Contacts of project partners are divided into the following fields:

- Event – activity of project presented at public event like fairs, demonstrations, eco-driving sessions
- Trade – contacts with tractors and machinery manufacturers and dealers, marketing managers, etc.
- School – contacts with students, secondary, high school and university professors and researchers
- Farmers - transfer the project results to farmers and forest workers through education, organisation of fuel saving trainings, etc.
- Press - presenting the project in agricultural engineering magazines, on conferences, internet, TV, etc.
- Government – contacts with members of EU commission bodies and national government agencies and departments



The graph shows the number of contacts for all project partners from 2010 (start of project) to 2013 (end of project). The Austrian partner has been the most active in terms of contacts in 2010, 2011 and 2013. In 2011, the number of contacts increased a lot at project level with 64 contacts from the Austrian partner and 31 for the French ones. In 2012, partners from Slovenia, Spain and Austria were the most active with respectively 35, 33 and 28 contacts.

Success stories

UK

Harper Adams University College is one of the UK's leading agricultural colleges and research institutions. Securing their support at the beginning of the project brought credibility and helped in the recruitment of pilot group farmers. Ruralnet Futures facilitated a meeting with Harper Adams, FJ-BLT and IRSTEA to identify synergies between Efficient20 and the University's research programmes and to review the proposed analysis of fuel consumption data. IRSTEA and Harper Adams plan to collaborate on publishing an academic paper based on the findings from this analysis after the end of the project. Under a funded contract, Harper Adams wrote the D3.1 report into emerging technologies and practices in agriculture to improve fuel efficiency.

France

Aile was solicited by CEMA - European association for the agricultural machinery industry - to present the Efficient20 project during a big event called "Green Challenge - Business solutions" on 11th October 2011 and jointly a Technical forum on the 12th to underline their commitment in the matter.

The context was that CEMA was in conflict with the European Commission who wanted to place them inside the eco-design directive and thus focus on machine efficiency. CEMA was convinced that more potential lies in their involvement in the entire process including operator efficiency, process efficiency and alternative energy sources and that it is hard to see the machine separately from its environment.

During this presentation, Dimitrios Savvidis, the Seconded National Expert and Policy Officer in Mechanical, Electrical and Telecom Equipment of the European Commission was very interested in joining the Efficient20 network. He is participating in the non-road mobile machinery commission. His current research interests are focused on the areas of exhaust emissions focusing in cold starts and Internal Combustion engines. Each area involves advanced numerical simulation coupled with experimental characterisation and modelling of complex engine behaviour. Some current projects are concerned with Biodiesel, ethanol blends, diesel particulate filters (DPF), gasoline engines and exhaust gas recirculation (EGR).



Belgium



The Faculty of Agronomic Sciences of Gembloux has leading research activities in the "Construction and Mechanic Unit". One of the best examples is the use of a tractor implemented with a CAN DATA recorder. This Unit was asked to participate in Efficient20, with this tractor as a support for tests (data acquisition), demonstration (live data transfer on giant led screen) and courses.

Eco-driving session in agricultural fair with Associated Member GxABT

Poland

Industry-Commerce Chamber of Agricultural and Food Processing Machines became partner in the project in September 2011. The Chamber has cooperated with the Industrial Institute of Agricultural Engineering for many years. Chamber members are Polish manufacturers and enterprises from different sectors (e.g.: agricultural, forestry machinery and foodstuffs). Cooperation with Chamber is focused on project promotion and its current performance at industry trade shows and professional meetings. The task of the Chamber has been to assist in establishing direct contacts during specialised conferences, demonstrations of machinery and to participate in national and international exhibitions and fairs.



Slovenia

Agromehanika d.d., Kranj is a Slovenian producer of farm mechanisation and is also one of the biggest manufacturers of special agricultural machinery in Central Europe. The majority of its products are exported to the EU and non EU countries and also other parts of the world. They produce a wide variety of tractor implements (mounted and towed tractor spraying machines for use in fields, orchards, vineyards, etc.) and special tractors AGT with isodiametric wheels in range from 22 kW to 45 kW engine power. Tractors AGT are designed for working on steep slopes as well as in wine and fruit growing. With different implements, tractors can also be used in municipal sector, forestry, industrial work, etc. Agromehanika is also representing in Slovenia two EU tractor producers, Same - Deutz Fahr (with Deutz Fahr tractor program) and Antonio Carraro. They started to support the Efficient20 project from its beginning and provided support in the different activities (fair promotions, field demonstrations, eco-driving sessions, etc.). They also helped with their tractors for field demonstrations and eco-driving sessions.



Influence of tractor tyre pressure on surface – demonstrated on sand and presented on regional Spring agricultural fair for Gorenjska region (organiser of mentioned fair - associated member Agromehanika d.d., Kranj)

Austria

The Fachschule Schlierbach is the cradle of the eco-driving competitions in Austrian agricultural schools. Hans Miglbauer developed and implemented the concept for eco-driving competitions in cooperation with teachers in other Upper Austrian schools.



Clever Driving Championship 2012

Efficient20 tip: get the D.4. 4 "Final report networking"
Ask the Efficient20 local partners for a copy or go to the project website <http://efficient20.eu/>

Recommendations for farmers and counsellors

- Monitoring the consumption for certain work is the basis for saving fuel
- Get the measurement method adapted to your habit: no need to use the most expensive or the most modern method, choose the one that suit you the best, the easier to follow and to apply to your work
- Remember about applying simple eco-driving methods – it could help you save fuel and limit your expenses
- Try only one or two eco-solutions at the same time, to learn how to apply them, to avoid complicating the work, to get easy results that will maintain the motivation. Tyre pressure and low engine speed are well suited for this, for soil tillage for example, you just have to consider these as initial settings before working.
- Check your machine settings regularly and test the adaption to the working conditions
- When buying a new machine, ask the dealer a comprehensive introduction
- Don't forget to control the optimal range of your tractor's engine revolves
- Planning and organising the working area before starting to work can bring efficient processing
- Remember about upgrading your qualification

Recommendations for manufacturers and dealers

- Basic information on fuel consumption should be available in a leaflet for every new machinery model as standard to allow the user to evaluate the consumption
- It is important to work on the instruction manual to make it user-friendly
- On-board computer design
 - The variation's speed of the display of the current consumption on embedded computer is very important. In fact, these variations will be considered by the driver in relation with topography, type of soil, machinery settings and other information in order to understand them. So there are learning possibilities from such simple display, but it should not vary too fast, or the driver will not take this information into account (this remark was very current from farmers). It shouldn't vary too slowly neither, or interpretation would be impossible. The parameters of the internal calculation (mobile average for example) are also very important and must be well designed.
 - full interpretation is permitted if the farmer can visualise both current and average consumption. Variations and subsequent learnings are easier to observe on current consumption, and the global consumption of the work (average consumption) permits to evaluate the final results of the work management in terms of energy.
- Ensure a customer-oriented aftersales service concerning on-board computer
- Continue promotional activities among farmers on efficient and fuel-saving equipment
- Organise practical courses of eco-driving at local level



Find more on
www.efficient20.eu

Efficient20 Partners



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